U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Fiscal Year 2023 Stockpile Stewardship and Management Plan – Biennial Plan Summary

Report to Congress

April 2023

National Nuclear Security Administration
United States Department of Energy
Washington, DC 20585

Message from the NNSA Administrator

The largest Department of Energy's National Nuclear Security Administration (DOE/NNSA) mission is designing, producing, delivering, and certifying the U.S. nuclear stockpile including the advancement of the underlying science and technology. The *Fiscal Year 2023 Stockpile Stewardship and Management Plan – Biennial Plan Summary* describes our efforts to implement the Administration's 2022 *Nuclear Posture Review* by maintaining a safe, secure, reliable, and effective nuclear weapons stockpile without nuclear explosive testing and revitalizing the nuclear security enterprise. Keeping with DOE/NNSA's commitments to Congress and the public, updated versions of the Stockpile Stewardship and Management Plan (SSMP) reports are published each year.

Included in the fiscal year (FY) 2023 SSMP are the details to accomplish the program requirements including producing 80 plutonium pits per year; continuing production of the B61-12 Life Extension Program (LEP) and the W88 Alteration 370 warheads on schedule; and achieving the first production units for the W80-4 LEP and W87-1 Modernization Program. The report also discusses other major activities in stockpile modernization, infrastructure refurbishment, science, research, technology, and engineering. Because of the ages of the weapons in the stockpile, new stockpile requirements, and the recapitalization needed in the production and science infrastructure, DOE/NNSA has been conducting weapon and infrastructure modernization simultaneously. Conducting these programs side-by-side is challenging because of the intense coordination required across the enterprise and with our partners in the Department of Defense. The SSMP describes on-going and planned activities.

The scientific and technological expertise of the people in the nuclear security enterprise is the backbone of the United States' deterrence. Our nuclear security enterprise workforce comprises experts at government-owned, contractor-operated national laboratories, production plants, and sites across the country and a smaller Federal workforce for planning, budgeting, management, and oversight. Since the days of the Manhattan Project, this model and the specialized talent of nuclear security enterprise personnel have delivered the stockpile needed for effective deterrence in the face of changing world conditions. The SSMP discusses the recruiting and retention efforts to attract the best talent in the United States.

For more than 75 years, the nuclear security enterprise has been at the forefront of cutting edge scientific and engineering work that has greatly enhanced national and global security. With continued support from Congress, DOE/NNSA will continue to anticipate future security challenges and deliver innovative solutions to meet them. Pursuant to statute, this FY 2023 SSMP is provided to:

The Honorable Patty Murray

Chair, Senate Committee on Appropriations

The Honorable Susan Collins

Vice Chair, Senate Committee on Appropriations

The Honorable Jack Reed

Chairman, Senate Committee on Armed Services

The Honorable Roger Wicker

Ranking Member, Senate Committee on Armed Services

The Honorable Dianne Feinstein

Chairman, Subcommittee on Energy and Water Development
Senate Committee on Appropriations

The Honorable John Kennedy

Ranking Member, Subcommittee on Energy and Water Development
Senate Committee on Appropriations

The Honorable Angus King

Chairman, Subcommittee on Strategic Forces
Senate Committee on Armed Services

The Honorable Deb Fischer

Ranking Member, Subcommittee on Strategic Forces
Senate Committee on Armed Services

The Honorable Kay Granger

Chairwoman, House Committee on Appropriations

The Honorable Rosa De Lauro

Ranking Member, House Committee on Appropriations

The Honorable Mike Rogers

Chairman, House Committee on Armed Services

The Honorable Adam Smith

Ranking Member, House Committee on Armed Services

The Honorable Chuck Fleischmann

Chairman, Subcommittee on Energy and Water Development, and Related Agencies
House Committee on Appropriations

The Honorable Marcy Kaptur

Ranking Member, Subcommittee on Energy and Water Development, and Related Agencies
House Committee on Appropriations

The Honorable Doug Lamborn

Chairman, Subcommittee on Strategic Forces
House Committee on Armed Services

The Honorable Seth Moulton

Ranking Member, Subcommittee on Strategic Forces
House Committee on Armed Services

Should you have any questions or need additional information, please contact Dr. Benn Tannenbaum, Associate Administrator for Congressional and Intergovernmental Affairs, at (202) 586-8368.

Sincerely,

Jill Hruby
Under Secretary for Nuclear Security
Administrator, NNSA

This page left blank intentionally

Message from the Secretary

The Department of Energy's National Nuclear Security Administration (DOE/NNSA) works hand in hand with the Department of Defense to maintain a safe, secure, and effective nuclear deterrent. The evolving global security environment involving two nation state nuclear competitors, coupled with an unprecedented range and mix of threats, means the United States must maintain a modern nuclear deterrent coupled with flexible and resilient capabilities. This report describes the activities and plans in DOE/NNSA to achieve these goals.

DOE/NNSA's advancements and innovations in science and engineering has paved the way for advancements in national defense and the future of clean power. In December 2022, the DOE/NNSA Lawrence Livermore National Laboratory achieved the first controlled fusion experiment in history – obtaining ignition by producing more energy from fusion than the laser energy used to drive it. This landmark achievement provides both unprecedented capability to gain new understanding for stockpile stewardship and invaluable insights into the prospects of clean fusion energy. It will undoubtedly spark even more discovery and other breakthroughs will be achieved.

This Administration is committed to investing the appropriate resources to support a responsive and resilient nuclear security enterprise. With the continued support of Congress, DOE/NNSA will provide a safe, secure, and effective nuclear stockpile now and into the future.

Sincerely,

Jennifer Granholm
Secretary of Energy

This page left blank intentionally

Executive Summary

The *Fiscal Year 2023 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP), including its classified annex, describes the Department of Energy's National Nuclear Security Administration (DOE/NNSA) program for implementing the Administration's *Nuclear Posture Review* by maintaining the nuclear stockpile's safety, security, and effectiveness over the next 25 years. DOE/NNSA publishes the SSMP annually, either in full report form or as a summary, in response to statutory requirements to support the President's Budget Request to Congress for Weapons Activities. Consistent with the *Nuclear Weapons Council Strategic Plan for FY 2019 – 2044*, this fiscal year (FY) 2023 summary report provides an integrated picture of current and future nuclear security enterprise activities and capabilities funded by the Weapons Activities account supporting the Nation's nuclear deterrent.

In partnership, the Department of Defense (DoD) and DOE/NNSA manage weapons modernization needs from concept assessment to full-scale production to retirement. This SSMP reflects rigorous mapping of nuclear security enterprise capabilities to address military requirements and the priorities identified in the 2022 *Nuclear Posture Review.*

In 2021, DOE/NNSA executed its largest program in its 21-year history, helping to advance the Nation's nuclear security mission through innovative science and technology solutions. DOE/NNSA worked to ensure the existing nuclear weapons stockpile's safety, security, and reliability; successfully produced the first refurbished weapon for two different warheads in the stockpile; continued to modernize infrastructure and advance plutonium pit production-related activities; reduced nuclear proliferation risks by securing and downblending nuclear materials; helped increase U.S. radiological response capacity; and continued to power the nuclear Navy.

DOE/NNSA's top priority is to deliver on its commitments across the board in a cost-effective manner. DOE/NNSA will forge transparent, productive, and enduring relationships with the interagency, its stakeholders, and its international allies and partners. By leveraging its innovative science and technology capabilities, DOE/NNSA will meet stockpile milestones, improve its ability to monitor future arms control and nonproliferation agreements, and establish a resilient enterprise to meet the geopolitical needs of today and tomorrow. DOE/NNSA will:

Maintain the Nation's Nuclear Deterrent's Safety, Security, and Effectiveness

With several warhead modernizations underway, DOE/NNSA is executing an unprecedented variety of complex component development and production work. Despite the continued challenges imposed by Coronavirus Disease 2019 (COVID-19)-related restrictions and supply chain delays, DOE/NNSA has continued to meet the Nation's nuclear deterrent requirements.

Near-Term and Out-Year Mission Goals:

- Deliver the B61-12 gravity bomb.
- Deliver the W88 Alteration (Alt) 370 (with a refresh of the conventional high explosive).
- Achieve the first production unit of the W80-4 warhead Life Extension Program (LEP) and ensure alignment with the DoD Long Range Standoff (LRSO) cruise missile replacement program.
- Support fielding Sentinel, formerly known as the Ground Based Strategic Deterrent, and advance the W87-1 Modification Program (formerly called the W78 Replacement Warhead).

- Provide the enduring plutonium pit production capability to produce 80 plutonium pits per year (ppy).
- Assure a continuous and reliable supply of strategic nuclear weapon components and the key materials that make up the components, including plutonium, uranium, lithium, tritium, and high explosives.
- Provide experimental and computational capabilities to support the annual assessment and certification of the stockpile.

Key Accomplishments:

Sustain the Stockpile

In 2021, DOE/NNSA:

- Delivered all scheduled limited life components for the B61, W76, W78, W80, B83, W87, and W88.
- Completed over 1,600 critical equipment calibrations on time in support of production activities.
- Completed seven tritium extractions at the Savannah River Site (SRS), more than doubling the previous record, and sustained base capabilities for multi-system operations and maintenance support to meet all limited life components exchange gas transfer system fills and gas transfer system Surveillance DOE/NNSA deliverables to DoD.
- Conducted surveillance activities for all weapon systems using data collection from flight tests, laboratory tests, and component evaluations to assess stockpile reliability without underground explosive nuclear testing, which culminated in completion of all annual assessment reports and generation of laboratory director letters to the President.
- Maintained its Office of Secure Transportation's spotless record by accomplishing 100 percent of assigned missions safely and securely, with no mission degradation despite the operational challenges inherent during the COVID-19 pandemic.

Modernize Weapons

- Completed the first production unit for the W88 Alt 370 in July 2021 and B61-12 LEP in November 2021, successfully producing the first refurbished weapons of each type and ready to produce the quantities needed by the military. This work helps modernize America's nuclear weapons stockpile, sustain the Nation's nuclear deterrent capabilities, and improve the safety, security, and reliability of the Nation's weapons. The W88 Alt 370 is carried on the Ohio-class ballistic missile submarines and will modernize older W88 warheads. The B61-12 will consolidate, and replace, three older B61 warheads variants and will be certified for delivery on strategic and dual capable military aircraft. The W88 Alt 370 and B61-12 LEP programs will be completed in FY 2026.
- Completed initial joint LRSO/W80-4 testing and component Baseline Design Reviews in preparation for transition to Phase 6.4, *Production Engineering*, in FY 2023.
- Completed its W87-1 Modification Program Weapon Design and Cost Report and prepared to enter Phase 6.3, *Development Engineering*, in FY 2022.

Strengthen Key Science, Technology, and Engineering Capabilities

Nuclear weapons stockpile and key nonproliferation activities are supported by the technical expertise resident in DOE/NNSA's Federal and management and operating partner workforces. DOE/NNSA cultivates technical expertise at the cutting edge in manufacturing, diagnostics, evaluation, and other areas at the plants and sites. DOE/NNSA maintains unparalleled scientific and engineering capabilities at the three national security laboratories that execute science-based stockpile stewardship.

Near-Term and Out-Year Mission Goals:

- Advance the innovative experimental platforms, diagnostic equipment, and computational capabilities necessary to ensure stockpile's safety, security, reliability, and effectiveness:
  - Achieve exascale computing by delivering an exascale-capable machine and modernizing the nuclear weapons code base
  - Develop an operational enhanced capability (advanced radiography and reactivity measurements) for subcritical experiments
  - Quantify the plutonium aging effects on weapon performance over time
  - Assure an enduring, trusted strategic radiation-hardened microsystems supply
- Maintain state-of-the-art manufacturing technologies supporting production operations.
- Continue implementing the Stockpile Responsiveness Program to fully exercise the nuclear security enterprise's workforce and capabilities.
- Nurture Strategic Partnership Programs that support other relevant needs while advancing the national security laboratories', production plants', and sites' long-term workforces and capabilities.

Key Accomplishments:

In 2021, DOE/NNSA:

- Delivered two next-generation computational simulation capabilities to support environmental specification, design, and qualification for future weapon systems. These code suites have been designed to effectively use the full power of DOE/NNSA's current and next-generation supercomputers including the DOE/NNSA exascale system, El Capitan.
- Made important contributions to the fight against COVID-19. Los Alamos National Laboratory (LANL) led the COVID-19 Testing Team for the DOE's National Virtual Biotechnology Lab and continues to work with Sandia National Laboratories (SNL), and other DOE sites, to help the Nation address COVID-19. Lawrence Livermore National Laboratory (LLNL) joined the international Human Vaccines Project to aid in developing a universal coronavirus vaccine and improve understanding on immune response where LLNL will leverage its knowledge in vaccine research response, most recently from designing new antibodies and antiviral drugs for COVID-19. SNL contributed by standing up a COVID-19 diagnostic lab for their workforce and NNSA, development of reagents for vaccines, and integrated virus monitoring, modeling, and analyst capability to track pandemic propagation to inform decisions associated with detection and diagnostics.
- Surpassed the fusion threshold by delivering 2.05 megajoules (MJ) of energy to a target, resulting in 3.15 MJ of energy output, during a December 5 Inertial Confinement Fusion experiment at LLNL's National Ignition Facility. This was the first controlled fusion experiment in history to reach this milestone, also known as scientific energy breakeven, meaning it produced more energy from fusion than the laser energy used to drive it. This historic, first-of-its kind achievement will provide unprecedented capability to support DOE/NNSA's Stockpile Stewardship Program and invaluable insights into the prospects of clean fusion energy.

- Performed two consecutive experiments using the Z pulsed power facility to measure the dynamic response of aged plutonium. These were the first back-to-back plutonium experiments on the Z pulsed power facility, which resulted in operational efficiencies and returned valuable data for stockpile stewardship.
- Supported the National Aeronautics and Space Administration's Perseverance rover landing on Mars. Perseverance carried the SuperCam, an instrument designed and built by a LANL-led international team comprising more than 300 people. SuperCam's capabilities include breaking up far-away rocks to study their composition and features the first scientific microphone to ever operate on Mars.
- Executed a record three subcritical experiments in a single year while planning and preparing for three additional subcritical experiment series to be executed in support of stockpile certification needs.

Modernize the Nuclear Security Infrastructure

DOE/NNSA continues to revitalize the facilities and corresponding infrastructure that make up the nuclear security enterprise. These upgrades are necessary to create a responsive and resilient enterprise that can meet national security missions today and in the future.

Near-Term and Out-Year Mission Goals:

- Recapitalize existing infrastructure to implement a plan to produce 80 ppy. The recommended strategy is a two-site solution:
  - Establish a reliable capability at the Plutonium Facility at LANL to deliver 30 WR ppy
  - Repurpose the Mixed Oxide Fuel Fabrication Facility at SRS as part of the Savannah River Plutonium Processing Facility (SRPPF) to produce 50 ppy as close to 2030 as possible
- Enable phasing out mission dependency on Building 9212 at the Y-12 National Security Complex in Oak Ridge, Tennessee, by relocating the facility's enriched uranium processing capabilities into existing facilities and the Uranium Processing Facility and extending key existing facilities' operational lifetime into the 2040s.
- Assure long-term actinide chemistry and materials characterization and deliver the Chemistry and Metallurgy Research Replacement Project.
- Modernize lithium and tritium facilities.
- Increase tritium production using two commercial power reactors to meet stockpile needs.
- Recapitalize the high explosives and nuclear weapons assembly infrastructure.
- Provide new laboratory space and equipment within the U1a Complex to support the Enhanced Capabilities for Subcritical Experiments portfolio through the U1a Complex Enhancements Project and Advanced Sources and Detectors equipment.
- Provide modern office and laboratory spaces to support the world-class workforce needed to maintain the nuclear weapons stockpile capabilities.
- Reduce the total deferred maintenance, as measured by the replacement plant value, of the nuclear security enterprise by not less than 45 percent by 2030.

Key Accomplishments:

In 2021, DOE/NNSA:

- Announced the approval of a key design milestone for the Los Alamos Plutonium Pit Production Project at LANL and the SRPPF project at SRS. These projects will reestablish, for the first time since the early 1990s, the capability to produce War Reserve plutonium pits to ensure the U.S. nuclear deterrent remains safe, secure, reliable, and effective now and in the future.
- Completed the Radiological Utility Office Building Equipment Installation Phase 2 project, enhancing the analytical chemistry and material characterization capabilities that support plutonium missions at LANL and the DOE/NNSA complex. This project moves programmatic operations to a modern facility and was completed two months ahead of schedule and $120 million under budget.
- Hardened its cyber infrastructure this past year, including replacing the Information Assurance Response Center's Enterprise Security Incident and Event Management tool to enhance continuous monitoring,[1] threat detection, and rapid investigation and response.
- Began to make parts to speed up design development and transition to production efforts in support of the W80-4 LEP and W87-1 Modification Program at the now-operational LLNL-Kansas City National Security Campus Polymer Enclave.

2022 Priorities

Modernize and Maintain America's Nuclear Weapons Stockpile

In 2022, DOE/NNSA:

- Continued to advance its nuclear weapons stockpile modernization, as two key milestones approach: the W80-4 LEP, where DOE/NNSA will achieve a producible design and prepare for production, and the W87-1 Modification Program where NNSA will, in coordination with DoD, validate the selected design option and initiate process development activities. The W80-4 LEP will ensure the effectiveness of the nuclear triad's bomber leg when coupled with the Air Force's LRSO cruise missile. The W87-1 will replace the aging W78 warhead to maintain the nuclear triad's intercontinental ballistic missile leg's safety, security, and effectiveness.
- Began implementing the recommendations of an enterprise-wide cybersecurity assessment that evaluated DOE/NNSA's overall cybersecurity posture. A final report was issued in May 2022. The assessment team interviewed staff at sites and across the complex on cybersecurity program implementation, workforce, supply chain risk management, enterprise architecture and technology roadmaps, and budget sufficiency. In addition, DOE/NNSA is committed to implement the President's Executive Order on Zero Trust Architecture (Executive Order 14028) to improve the security of information technology systems from cyber attacks.
- Advanced its production and infrastructure modernization goals. Revitalizing DOE/NNSA infrastructure requires managing a $120 billion enterprise where more than half the facilities are in insufficient condition and nearly as many are beyond their life expectancy. In 2022, DOE/NNSA continued to improve its new data-driven and risk-informed infrastructure stewardship tools to prioritize risks and optimize investment impacts. DOE/NNSA also continued advancing a novel

[1] *Continuous monitoring*—A strategy that enables information security professionals and others to see a continuous stream of near real-time snapshots of the state of risk to their security, data, network, end points, and even cloud devices and applications.

pilot program that is challenging norms to create a streamlined process for acquiring noncomplex, nonnuclear capital construction facilities. Finally, DOE/NNSA and DOE Federal staff moved into the newly constructed John A. Gordon Albuquerque Complex.

- Continued its efforts to design facilities to produce plutonium pits, including working toward reaching a 90 percent design completion and establishing a definitive scope, schedule, and cost baseline for the pit production projects at LANL and SRS.

Fiscal Year 2023 Stockpile Stewardship and Management Plan – Biennial Plan Summary

Table of Contents

Legislative Language

Title 50 of United States Code Section 2523 (50 U.S. Code § 2523), requires that:

> The Administrator, in consultation with the Secretary of Defense and other appropriate officials of the departments and agencies of the Federal Government, shall develop and annually update a plan for sustaining the nuclear weapons stockpile. The plan shall cover, at a minimum, stockpile stewardship, stockpile management, stockpile responsiveness, stockpile surveillance, program direction, infrastructure modernization, human capital, and nuclear test readiness. The plan shall be consistent with the programmatic and technical requirements of the most recent annual Nuclear Weapons Stockpile Memorandum.

Pursuant to previous statutory requirements, the Department of Energy's National Nuclear Security Administration (DOE/NNSA) has submitted reports on the plan to Congress annually since 1998, with the exception of 2012.[1]

The Fiscal Year 2023 Stockpile Stewardship and Management Plan (SSMP) is a biennial plan summary report of DOE/NNSA's 25-year program of record to maintain the safety, security, and effectiveness of the nuclear stockpile and is primarily captured in this single, unclassified document. A classified annex to the SSMP contains supporting details concerning the U.S. nuclear stockpile and stockpile management.

[1] In 2012, a *Fiscal Year 2013 Stockpile Stewardship and Management Plan* was not submitted to Congress because analytical work conducted by the DoD and NNSA to evaluate the out-year needs for nuclear modernization activities across the nuclear security enterprise had not yet been finalized.

Chapter 1
Strategic Context for Managing the Nuclear Weapons Stockpile

The U.S. nuclear deterrent is the foundation of the national defense, which backstops U.S. integrated efforts across warfighting domains, other instruments of national power, and the United States' network of alliances and partnerships. While eliminating nuclear weapons has been a goal for generations, current activities by several nuclear powers appear to be at odds with this goal. Russia is relying on nuclear weapons as a means to counter U.S. conventional superiority, replacing Soviet-era systems with new missiles, submarines, and aircraft while developing new types of tactical nuclear weapons. China is trying to broaden its political and economic influence, and in the nuclear arena, is increasing the number and types of nuclear weapons in its arsenal. Further, North Korea has expanded its number of nuclear weapons and range of delivery capabilities, and Iran continues to develop its nuclear program. For the foreseeable future, nuclear weapons will continue to provide unique deterrence effects that no other element of U.S. power can replace given the reality of today's evolving and uncertain international security environment.

Ensuring the U.S. strategic deterrent remains safe, secure, and effective, and that the United States' deterrence commitments to its allies remain strong and credible requires significant and coordinated effort. Responsibility for this mission is shared by the Department of Defense (DoD) and the Department of Energy's National Nuclear Security Administration (DOE/NNSA). Only through the two Departments aligning their priorities, programs, and funding can U.S. nuclear forces meet deterrence and assurance requirements.

To execute the Nation's nuclear weapons programs, DOE/NNSA partners with DoD through the Nuclear Weapons Council on the joint nuclear weapons life cycle process. DoD and DOE/NNSA use this process to manage weapons' sustainment and modernization needs from concept assessment to full-scale production, and finally, to retirement and dismantlement. DoD and DOE/NNSA continue to make progress across the current major warhead programs as DOE/NNSA continues to perform an unprecedented variety of component development, qualification, system integration, and production activities.

The weapons comprising the U.S. nuclear stockpile are currently assessed to be safe, secure, and effective, and DOE/NNSA's infrastructure is currently adequate to support stockpile actions. However, continued science and infrastructure investments are needed to ensure the stockpile continues to meet these requirements. For most of the post-Cold War period, the focus of the nuclear security enterprise has been to sustain existing nuclear weapons and improve the ability to assess their safety, security, reliability, and effectiveness without nuclear explosive testing. When aging issues were identified in the stockpile, weapons were partially refurbished without changing their military characteristics. Additionally, elements of the production infrastructure were dismantled, and other elements were not sustained due to limited needs within the enterprise.

Today, much of the stockpile has aged without comprehensive refurbishment. At a time of rising nuclear risks, a partial refurbishment strategy no longer meets the needs of the nuclear deterrent. To respond to the current environment with a balanced, flexible stockpile, it is important that the nuclear security enterprise's production infrastructure is re-established, repaired as appropriate, and modernized. Recapitalizing the nuclear security enterprise, including the workforce, infrastructure, production capacity and capabilities, and scientific base that support it, is key to ensuring a safe, secure, and effective stockpile. A resilient and responsive production capability is necessary for DOE/NNSA to continue to support the nuclear deterrent and afford the United States the ability to adapt to changes in the strategic environment. Therefore, DOE/NNSA is currently undertaking a risk-informed, complex, and time-constrained modernization and recapitalization effort to ensure continued mission success, in conjunction with the priorities identified in the 2022 *Nuclear Posture Review*.

1.1 Overview

DOE/NNSA draws authority for managing the Nation's nuclear stockpile from the *Atomic Energy Act of 1954* (42 U.S. Code § 2011 *et seq.*) and, more specifically, the *National Nuclear Security Administration Act* (50 U.S. Code § 2401 *et seq*.). DOE/NNSA's broad set of enduring missions are to protect the Nation by maintaining a safe, secure, and effective nuclear weapons stockpile, reduce global nuclear threats, and provide the Navy's submarines and aircraft carriers with militarily effective nuclear propulsion. Activities related to DOE/NNSA's stockpile mission conduct are referred to in this document as Weapons Activities.

DOE/NNSA's annual Stockpile Stewardship and Management Plan (SSMP) has two primary purposes:

- Document DOE/NNSA's plans to:
  - Maintain the current stockpile
  - Modernize the stockpile as needed to respond to evolving deterrent needs
  - Advance the science that enables DOE/NNSA to manage the U.S. nuclear weapons stockpile while employing science-based stockpile stewardship to enhance the potential performance and understanding of the stockpile's aged, modified, or modernized nuclear weapons
  - Maintain and modernize the supporting infrastructure
  - Sustain DOE/NNSA's highly skilled workforce necessary for this work
- Provide DOE/NNSA's formal response to multiple statutory reporting requirements, which can be found in Appendix A, "Requirements Mapping," including:
  - Annual Life Extension Program reporting required under the Explanatory Statement accompanying the *Consolidated Appropriations Act, 2017* (P.L. 115-31)
  - Actual or potential risks to, or specific gaps in, any element of the industrial base that supports nuclear weapons components subsystems or materials, in addition to any mitigation actions needed as requested through Section 3135 of the *National Defense Authorization Act for Fiscal Year 2022* (P.L. 117-81)

This fiscal year (FY) 2023 SSMP serves as the annual plan for sustaining the nuclear weapons stockpile required by statute. The 25-year strategic plan was developed in alignment with strategic guidance, including the 2022 *Nuclear Posture Review*, the *Nuclear Weapons Council's Strategic Plan for Fiscal Years (FY) 2019 – 2044,* the *FY 2020 – 2025 Nuclear Weapons Stockpile Plan,* and other policy directives (see Section 1.2).

1.2 Policy Framework Summary

The *National Nuclear Security Administration Act* (50 U.S.C § 2401, *et seq*.) directs DOE/NNSA "to maintain and enhance the safety, reliability, and performance of the U.S. nuclear weapons stockpile, including the ability to design, produce, and test, to meet national security requirements."

Recently, the 2022 *National Defense Strategy* and the accompanying *Nuclear Posture Review* reinforced that the United States will maintain nuclear forces that are responsive to the threats we face, and affirmed the following roles for nuclear weapons:

- Deter strategic attacks
- Assure Allies and partners
- Achieve U.S. objectives if deterrence fails

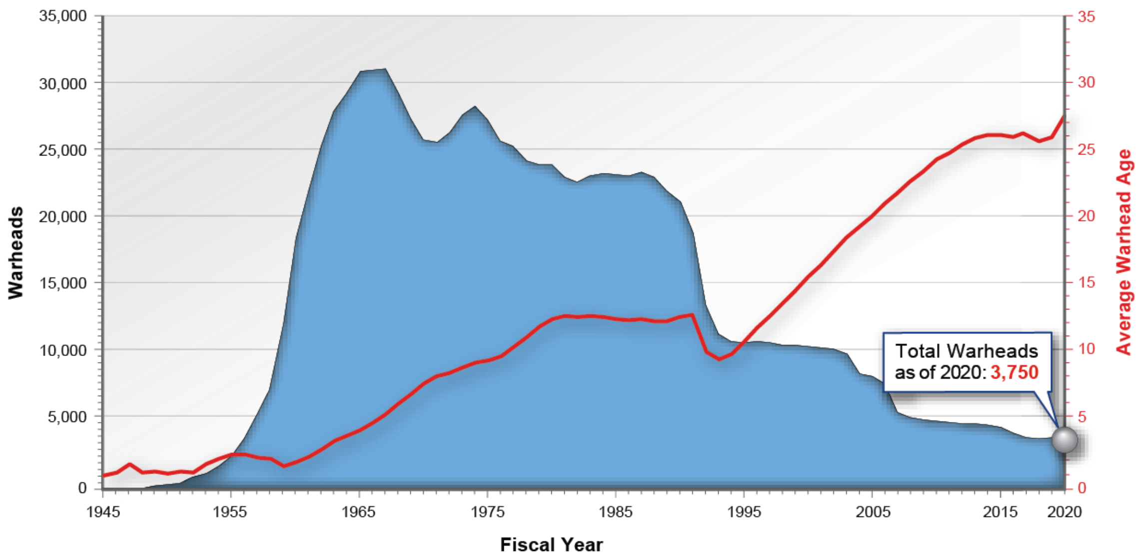
Furthermore, the 2022 *Nuclear Posture Review* represented a comprehensive, balanced approach to U.S. nuclear strategy, policy, posture, and forces and reaffirmed that maintaining a safe, secure, and effective nuclear deterrent and strong and credible extended deterrence commitments remain a top priority for DoD, DOE/NNSA, and the Nation.

1.3 Nuclear Weapons Stockpile Summary

The nuclear stockpile's size and composition continues to change in response to U.S. national security needs, though the average warhead age in the stockpile remains high. Many weapons are considerably past their original design life expectancy and require stockpile management activities to assess their condition and perform additional maintenance and enhanced surveillance to ensure operability and extend weapon lifetimes. With several major warhead modernization activities underway, DOE/NNSA is making significant progress toward reducing the average warhead age, while concurrently looking to meet emerging challenges on a time scale that does not put the U.S. nuclear deterrent at risk. DOE/NNSA is also enhancing its science, technology, and engineering capabilities to improve the production processes' efficiency and effectiveness. The change in the nuclear weapons stockpile's size and age over time is illustrated in **Figure 1–1**.

The current stockpile consists of active weapons, which are maintained to meet military requirements, and inactive weapons, which are used to augment, or replace, warheads in the active stockpile as necessary. Retired weapons are not included in the count of stockpile weapons. **Table 1–1** reflects the major characteristics of the Nation's current stockpile, which is composed of two types of submarine-launched ballistic missile warheads, two types of intercontinental ballistic missile warheads, several types of gravity bombs, and a cruise missile warhead.

The classified annex to this plan includes specific technical details about the stockpile by warhead type.



Note: NNSA closely tracks the age of each component within every nuclear weapon in the Nation's stockpile as part of ensuring safety security, and reliability. The age of each weapon is taken from the day that final assembly at the Pantex Plant is completed. The age of each weapon is reset to "zero" following a major modernization, such as a life extension, after which the weapon is certified by the national security laboratories for an additional 20-30 years, depending on the weapon type and modernization conducted. It is important to note that, while a life extension does reset the age of a weapon to zero for purposes of tracking (such as this figure depicts), components within that weapon are older than the assigned weapon age. Both weapon age and the age of each component within each weapon are tracked by NNSA.

Figure 1–1. Size and age of the U.S. nuclear weapons stockpile, 1945–2020

Table 1–1. Current U.S. nuclear weapons and associated delivery systems

Warheads—Strategic Ballistic Missile Platforms					
Type [a]	***Description***	***Delivery System***	***Laboratories***	***Mission***	***Service***
W78	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LANL/SNL	Surface to surface	Air Force
W87-0	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LLNL/SNL	Surface to surface	Air Force
W76-0/1/2	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
W88	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
Bombs—Aircraft Platforms					
B61-3/4	Non-strategic bomb	F-15, F-16, certified NATO aircraft	LANL/SNL	Air to surface	Air Force/Select NATO forces
B61-7	Strategic bomb	B-2 bomber	LANL/SNL	Air to surface	Air Force
B61-11	Strategic bomb	B-2 bomber	LANL/SNL	Air to surface	Air Force
B83-1	Strategic bomb	B-2 bomber	LLNL/SNL	Air to surface	Air Force
Warheads—Cruise Missile Platforms					
W80-1	Air-launched cruise missile strategic weapons	B-52 bomber	LLNL/SNL	Air to surface	Air Force

LANL = Los Alamos National Laboratory
NATO = North Atlantic Treaty Organization
LLNL = Lawrence Livermore National Laboratory
SNL = Sandia National Laboratories

[a] The suffix associated with each warhead or bomb type (e.g., "-0/1/2" for the W76) represents the modification associated with the respective weapon.

1.4 Overall Strategy, Objectives, and Prioritization of Weapons Activities

DOE/NNSA continues to execute its long-standing nuclear warhead modernization efforts in conjunction with the modernization of DoD delivery platforms, the nuclear weapons required for those platforms, and the DOE/NNSA infrastructure needed to produce and maintain those weapons. This approach will ensure the necessary flexibility needed for future policy decisions related to nuclear modernization as the United States adjusts to the changing international threats facing the United States and its allies and partners. The nuclear weapons stockpile is currently safe, secure, and militarily effective. However, the United States must continue to invest in weapons and infrastructure modernization programs to provide the capabilities needed to ensure the deterrent's viability into the future. For these reasons, DOE/NNSA continues to look for innovative ways to meet emerging challenges on a timescale that does not put the U.S. nuclear deterrent at risk and to enhance science, technology, and engineering capabilities to improve production processes efficiency and effectiveness. Due to the long lead times necessary to prepare and establish nuclear capabilities, the United States will not have the weapons and infrastructure in place to support the nuclear stockpile unless DOE/NNSA takes action to reestablish and recapitalize these capabilities now.

The FY 2023 budget for Weapons Activities includes funding for major nuclear modernization programs and was developed in support of the Administration's 2022 *Nuclear Posture Review*:

- **Define the Capability to Effectively Engage and Defeat Hardened and Deeply Buried Targets.** The Nuclear Weapons Council established a joint NNSA/DoD Hard and Deeply Buried Target Defeat Team, coordinated through the Assistant Secretary of Defense for Nuclear Chemical and Biological Defense Programs/Office of Nuclear Matters, to determine future options for defeating such targets.
- **Advance the W87-1 Modification Program.** The W87-1 Modification Program will replace the aging W78 warhead using a modified existing legacy W87-0 design and will deploy new technologies that improve safety and security, address material obsolescence, and improve warhead manufacturability. In FY 2022, DOE/NNSA matured select technologies and furthered system test and qualification planning.

> ***Major Goals of Weapons Activities***
>
> - *Ensure the nuclear weapons stockpile continues to meet DoD deterrent requirements while enhancing warhead safety and security*
> - *Modernize production capabilities and nuclear security enterprise facilities*
> - *Provide experimental and computational capabilities to support the stockpile annual assessment and certification*
> - *Recruit, train, and retain a highly skilled and diverse workforce to meet mission deliverables*

- **Develop the W93.** The W93 Modernization Program is a new program of record established to support the Navy's identified need for a new reentry body. Anchored on previously tested nuclear components, the W93 will incorporate modern technologies to improve safety, security, and flexibility to address future threats. It will be designed for ease of manufacturing, maintenance, and certification. Key nuclear components will be based on currently deployed, and previously tested nuclear designs, and extensive stockpile component and materials experience. It will also ensure the continued viability of DoD's operational flexibility and effectiveness as the United States transitions from Ohio-class submarines to a smaller fleet of Columbia-class submarines. The W93 will not require additional nuclear explosive testing to be certified.

Carrying out the W93 program is vital for continuing longstanding cooperation with the United Kingdom, which is also modernizing its nuclear forces. As an allied but independent nuclear power that contributes to the North Atlantic Treaty Organization's nuclear deterrent posture, the United Kingdom's nuclear deterrent is critical to U.S. national security.

In summary, the United States must continue its ability to maintain and certify a safe, secure, and effective nuclear arsenal. Synchronized with DoD delivery platform replacement programs, DOE/NNSA will sustain and deliver the warheads necessary to support the Nation's strategic and non-strategic nuclear capabilities on time by:

- Completing the B61-12 Life Extension Program
- Completing the W88 Alteration 370
- Synchronizing DOE/NNSA's W80-4 warhead with DoD's Long Range Standoff (LRSO) cruise missile program and supporting the Air Force's scheduled LRSO initial and final operational capability dates
- Exploring future ballistic missile warhead options to meet the required military characteristics based on the threats and vulnerabilities of potential adversaries, including possible common reentry systems for Air Force and Navy systems

DOE/NNSA uses several major strategies to sustain and maintain the stockpile and support the DOE/NNSA mission priorities to maintain the safety, security, and effectiveness of the Nation's nuclear deterrent; strengthen key science, technology, and engineering capabilities; and modernize the nuclear security infrastructure including:

- Assessing the stockpile annually through science-based stockpile stewardship:
  - Assessing whether the current and future nuclear stockpile's safety, reliability, and performance can be assured in the absence of underground nuclear explosive testing
  - Renewing, developing, and enhancing science capabilities to assess effects of aging, remanufacture and material options, and evolving threat environments on warhead performance
  - Developing modern materials and design and manufacturing options to enable a more modern and efficient production complex
  - Maintaining a nuclear explosive test capability as a safeguard
- Extending the nuclear deterrent's life through modernizations:
  - Replacing obsolete technology
  - Enhancing stockpile safety and security
  - Meeting military requirements
- Assuring the capabilities to support the nuclear deterrent in the near-term and long-term (Note: These capabilities are discussed in Chapter 3, "Weapons Activities Capabilities that Support the Nuclear Security Enterprise"):
  - Renewing and sustaining critical production, manufacturing, and research capabilities
  - Assuring a stable, reliable, and trusted domestic supply chain for nuclear weapon components and subsystems

- Advancing innovative experimental platforms, diagnostic equipment, and computational capabilities:
  - Keeping technical expertise and capabilities on the cutting edge to support a responsive and resilient enterprise
- Providing safe and secure transport of nuclear weapons, weapon components, and special nuclear materials to meet mission requirements

The Integrated Stockpile Model in **Figure 1–2** shows how the stockpile cycle's main activities—plan, modernize, maintain, assess, and certify—link these strategies to sustain the stockpile and support mission priorities.

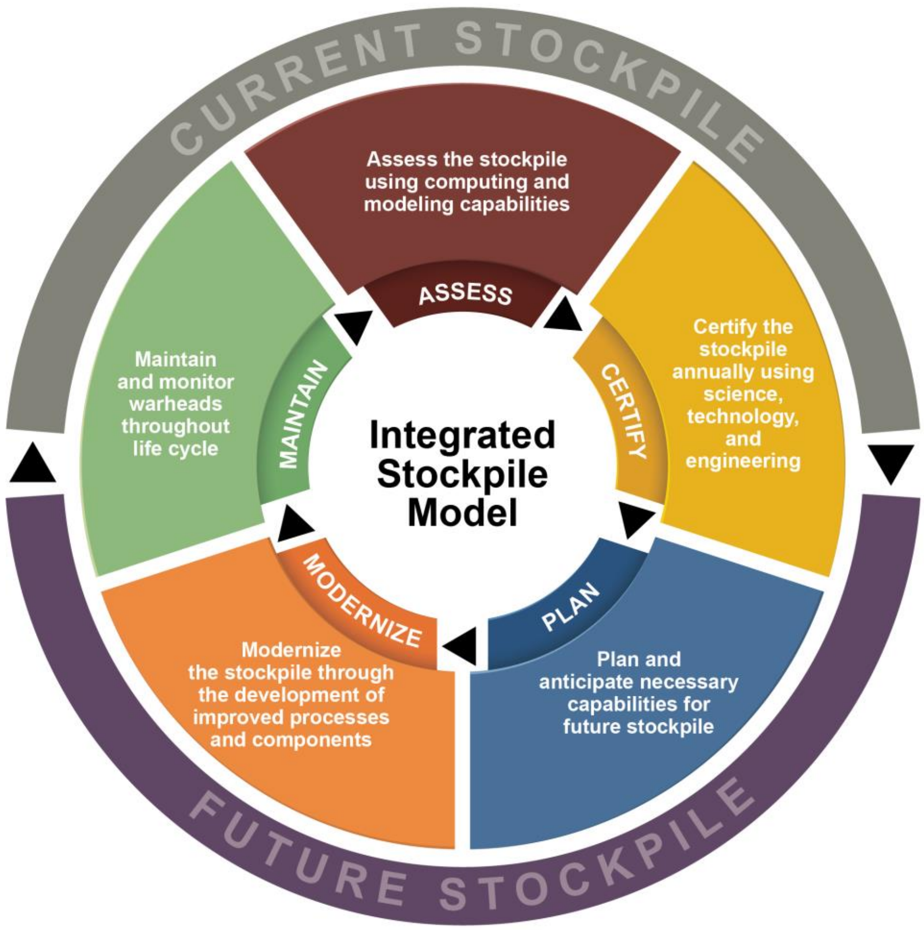


Figure 1–2. Integrated stockpile model

1.5 Summary of Key Challenges in Executing the Stockpile Stewardship and Management Plan

DoD continues to make progress on the first recapitalization of the triad[1] since the end of the Cold War, and this effort cannot be accomplished alone. Consistent, on-going schedule integration between the warhead and delivery programs managed by DOE/NNSA and DoD, respectively, is key to the delivery of timely and cost-effective capabilities that meet the defense needs of the Nation. The partnership between DoD and DOE/NNSA continues to thrive through the interagency Nuclear Weapons Council, which has made tremendous progress to align priorities, schedules, and investments between the Departments to ensure the Nation's nuclear deterrent's future viability.

Nearly all the systems that comprise the current U.S. nuclear deterrent are well beyond their original service lives and further life extensions to meet future requirements are no longer cost-effective. DoD is addressing challenges within its aging nuclear command, control, and communications system; delivery systems; and platforms, and DOE/NNSA is addressing similar challenges as the nuclear warheads in the stockpile continue to age. Additionally, much of the DOE/NNSA nuclear weapons infrastructure continues to require near-term and longer-term investments to provide a safe, and secure working environment with the capabilities and capacities necessary to meet military requirements. As a result, the nuclear security enterprise faces a challenge acquiring and fielding modern replacement systems concurrently in each leg of the triad while also investing in an updated nuclear weapons stockpile and supporting infrastructure.

One of the most critical challenges that DOE/NNSA must address is the modernization and recapitalization of existing infrastructure in parallel with increasing mission requirements. Components, subsystems, buildings, and equipment need to be replaced, not just life extended. This necessity is particularly critical for the production facilities and strategic material production capabilities and capacities within the nuclear security enterprise.

DOE/NNSA has resourced plans to renew the essential time-critical manufacturing capabilities prioritized to meet DoD near-term to intermediate-term warhead deliveries and maintain workforce safety. DOE/NNSA's plans focus on five areas:

- Establishing an 80 pits per year production capability
- Reestablishing high explosives synthesis, formulation, and production capabilities
- Modernizing and enhancing the facilities and capabilities needed to meet near- to long-term needs for tritium
- Modernizing the production capabilities for secondary assemblies, radiation cases, and replacing the current lithium production facility
- Modernizing and enhancing non-nuclear component research, development, testing, and production capabilities

Figure 1–3 shows the timeline necessary to meet warhead needs.

[1] A combination of platforms and weapons, the three legs of the U.S. nuclear triad (land, sea, and air), serve as the backbone of America's national security (https://www.defense.gov/Experience/Americas-Nuclear-Triad/).

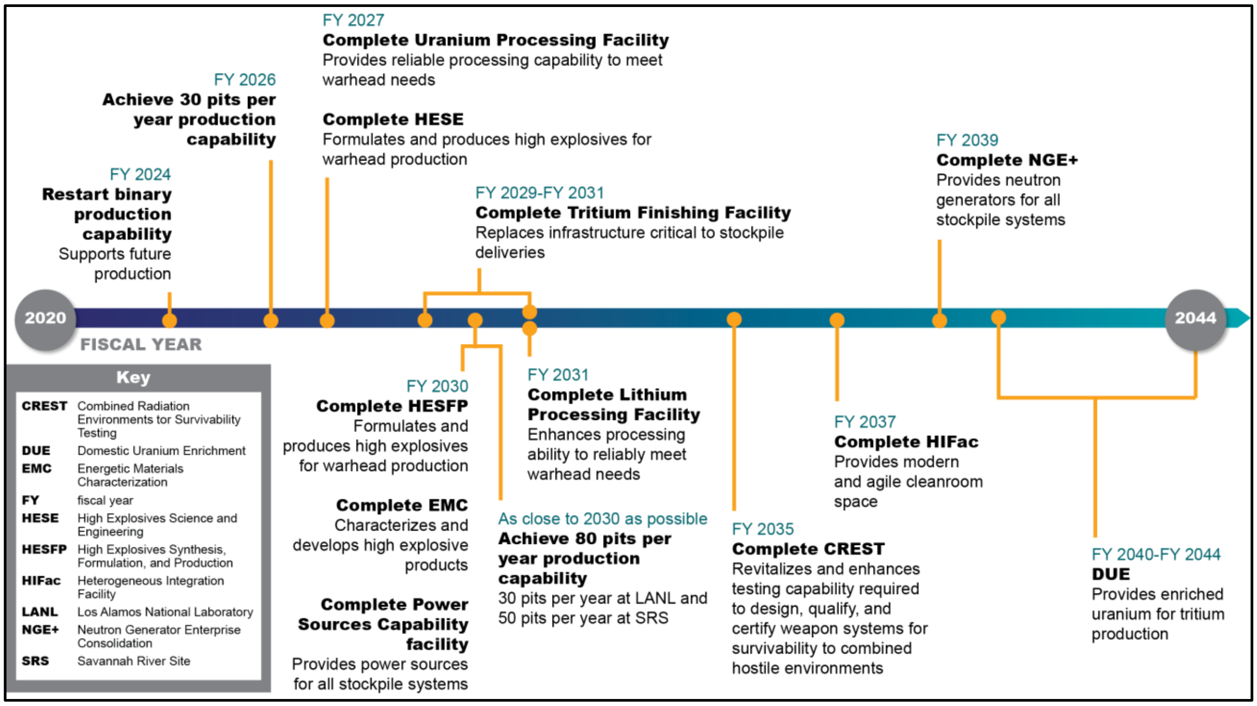


Figure 1–3. Timeline for key infrastructure and capability investments for future warheads

- The nuclear weapons stockpile needs updated technologies that require investment in new processes, technologies, and tools to design, qualify, certify, and produce warheads in accordance with stringent and evolving stockpile specifications and requirements. The increased number of concurrent weapon system builds entail three requirements:
  - Maturing new options with shortened development cycles
  - Advancing the ability to predict weapon performance in configurations that were not tested underground
  - Evaluating the impact of new materials and processes, reusing aging components in future systems, and enhancing production throughput
- Pursuit of only the priority activities described above does not exercise all phases and aspects of the joint nuclear weapons life cycle. DOE/NNSA must devote some effort to less time-sensitive activities to transfer knowledge and skills to the newer generation of nuclear weapon designers and engineers, accelerate and enhance the weapon life cycle, and strengthen integration between DoD and DOE/NNSA to ensure sustainment of all required capabilities. This continued focus is reflected in the inclusion of Appendix E, which resubmits information on the programs, projects, and activities of the Stockpile Responsiveness Program.
- The nuclear weapons supply chain availability and trustworthiness must be sustained to assure industrial base viability and guard against potential counterfeit and sabotage. DOE/NNSA has implemented several initiatives through the Nuclear Enterprise Assurance program to assure supply chain protection. For example, DOE/NNSA's nuclear security enterprise provides the tools and capabilities needed for trusted radiation-hardened silicon microelectronics. DOE/NNSA is installing new tooling and planning recapitalization efforts to extend the life of key and critical facilities to ensure continued capability. DOE/NNSA is also interacting and collaborating with

partners to establish research and development efforts that could serve as a future production capability.

- In FY 2021 DOE/NNSA developed the nuclear security enterprise industrial base (NIB) monitoring framework to provide for the continued viability of the nuclear weapons stockpile. This framework takes a holistic approach to monitoring the industrial base that supports nuclear weapons components, subsystems, and materials through the establishment of four pillars. These four interdependent pillars of activities (supply chain, operations, logistics, and workforce) function in concert to ensure that challenges to maintaining the stockpile are viewed with a broad lens and that gaps or risk in specific areas relating to the NIB are proactively identified. Many of these challenges within specific areas of the NIB are presented throughout the SSMP, along with ongoing and future mitigation strategies. The monitoring framework leverages the management processes of numerous programs, working groups, and teams across the nuclear security enterprise and continues to evolve to properly account for a continuously changing national security environment. A new addition to the FY 2023 SSMP, Appendix F, provides further details on the framework and DOE/NNSA's approach to monitoring the NIB.

Chapter 2
Stockpile Management

This chapter summarizes the activities the Department of Energy's National Nuclear Security Administration (DOE/NNSA) manages to maintain the Nation's nuclear weapons stockpile. These activities include sustaining, modernizing, and dismantling nuclear weapons; maintaining and modernizing production operations; and optimizing the scientific tools that underpin these efforts.

Stockpile Management Accomplishments

- *Completed Annual Assessment Cycle 26*
- *Achieved B61-12, W88 Alt 370, and W87-1 deliverables*
- *Achieved goals for Stockpile Sustainment activities*

DOE/NNSA coordinates and plans with the Department of Defense (DoD) through the Nuclear Weapons Council to manage the current and future stockpile through four major program areas:

- **Stockpile Sustainment** performs single-system and multi-system sustainment activities (i.e., assessment, surveillance, maintenance, and response to emerging issues) for all weapons systems in the stockpile. Stockpile Sustainment includes limited life component (LLC) exchanges, surveillance activities, significant finding investigations (SFI), weapons reliability reporting, and annual assessments that provide a comprehensive understanding of the health of the stockpile.
- **Stockpile Major Modernization** includes life extension programs (LEPs), modification programs (Mod), and major Alts that extend the life of weapons in the stockpile, enhance system security and safety features, and address issues related to aging or component obsolescence. It also includes modernization programs that do not constitute an LEP, Mod, or Alt, but provide a modernized warhead capability (e.g., the W93).
- **Weapons Dismantlement and Disposition (WDD)** handles dismantlement of retired weapons and disposition of weapon components, which can generate components and materials for Weapons Activities and other DOE/NNSA mission areas.
- **Production Operations** provides DOE/NNSA with a multi-system manufacturing-based program that drives site production base capabilities for warhead modernization activities, weapon maintenance, surveillance, weapon assembly and disassembly, and weapon reliability and safety testing. Production Operations encompasses sustaining all weapon systems capabilities that enable weapon production and are not specific to one material stream. It coordinates closely with Production Modernization, which focuses on the special nuclear materials and components (such as plutonium and uranium), as well as non-nuclear component modernization. These capabilities are discussed in Chapter 3.

The remainder of Chapter 2 is organized around these four major areas as depicted in **Figure 2–1**.

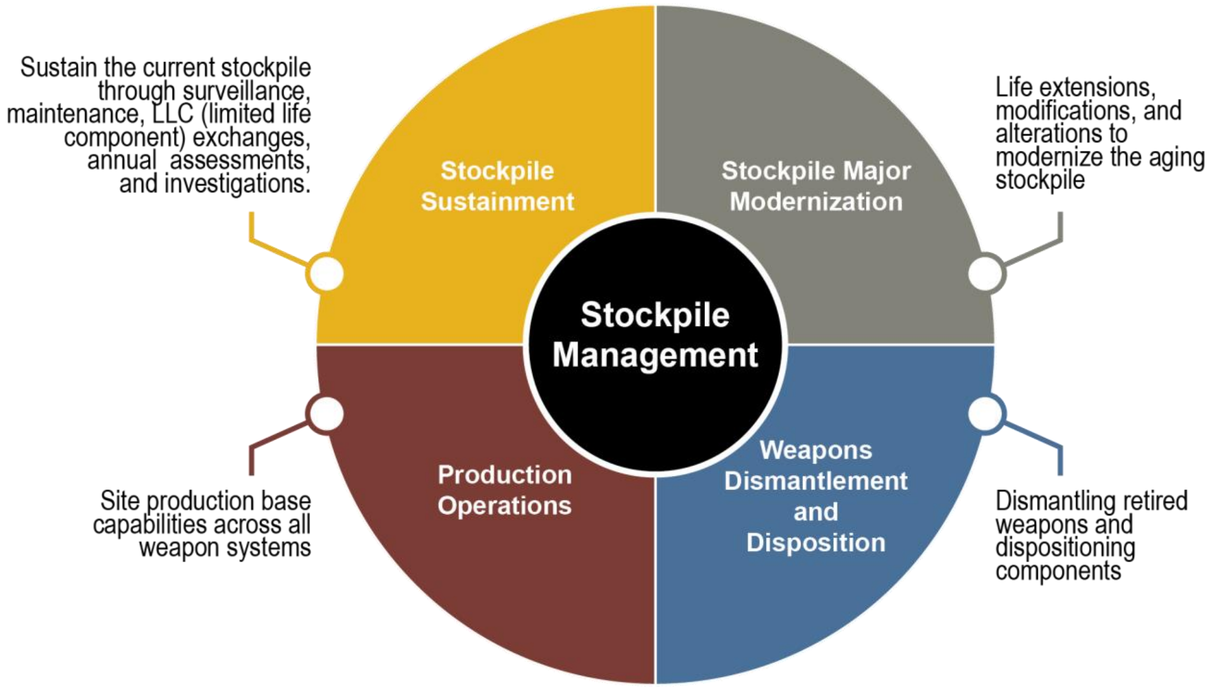


Figure 2–1. Major Stockpile Management Programs

Managing the stockpile requires comprehensive planning for all stockpile elements to integrate these activities with each other and with production capabilities. However, these activities alone cannot sustain the nuclear deterrent. Managing the stockpile also depends on a strong set of enabling capabilities covering the necessary science, technology, design, production, materials, and processes, as well as a workforce with the requisite skill set to execute these tasks. These individual capabilities and the linkages to stockpile management are described in Chapter 3. Chapter 4 and Appendix C of this report address two specific elements of these capabilities—infrastructure and workforce—across all capabilities at an enterprise level, further reinforcing the need to sustain the health of capabilities used to support the enduring stockpile mission. To achieve success in these areas, it is crucial that every capability listed in Chapter 3 of this Stockpile Stewardship and Management Plan – Biennial Plan Summary (SSMP) is healthy and fully and efficiently executed.

2.1 Sustaining the Stockpile

Stockpile sustainment activities are prioritized and performed to ensure the daily health of the stockpile. These activities include surveillance, annual assessments, and routine maintenance to ensure weapons remain safe, secure, and effective over the projected life cycle. Weapons that remain in the stockpile are eventually updated through modernization programs to address modified military requirements, resolve any anomalies, and meet updated safety and security standards. These modernization activities (LEPs, Mods, and Alts) are addressed through the Stockpile Major Modernization activities discussed in Section 2.2.

2.1.1 Assessing the Stockpile

The status of the stockpile is evaluated through continuous, multi-layered assessments of the safety, security, and military effectiveness of each U.S. nuclear weapon system. The annual stockpile assessment process evaluates the state of the stockpile by conducting physics and engineering analyses, experiments (such as hydrodynamic and subcritical experiments), and computer simulation/modeling. Assessments may also evaluate the effects of aging on performance and quantify performance thresholds, uncertainties, and margins. They assemble a body of evidence to measure performance at the part, component, subsystem, and system levels to determine whether required performance characteristics are met. The processes combine data, analysis, and expert judgment with simulations and continually advancing capabilities to develop a final evaluation of the stockpile.

2.1.1.1 Annual Assessment

The directors of the three national security laboratories conduct independent annual assessment reviews on the state of all stockpile systems for which they are responsible. The Commander of the U.S. Strategic Command (USSTRATCOM) is also required by statute (50 U.S. Code 2525) to assess the stockpile each year based in part on inputs from the national security laboratories. This process is not a recertification of the weapons in the stockpile; it is an assessment of each system's existing certification basis, considering information generated by the SSMP in the past year. Each annual assessment builds on previous years' experience with each weapon system and incorporates new information and state-of-the-art capabilities, from stockpile maintenance, surveillance, experiments, simulations, and other sources to update the technical basis of each weapon system.

The assessments and conclusions in the Annual Assessment Reports are subject to inter-laboratory peer review by Red Teams and subject matter experts appointed by each laboratory's director, program managers, and senior laboratory management. This effort culminates in a written summary and conclusion of the assessments from each laboratory director and the USSTRATCOM Commander, which are included as unabridged attachments to the statutorily required *Report on Stockpile Assessments*, prepared annually by the Nuclear Weapons Council for formal endorsement by the Secretaries of Energy and Defense, and submitted to the President.

2.1.1.2 Weapon Reliability

Each September, DOE/NNSA publishes the *Weapons Reliability Report*, which provides an updated summary of reliability and yield characteristics of all weapons in the stockpile. The report's purpose is to communicate to stakeholders the assessed reliability, reliability risks, and the effects of test limitations. The report is the principal DOE/NNSA report on weapon systems reliability that USSTRATCOM uses for strategic planning actions. The Annual Assessment Review process informs this report, which incorporates data from surveillance activities.

2.1.1.3 Advanced Certification and Qualification

Advanced certification develops tools and methods to ensure the safety and reliability of the current stockpile and prospective systems for stockpile modernization without further underground nuclear explosive testing. This subprogram delivers assessment methodologies, diagnostic and experimental techniques, data analysis methods, and assessments of the certifiability of design options for future stockpile needs. Advanced certification activities preserve and reanalyze legacy nuclear test data and validate simulation codes and models against improved physics models and hydrotest and subcritical experimental data. These activities enhance DOE/NNSA's understanding of a weapon system's performance and possible failure modes, improve the quantification of margins and uncertainties, and improve the fidelity and agility of certification methodologies.

DOE/NNSA "qualifies" nuclear weapons components, subsystems, and integrated systems to the military characteristics and stockpile-to-target sequence (STS) environmental requirements, including normal, abnormal, and hostile environments. Qualification plans for each stockpile system lay out the experimental data, modeling, simulation capabilities, and production data required to ensure system functionality.

While qualification is carried out by each warhead program, Advanced Qualification activities seek to improve qualification methods by anticipating needs and developing the tools, capabilities, and material fabrication options that will enable qualification of replacement or new materials/components, often with increased responsiveness or enhanced properties. These activities are key to address the qualification challenges for advanced manufacturing methods, for replacement materials, and for new systems architectures. Additionally, these activities are focused on methods to streamline qualification processes to reduce costs, timescales, resources, floor space, and testers, and to standardize methods and requirements across warhead systems. Advanced certification and qualification activities promote the development of design for manufacturability. Close coordination between materials and components development and between design and production agencies enables design for manufacture.

2.1.1.4 Quantification of Margins and Uncertainties

Assessing weapon performance requires integrating many sources of data and expertise. One way performance is gauged is through the quantification of margins of uncertainties methodology, which evaluates the degree to which a weapon operates within the bounds of specified operating characteristics or requirements. This methodology supports nuclear stockpile decision-making and enables risk-informed decisions. A key metric is the confidence factor, or the ratio of margin (M) to uncertainty (U), M/U. Margin is the difference between the expected value and the minimum value of a parameter to ensure some aspect of warhead functioning is performing properly. Uncertainty is the degree to which these values are known. Stockpile Research, Technology, and Engineering activities (also referred to as Stockpile Stewardship activities) evaluate approaches to increase margin when possible and to quantify uncertainties. These tasks are achieved by performing experiments in areas such as material properties to provide data for improving the reliability of the models and experimental platforms used to simulate warhead operation. In summary, quantification of M/U provides an increased understanding of the basis for the assessed confidence in the weapons system performance.

2.1.2 Stockpile Surveillance

Surveillance activities provide data to evaluate the safety, security, reliability, and performance of weapons in the stockpile in support of annual assessments. The cumulative body of this data supports future stockpile decisions regarding weapon LEPs, Alts, Mods, or other weapon systems not in those categories based on the assessment activities described above. The surveillance program has six goals:

- Identify manufacturing and design defects that could affect safety, security, reliability, or performance
- Assess risks to the safety, security, and performance of the stockpile
- Determine the margins between design requirements and performance at the system, component, and material levels
- Identify aging-related changes and trends at the subsystem, component, and material levels
- Further develop capabilities for predictive assessments and provide lifetime estimates of stockpile components and materials
- Provide critical data for the annual *Weapons Reliability Report* and the *Report on Stockpile Assessments*

DOE/NNSA conducts stockpile surveillance through weapon disassembly and inspection, stockpile flight-testing, stockpile laboratory testing, component testing, material evaluation, and test equipment. DOE/NNSA continually refines planning requirements for stockpile evaluation activities based on new surveillance information, new diagnostic tool deployment, annual assessment findings, and analysis of historical information using modern assessment methodologies and computational tools.

2.1.2.1 Disassembly and Inspection

Weapons sampled from the production lines or returned from DoD custody are inspected during disassembly. Weapon disassembly is conducted in a controlled manner to identify any abnormal conditions and preserve the components for subsequent evaluations. These inspections may detect anomalies that give important clues to the health of the weapons while also advancing inspection technologies and techniques that enhance knowledge and understanding of the stockpile.

2.1.2.2 System, Flight, Laboratory, and Component Testing

A subset of weapons that have undergone disassembly and inspection (D&I) are reassembled into joint test assembly (JTA) configurations to represent the original build to the greatest extent possible. Select non-nuclear components from weapon systems are used directly in the JTA, while nuclear materials are replaced with surrogate materials and custom diagnostic equipment. JTAs may contain extensive telemetry instrumentation to provide detailed information on component and subsystem performance during flight environments. JTA units are delivered to and flown by the DoD operational command responsible for the system. For each weapon system, JTAs are flown on delivery platforms to gather the information required to assess the effectiveness and reliability of the weapon, the launch or delivery platform, and the associated crews and procedures. System-level flight tests are conducted jointly with the Air Force and Navy.

After D&I, certain components of selected weapons are reassembled into test bed configurations using parent unit parts. Stockpile laboratory tests conducted at the subsystem, or component level, assess major assemblies and components and ultimately, the materials that comprise the components. This surveillance process enables detection and evaluation of the onset of aging, trends, and anomalous changes at the component or material level.

Components and materials from the D&I process undergo further evaluations to assess component physical configuration, functionality, performance margins and trends, material behavior, and aging characteristics. The testing can involve nondestructive and destructive evaluation techniques and can be used to aid in developing predictive performance and aging models of components and materials.

2.1.2.3 Testing Equipment

Testers can be applied to systems, subsystems, major components, and processes. Testers perform two key functions. First, they provide the mechanical, electrical, and radiofrequency stimuli to the system in a specified sequence to evaluate component functionality relative to requirements. Second, the testers simultaneously collect data on the components' and subsystems' performance and for product acceptance. The data collected are used as input to assess the performance and assert the continued certification of the weapon system as safe, secure, and effective.

2.1.2.4 Anomaly Investigative Process

When anomalies that could significantly affect weapon safety, security, reliability, or effectiveness arise in surveillance data or are identified or reported to DOE/NNSA by DoD, technical analyses are conducted to determine whether observations warrant an SFI. SFIs are also opened for anomalies discovered anywhere in the stockpile when unexpected phenomena are observed. Such occurrences are investigated by the design agency responsible for the anomalous component. Investigations can include modeling of historical data, focused materials experiments, research and studies, major system test replication, and subsystem and subcomponent tests. These SFIs can continue through several annual assessment cycles. SFIs are closed after the impacts to system performance, reliability, or safety have been assessed and follow-up actions are determined, if necessary. A tracking and reporting system monitors anomalies and SFIs progress from initial discovery through closure, and the status of any corrective actions taken.

2.1.3 Maintaining the Stockpile

Maintaining the current stockpile comprises many ongoing activities:

- Completing LLC exchanges of gas transfer systems (GTS), power sources, and neutron generators, as required, to sustain system functionality
- Responding to emerging issues that do not rise to the level of a major Alt or LEP through maintenance, minor repairs and rebuilds, incorporation of surety features, and other changes
- Maintaining production authorization by conducting periodic nuclear explosives safety studies
- Maintaining specialized support equipment, such as custom tooling, for stockpile operations
- Provisioning for spare and replacement parts that are consumed in stockpile operations

2.1.3.1 Limited Life Components

Weapons contain LLCs that require periodic replacement to sustain system functionality and performance. Age-related changes affecting these components are predictable and well understood, and surveillance is conducted to ensure the components continue to meet performance requirements throughout the projected lifetime. Periodic LLC exchanges replace these components at defined intervals throughout a weapon's lifetime. DOE/NNSA produces LLCs and collaborates with DoD to jointly manage component delivery and installation. These components include GTSs, power sources, and neutron generators.

Gas Transfer Systems

GTSs are designed, produced, filled, and delivered to DoD for existing weapon systems. Modern GTS designs extend LLC intervals and increase weapon performance margins, thereby improving maintenance efficiency and enhancing weapon safety and reliability. Function-testing life storage units and development hardware validates performance characteristics and provides research and development (R&D) to inform current and future GTS designs. New GTS designs are evaluated to verify the GTSs may be loaded in the production facilities and meet weapons systems performance characteristics. In parallel to these R&D efforts, production facilities are maintained for gas-loading operations, GTS surveillance, and tritium recovery from end-of-life GTSs.

Power Sources

Current and future planned nuclear weapons require compact, highly specialized power sources that meet stringent reliability and performance requirements. Requirements for size, weight, active life, responsiveness, and output are unique to nuclear weapon applications and are not readily available from commercial suppliers. This capability supports nuclear weapons and other national security missions, including prototyping and parts development, through the full life cycle requirements of power source components through early-stage R&D and modeling, technology maturation, design and development, production, surveillance, and disassembly.

Neutron Generators

Neutron generators are highly complex LLCs integral to nuclear weapon function. The DOE/NNSA neutron generator enterprise, which is an integrated design and production agency, manages the neutron generators' entire life cycle to meet DOE/NNSA's commitments, including scientific understanding through design, development, qualification, production, surveillance, dismantlement, and disposal.

2.1.3.2 Integrated Surety Architecture

The Integrated Surety Architecture program enhances DOE/NNSA transportation surety for over-the-road shipments of nuclear weapons by developing enhanced capability shipping configurations to support transportation security. The program is implementing enhanced capability shipping configurations across the stockpile to address the maximum number of future shipments. Integrated Surety Architecture is a DOE/NNSA requirement for over-the-road shipment of any nuclear weapon planned to be in the active stockpile after 2025.[1]

2.2 Stockpile Major Modernization

Stockpile major modernization activities are performed through a series of planned LEPs, Mods, and Alts enabled by a strong set of science, technology, and engineering capabilities. **Figure 2–2** displays these plans, which fully reflect the priorities established and formally authorized by the Nuclear Weapons Council. Some modernization programs do not yet have approved first production units but reflect notional first production units, coordinated with DoD, for planning purposes.

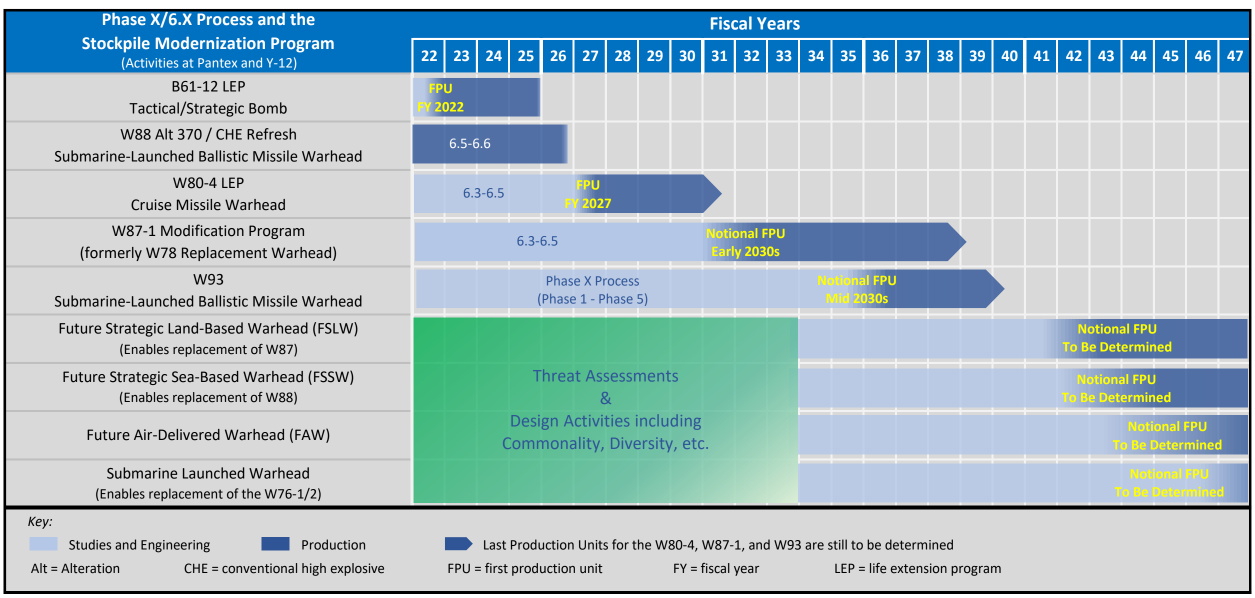


Figure 2–2. DOE/NNSA Warhead Activities

Currently, the long-term vision for the nuclear weapons stockpile seeks to build additional flexibility for the Nation to enable rapid response to unforeseen contingencies while incorporating features and technologies that enhance safety and security, as appropriate and practicable. DOE/NNSA will incorporate flexibility-enabling design strategies and an advanced digital enterprise that promotes system

[1] Stated in 50 U.S.C. 2538 (d).

modernization activities, and exercise capabilities through the Stockpile Responsiveness Program. These improvements will enhance the Nation's ability to counter adversaries' capabilities, stockpile aging, and variables associated with supporting U.S. hedge capabilities.

Qualification-ready and certification-ready options for materials, components, and systems must be developed to meet resilience requirements for the U.S. nuclear deterrent, and matured in advance to be viable for consideration and available when needed to support Nuclear Weapons Council down-select decisions, development, and production. The activities that lead to this state of readiness depend on advanced scientific and engineering capabilities that enable design, qualification and certification processes, and improve the responsiveness of the nuclear security enterprise in terms of cycle time and digital design tools. These science-based enabling efforts are described in Chapter 3.

2.2.1 *Phase X Process* (Nuclear Weapons Life Cycle)

The responsibilities of DoD and DOE/NNSA for the development, testing, and production of proposed nuclear weapons were originally established through the 1953 joint agreement between the then Atomic Energy Commission and DoD, which introduced the concept of weapon acquisition phases. The original agreement was supplemented over the years to clarify various areas of joint departmental cooperation. However, the United States' decision to halt underground nuclear explosive testing in 1992 affected the joint agreement as it was no longer updated regularly. Emerging DoD requirements for future systems necessitated updated procedural guidelines defining the full seven phase nuclear weapons life cycle. This necessity was accomplished through the recently implemented *Phase X Process,* which updates the original agreement and the joint DoD and DOE/NNSA procedures governing the full life cycle for nuclear weapons.

The updated guidelines also supplement the existing Nuclear Weapons Council-approved Procedural Guidelines for the *Phase 6.X Process*, which define the framework for existing nuclear weapon refurbishment activities. The *Phase X Process* includes procedures for program study, development, production, sustainment, and nuclear weapons systems dismantlement.

Joint DoD-DOE/NNSA nuclear weapons life cycle guidelines, including those under the *Phase X* and the *Phase 6.X Processes*, support increasing emphasis on modernization activities to sustain U.S. nuclear deterrence priorities and capture DoD-DOE/NNSA best practices for nuclear weapons acquisition and sustainment. The Nuclear Weapons Council's Procedural Guidelines for the *Phase 6.X Process* provide the framework for nuclear weapon refurbishment activities and will continue to be used, even with the updated *Phase X* Procedural Guidelines for Phase 1-7 nuclear weapon design, development, production, sustainment, and dismantlement activities.

2.2.1.1 *Phase 6.X Process*

Nuclear weapons have been historically developed, produced, maintained, retired, and dismantled in a process known as the Nuclear Weapons Life Cycle (now Phase X). This process has not been exercised in its entirety since the end of the Cold War, with the United States executing only Phases 6 and 7 in recent decades. DOE/NNSA's Major Stockpile Modernization activities have been guided by the *Phase 6.X Process* instead, which was developed for non-routine Alts, Mods, and LEPs and starts from an existing warhead design, rather than being used to develop and field a complete warhead. The phases of this process are very similar to stages 1–6 of the life cycle. These phases, and the relation of the *Phase 6.X Process* to the Nuclear Weapons life cycle, are shown in **Figure 2–3.**

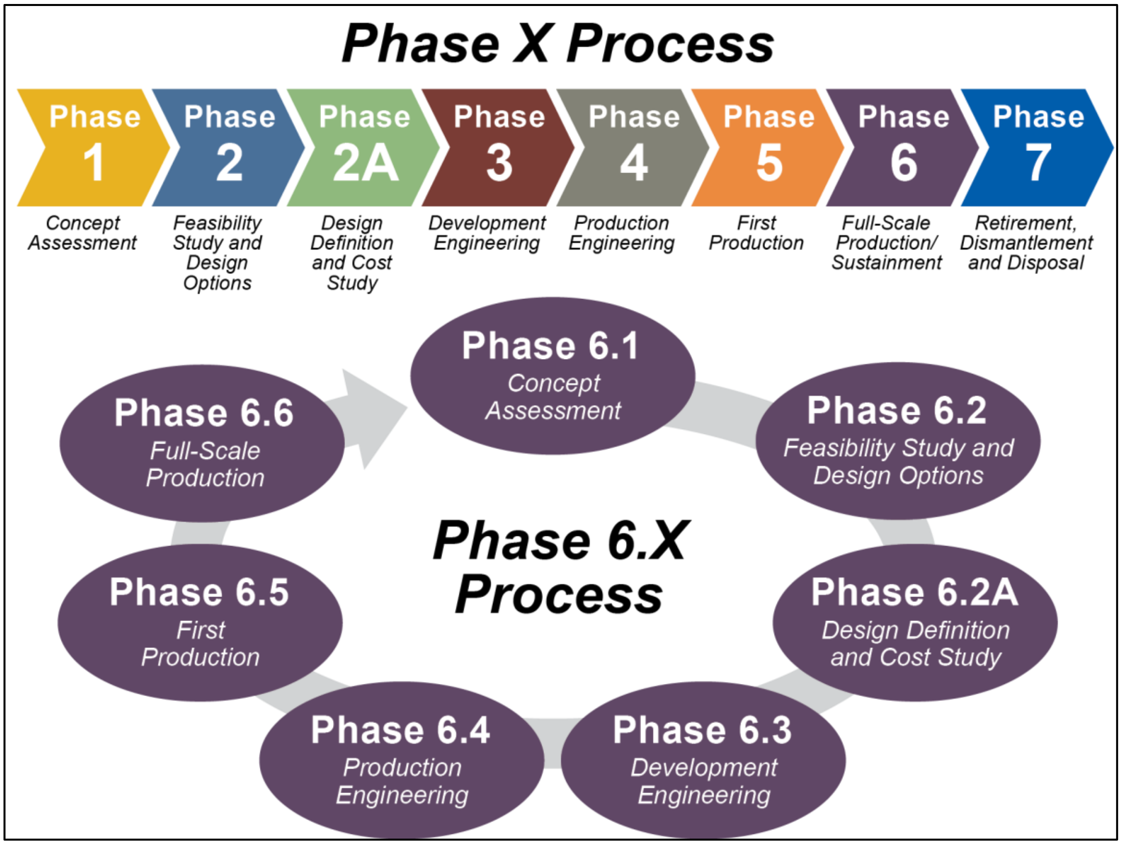


Figure 2–3. Phase X and *Phase 6.X Processes*

2.2.2 B61-12 Life Extension Program

The B61-12 LEP addresses multiple components that are nearing end-of-life, in addition to military requirements for reliability, service life, field maintenance, safety, and use control. The life extension scope includes refurbishment of nuclear and non-nuclear components and incorporates component reuse where possible. With the addition of an Air Force-procured tail kit assembly, the B61-12 LEP will consolidate and replace the B61-3, -4, and -7 bomb variants.

2.2.2.1 Status

The B61-12 received authorization to enter Phase 6.5, *First Production,* in fiscal year (FY) 2021, and completed its first production unit in November 2021. In 2022, the Nuclear Weapons Council formally accepted the B61-12 into the stockpile and authorized Phase 6.6, *Full-Scale Production*. The B61-12 LEP required re-planning to allow re-qualification of base metal electrode affected components,[2] similar to the W88 Alt 370. The requalification efforts are on or ahead of the re-baselined plan.

DOE/NNSA achieved the first production unit for the B61-12 LEP on November 23, 2021

[2] In FY 2019 – FY 2020, DOE/NNSA experienced technical issues associated with a limited number of electrical components that affected some production component schedules. This base metal electrode issue led to re-planning of the schedules for both the B61-12 LEP and the W88 Alt 370 programs.

2.2.3 W88 Alteration 370 Program

The W88 warhead has been deployed for more than three decades, and several updates are required to address aging issues and to maintain readiness. The W88 Alt 370 Program modernizes the arming, fuzing, and firing subsystem; improves surety; replaces the conventional high explosive and associated materials; and incorporates a lightning arrestor connector, trainers, joint test assemblies, and associated handling gear. The W88 Alt 370 conversion is scheduled to run concurrently with LLC exchanges of GTSs and neutron generators. This program does not extend the life of the warhead.

2.2.3.1 Status

The W88 Alt 370 received authorization to enter Phase 6.5 in FY 2021 and completed the system-level first production unit in July 2021. The Nuclear Weapons Council formally accepted the W88 Alt 370 into the stockpile in December 2021 and authorized Phase 6.6, *Full-Scale Production,* entry in 2022. The W88 Alt 370 required replanning to allow re-qualification of base metal electrode-affected components, like the B61-12. Requalification efforts were completed in the third quarter of FY 2021, in accordance with the re-baselined plan.

2.2.4 W80-4 Life Extension Program

The W80-4 LEP will deploy with the Air Force's Long Range Standoff (LRSO) cruise missile. This integrated program will replace the aging AGM-86 air-launched cruise missile and the W80-1 warhead. The LRSO will improve the Air Force's capability to defeat adversary Integrated Air Defense Systems by enhancing the bomber force's delivery and survivability capabilities. The W80-4 LEP is on track to support fielding the Air Force's scheduled LRSO cruise missile initial and final operational capability dates.

The LRSO and W80-4 Life Extension Program joint test teams completed the first powered flight test of a LRSO Cruise Missile with W80-4 Warhead released from a B-52 aircraft. The missile successfully released from the aircraft, powered its engine, and executed all in-flight maneuvers. A Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratories (SNL) team developed the warhead test asset, an Environmental Test Unit. The Environmental Test Unit successfully executed all pre-arm/pre-release criteria and collected environmental data for the duration of the flight. This is a significant milestone for the joint program and first collection of representative LRSO free flight data, used to populate the W80-4 STS, define environmental specifications, inform design decisions, and validate computational models.

2.2.4.1 Status

In FY 2019, the Nuclear Weapons Council directed entry of the W80-4 LEP into Phase 6.3, *Development Engineering*. During this phase, weapon system design will continue to be refined. There are four primary deliverables:

- Baseline design, which will advance production engineering processes
- Preliminary Design Review and Acceptance Group Review, which will indicate DoD acceptance of the baseline design and its associated plan for certification
- Baseline Cost Report
- Nuclear Weapons Council approval of the military characteristics and STS

The W80-4 program office anticipates entering Phase 6.4, *Production Engineering*, in the second quarter of FY 2023.

2.2.5 W80-4 Alteration (Sea-Launched Cruise Missile)

After extensive interagency deliberation and approval of the 2022 *Nuclear Posture Review*, it was determined that the Sea-Launched Cruise Missile-Nuclear (SLCM-N) program was no longer needed. The 2022 *Nuclear Posture Review* made this determination in light of the deterrence contributions of the W76-2 and other capabilities, as well as the program's estimated cost relative to other ongoing nuclear modernization efforts. Therefore, consistent with the Administration's 2022 *Nuclear Posture Review*, DOE/NNSA did not request funding for this program.

2.2.6 W87-1 Modification Program

The W87-1 will be deployed alongside the W87-0 on the Sentinel, formerly known as the Ground Based Strategic Deterrent. It will replace the aging W78 warhead by modifying the existing legacy W87-0 design. After the B61-12 achieves initial operational capability, the W78 warhead will become the oldest weapon system in the stockpile and the only system not to have received a major refurbishment or upgrade. Critical W78 components continue to age, while the military requirements for the safety and security features of the W78 warhead have changed since the W78 entered the stockpile in 1979. The W87-1 Modification Program will meet DoD and DOE/NNSA requirements for performance, safety, and security and is slated to deploy on the Sentinel in the early 2030s.

2.2.6.1 Status

Following authorization from the Nuclear Weapons Council in September 2018, the W87-1 restarted Phase 6.2, *Feasibility Study and Design Options*, in January 2019. The program completed 6.2 and entered Phase 6.2A, *Design Definition and Cost Study,* in the fourth quarter of FY 2021. As of the end of FY 2022, the program is awaiting Nuclear Weapons Council approval to enter Phase 6.3, *Development Engineering*. DOE/NNSA previously established a W87-1 Federal program office along with the requisite staff, program plans, and management documents. In 2019, the Nuclear Weapons Council selected a single surety architecture for the W87-1, and DOE/NNSA continues to evaluate component features through feasibility and trade studies.

2.2.7 W93 Program

The W93 will address future Navy ballistic missile requirements. It will incorporate modern technologies to improve safety, security, and flexibility to address future threats and will be designed for ease of manufacturing, maintenance, and certification. All key nuclear components will be based on currently deployed and previously tested nuclear designs, and extensive stockpile component and materials experience. It will not require additional nuclear explosive testing to certify. The program will use the Nuclear Weapon *Phase X Life Cycle Process* for integrated nuclear weapons system acquisition, rather than the *Phase 6.X Process* (see Section 2.2.1 for additional information regarding these life cycle processes). Work in support of the W93 Program will include Phase 1, *Concept Assessment*, which evaluates warhead architectures and available technologies against a potential range of desired attributes, draft military characteristics, and known constraints. It will also inform DoD's program activities for the associated Mk7 reentry body within which the W93 would be deployed.

Carrying out the W93 program is vital for continuing DOE/NNSA's longstanding cooperation with the United Kingdom, which is also modernizing its nuclear forces. As an allied but independent nuclear power that contributes to the North Atlantic Treaty Organization's nuclear deterrent posture, the United Kingdom's nuclear deterrent is critical to U.S. national security.

2.2.7.1 Status

The W93 completed Phase 1, *Concept Assessment*, in the third quarter of FY 2022. The Nuclear Weapons Council has authorized the program to proceed into Phase 2, *Feasibility Study and Design Options*.

2.2.8 Future Warheads

DOE/NNSA is coordinating with DoD to define the appropriate ballistic missile warheads to support anticipated future threats. These warheads currently include the Future Strategic Land-Based Warhead, the Future Strategic Sea-Based Warhead, the Future Air-Delivered Warhead, and a Submarine-Launched Warhead (to replace the W76-1/2) that will be needed in the 2040s.

2.3 Weapon Dismantlement and Disposition

WDD activities disassemble retired weapons into major components. Those components are then assigned for reuse, storage, surveillance, or for additional disassembly and subsequent disposition of constituent parts and materials. The dismantlement schedule for retired nuclear weapons is planned to provide the materials and components required for the stockpile (in particular, LEPs, Mods, and Alts), and considers the needs of other programs for these materials. WDD also maintains the proficiency of technicians and balances work scope at the production sites.

> ***WDD Accomplishments***
>
> *Weapon Dismantlement and Disposition team completed over 275 arming, fuzing, and firing tear downs – well above the year's goal of 150.*

Dismantlement rates are affected by many factors, including weapon system complexity, availability of qualified personnel, equipment, and facilities, logistics, policy and directives, and legislative requirements. DOE/NNSA's current 5-year Dismantlement Plan balances physical constraints with legislative, policy, and directive guidance. The WDD work scope includes management of retired nuclear weapon systems (e.g., managing safety concerns), characterization of weapon components, disassembly of weapons and components, and final component disposition (e.g., component reuse and material recycle and recovery). WDD activities occur across all sites in the nuclear security enterprise.

2.3.1 Status

DOE/NNSA continues to make significant progress on dismantling weapons and component disposition. As noted in prior SSMPs, DOE/NNSA was on pace to complete the dismantlement of all warheads retired before FY 2009 by the end of FY 2022; however, the global Coronavirus Disease 2019 pandemic delayed the dismantlement of a small number of these retired warheads until after FY 2022. DOE/NNSA remains committed to completing this effort. In addition, DOE/NNSA has developed return schedules to remove retired weapons from DoD facilities while meeting DoD operational requirements. WDD continues to characterize components coming off the dismantlement line, and sites are eliminating excess component inventories.

2.4 Production Operations

Production Operations provides the base capabilities to enable weapon operations (assembly, disassembly, and production) planned for the warhead modernization, stockpile systems, and the WDD programs. Production Operations' goal is to maintain the base capability required to sustain a responsive and resilient stockpile through robust management and production process engineering, manufacturing, and production technology resources. The program accomplishes this goal by maintaining the tools and personnel necessary for supporting major manufacturing, assembly, disassembly, maintenance, and production data management for all nuclear weapons in the stockpile and modernization efforts.

Production Accomplishments

- *Sustained base capabilities for multi-system operations and maintenance support to meet all LLC exchange GTS fills and surveillance deliverables*
- *KCNSC completed over 1,600 critical equipment calibrations in support of production activities.*
- *Supported over 800 LLNL engineering authorizations and 350 product realization team meetings.*
- *Accepted over 130,000 SNL components at a 100 percent acceptance rate.*

At individual enterprise sites, Production Operations facilitates the capability and capacity to sustain the nuclear security enterprise's production mission, mainly through sustaining and expanding the multi-program enabling workforce. The base labor capacity the program provides is essential to preventive and corrective maintenance, calibrations, quality assurance, qualification, production logistics, manufacturing execution systems, process flow, and scheduling activities. Production Operations also maintains critical multi-weapon system supporting equipment at certain sites and select programmatic infrastructure.

Production Operations also serves as the demand signal for the modernization of production capabilities and capacity to improve efficiency and maintain manufacturing operations that will meet future requirements. The program requires close coordination with the Production Modernization and Advanced Manufacturing Development programs, which are charged with development and initial deployment of new, or replacement, manufacturing capabilities. It also heavily depends on required infrastructure modernization to ensure base capabilities with adequate capacities, space, and equipment are in place.

2.4.1 Status

Production Operations is expanding the nuclear security enterprise's base capability sustainment capacity to meet a significant increase in demand associated with the ramp up in warhead modernization activities and Production Modernization projects.

As the Production Support program evolved into Production Operations within the Office of Stockpile Production Integration, it has taken on additional scope in enterprise capacity modeling and planning. This emerging function aligns well with Production Operations' role as a demand signal for modernizing nuclear security enterprise production capability and capacity expansion.

Chapter 3
Weapons Activities Capabilities that Support the Nuclear Security Enterprise

> ***Key Changes to Weapons Activities Capabilities***
>
> - *Revision of capabilities within the Weapon Science and Engineering Area to better align with DOE/NNSA mission-related activities*
> - *Simplification of the capabilities within the Weapon Material Processing and Manufacturing Area*

Chapter 2 describes how the Department of Energy's National Nuclear Security Administration (DOE/NNSA) fulfills the critical mission to assess, surveil, modernize, and qualify the nuclear weapons stockpile, and certify it is safe, secure, and effective. Chapter 3 focuses on the Weapons Activities capabilities required to accomplish this mission. DOE/NNSA delivers the capabilities required for an effective nuclear deterrent that provides the Nation with the ability to adapt and respond to a dynamic security environment, emerging strategic challenges, and geopolitical and technological changes. The Department of Defense (DoD) supplements the Weapons Activities capabilities with specific efforts, including platforms for flight tests.

The Weapons Activities capabilities described in this chapter directly support 2022 *NNSA Strategic Vision* Mission Priority #1, design and deliver the Nation's nuclear stockpile. To accomplish this mission, DOE/NNSA must sustain the current stockpile, undertake comprehensive weapons modernization, recapitalize the nuclear weapons infrastructure, and strengthen cutting-edge science, technology, and engineering capabilities.

More than 30 key Weapons Activities capabilities support conduct of the Integrated Stockpile Model introduced in Chapter 1, Figure 1–2, and each capability may support multiple parts of this model. This interdependency between model activities and capabilities, and among the capabilities, is described throughout Chapter 3. **Figure 3–1** shows the seven interdependent areas, previously termed portfolios, each containing a suite of capabilities that, combined, address a particular aspect of Weapons Activities. While most Weapons Activities capabilities are applicable only to the stockpile mission, many are also used to support nonproliferation, naval reactors, and counterterrorism activities. Examples are discussed throughout this chapter.

The nuclear security enterprise elements that comprise Weapons Activities capabilities are illustrated in **Figure 3–2**. These elements include the human capital, physical assets, resources, and enabling processes underpinning the Weapons Activities capabilities. All four elements must be sustained, modernized, and advanced to meet current and future missions. The capabilities cannot function as a system if any of these elements are missing.

Weapons Activities capabilities require periodic evaluation across all four elements to assess their health and continued investment. That evaluation is reflected in this chapter and continues in Chapter 4, "Infrastructure and Operations."

Figure 3–1. DOE/NNSA Weapons Activities capability areas

Figure 3–2. Weapons Activities capability elements

Many of the capabilities described below are unique to the nuclear security enterprise. The highly specialized materials, various supply chain component lot sizes, security requirements, advanced computing and research requirements, and stringent manufacturing specifications required for nuclear weapons development and production make the work difficult, or unprofitable, for commercial providers. DOE/NNSA must sustain the health of the Weapons Activities capabilities to continue availability of these niche functions. In addition, the national security requirements for nuclear weapons require trusted domestic vendors for certain materials and processes.

This chapter's sections describe the Weapons Activities Capabilities areas, their constituent capabilities, specific support to the nuclear deterrent mission, and how they link and integrate with other areas and capabilities. See Chapter 4 and Appendix C for an enterprise-level overview of major infrastructure investments and the supporting workforce tied to Weapons Activities capabilities. In Chapter 4, Section 4.2.1, the programmatic infrastructure investments supporting each capability area are aligned with each of the sections in this chapter.

3.1 Weapon Science and Engineering Area

The Weapon Science and Engineering area includes the suite of physical sciences and engineering disciplines that comprise the theoretical and experimental capabilities necessary to assess the current nuclear stockpile and certify future stockpile weapons. This portfolio of capabilities is closely linked to the Weapon Simulation and Computing area (Section 3.2) and the Weapon Design and Integration area (Section 3.3). Capabilities in all three areas routinely support efforts in the other two, and all three areas are needed to deliver stockpile mission priorities of assuring an effective, resilient, and flexible nuclear deterrent.

3.1.1 Atomic Physics, Nuclear Physics, Nuclear Engineering, and Radiochemistry

Atomic, nuclear, and radiochemical properties relevant to weapons are critical to enhancing predictive capabilities and designing validation experiments that increase confidence in simulation models. New measurements and evaluations of experimental data that impact, or inform, weapon properties can reduce uncertainties in predictive simulations and improve reassessments of historic underground nuclear explosive test data used to validate and constrain weapons simulations. Reducing uncertainty is critical to the certification strategy for future stockpile options and assessments of the existing stockpile as weapons age.

Atomic physics is the study of interactions among electrons, atomic nuclei, and photons (particularly X-rays). Atomic physics processes, such as X-ray generation, are relevant to the function of nuclear weapons. Facilities such as the National Ignition Facility (NIF), Omega Laser Facility (Omega), Los Alamos Neutron Science Center (LANSCE), and Z pulsed power facility (Z) provide capabilities to explore atomic physics processes that occur in nuclear weapons to inform, improve, and validate computational models.

Nuclear physics is the study of atomic nuclei and their constituents, while nuclear engineering is the translation of nuclear physics principles to the applications of nuclear interactions including fission and fusion. Nuclei undergo complex reaction pathways and provide a significant energy source in nuclear weapons, requiring accurate and precise nuclear data for stockpile performance and safety assessments. Nuclear forces are challenging for theoretical understanding, necessitating experimental measurements. Data are collected at large experimental facilities such as LANSCE, other DOE national laboratories (e.g., Argonne National Laboratory, Berkeley National Laboratory) and academic institutions (e.g., Texas A&M University, Triangle Universities Nuclear Laboratory). Integral measurements used to validate the nuclear data libraries are performed at facilities such as the National Criticality Experiments Research Center at the Nevada National Security Site.

Radiochemistry is the study of radioactive materials and their interactions and is the basis of DOE/NNSA's modern connection to legacy underground nuclear explosive test data. Radiochemical data from the United States' extensive underground nuclear explosive test history database are used to inform modern-day assessments of weapon performance as part of stockpile stewardship. New measurement techniques have enabled analysis of additional reaction products from legacy underground nuclear explosive tests, and the results supplement benchmarking models from those events. Radiochemistry also supports other scientific areas; for example, it is used to develop target materials for nuclear reaction measurements and it is an important element of the diagnostic capabilities used by high energy density (HED) experiments. DOE/NNSA is the nuclear forensics[1] lead for the U.S. Government and employs radiochemistry tools to address national security problems.

3.1.1.1 Status

DOE/NNSA's atomic physics understanding is strong at the limits of high and low temperatures and high and low densities. Between these extremes, there is uncertainty in the fundamental theories, with minimal benchmarked data to inform them. These uncertainties in basic properties lead to increased uncertainties regarding final integrated simulation outputs. A concern for future workforce development and growth in atomic physics is that only a small number of university programs offer relevant training.

Over the past decade, nuclear physics experiments for stockpile stewardship have increased in precision and complexity. New detector systems that use novel materials and modern engineering techniques are enabling unprecedented data precision and providing new data from competing reactions. Coupling nuclear theory to experiments is also expanding predictive methods toward determining nuclear properties for radioactive materials that are difficult to measure. Support for fast neutron facilities (> 0.1 MeV) remains imperative, as reaction product measurements provide additional accuracy for nuclear data and code validation.

Nuclear data evaluation is an established methodology that requires high-quality measurements coupled with theoretical reaction calculations to improve predictive simulations. Data evaluators reconcile newly acquired measurements with existing data and physics models to determine "best value" quantities and uncertainties. Significant investment in training evaluators is essential to providing long-term support to the nuclear data pipeline.

The key radiochemical facilities across the nuclear security enterprise are in high demand, but they are aging. Some urgent infrastructure needs have been addressed, but additional recapitalization is required to obtain measurements for evaluating legacy test data, modern HED experiments, and nuclear data collection.

Many personnel with the knowledge, skills, and abilities in this specialized field have retired, resulting in knowledge gaps about historical methods. Qualified radiochemists must have specialized knowledge and hands-on laboratory training. While the number of radiochemistry programs at universities has increased, most programs do not address the specific needs of the nuclear security enterprise, necessitating training and knowledge transfer between existing employees and new hires.

[1] For further information on DOE/NNSA's nuclear forensics work, refer to *NNSA Prevent, Counter and Respond – NNSA'S Plan to Reduce Global Nuclear Threats.*

3.1.2 Materials Science, Chemistry, High Explosives and Energetics Science and Engineering, and Actinide Science

The Materials Science and Engineering capability aids in understanding how all the materials in a nuclear weapon system perform in diverse and extreme environments throughout its entire life cycle. This capability plays a key role in resolving stockpile and production issues, validating computational models, and developing new materials (e.g., materials produced through advanced manufacturing or designed to replace environmentally hazardous and/or difficult to manufacture legacy materials). In addition, Materials Science and Engineering experiments contribute to stockpile surveillance, where the effects of aging materials must be detected and evaluated to support the stockpile annual assessment. When materials used in the stockpile must be replaced due to aging issues or obsolescence, new materials are developed, studied, and certified for insertion into the stockpile and are vital to extending weapon systems' life. The qualification of new or replacement materials reduces risks and may improve the overall safety and reliability of the stockpile.

Within the Materials Science and Engineering capability, dynamic material studies investigate the compressive behavior, structural transformations, deformation, fracture, and chemical reactions that occur in materials subject to impulsive loading. Experimental investigations of the static properties and dynamic response of stockpile materials in relevant regimes requires specialized facilities such as NIF, Z, LANSCE, Joint Actinide Shock Physics Experimental Research, and Technical Area 55 (TA-55) gas gun facilities. The data generated from these studies is used to create and validate material physics models that contribute to a confident prediction of weapon performance and is increasingly being used for material replacement decisions and to define requirements for components qualification.

The High Explosives and Energetics Science and Engineering capability is the study of detonation and deflagration physics, shock wave propagation, and reaction initiation. It includes the study of the design, synthesis, manufacture, inspection, testing, and evaluation of high explosives (HE) and other energetic materials and components for specific applications. Knowledge of HE and energetic materials is crucial to understand nuclear weapon safety and performance.

These areas are structured to address challenges and meet weapon delivery schedules.

The Chemistry and Chemical Engineering capability encompasses the study of the fundamental composition, structure, bonding, and reactivity of matter in a given state and under processing conditions. This capability plays a key role in the design and improvement of manufacturing processes for weapon components. It is essential for synthesizing, purifying, processing, and fabricating all of the materials that are currently fielded in stockpile warheads, and it is critical for resolving stockpile surveillance issues. It is also necessary for developing and qualifying new materials proposed for near-term warhead modernizations and future system requirements. This capability supports experimental testing and computational tools that help to understand the chemical reactions that control material creation and compatibility as well as the mechanisms and effects of aging and degradation to ensure the quality, performance, and safety of the current stockpile.

Actinide science is the study of physics and chemistry of elements from actinium to lawrencium. This science is important to the understanding of production, purification, compatibility, targets, and behavior of actinide materials relevant to the stockpile. Overall, the nuclear security enterprise workforce meets mission needs related to capabilities across materials science, chemistry, and actinide science, and these capabilities come together in support of mission priorities such as new pit production.

3.1.2.1 Status

Materials science efforts across the nuclear security enterprise have yielded important results in characterizing current stockpile materials under extreme conditions. This capability is strengthened by expanded experimental and computational investigations and enhanced collaborations among DOE/NNSA national security laboratories and nuclear weapons production facilities, sites with experimental platforms, and networks with strategic academic partners.

DOE/NNSA performs Materials Science and Engineering experiments using a broad range of research and development (R&D), testing, and evaluation facilities. Experimental facilities are supported by fabrication capabilities in the complex and with industrial partners. Several new materials and increased scrutiny of how legacy materials change with age are putting significant strain on throughput at existing facilities.

The current capability's scope presents challenges in maintaining an expert workforce and sustaining modern facilities. Developing a sustainable workforce requires active partnering with academic institutions and industry. Furthermore, onboarding that allows significant training time in specialized areas, and stable investments in programs that support foundational applied sciences, are required. Some facilities, such as upgraded plutonium facilities, the new Uranium Processing Facility, and renovated radiological space, have received major capital investments for replacement. Future investments are needed for the new lithium facility, as well as modernized laboratory space to house radiological and general chemical synthesis.

Meeting current and future challenges requires continued investments in sustaining DOE/NNSA's existing infrastructure and capabilities while transforming relevant infrastructure to be responsive and agile. DOE/NNSA has the Energetic Materials Characterization project underway and plans to recapitalize additional HE facilities to meet these challenges, including the HE Applications Facility, Site 300, and the National Energetic and Engineering Weapons Campus, including the Detonator Production Facility.

Several key actinide science facilities across the nuclear security enterprise are in high demand, but they are aging. Some urgent infrastructure needs have been addressed, but additional recapitalization in facilities and key equipment such as accelerators is required to obtain fundamental actinide science material properties measurements, to perform evaluations supporting efficiencies in manufacturing, and to interpret legacy underground nuclear explosive tests.

Many personnel with the knowledge, skills, and abilities in this specialized field have retired, creating knowledge gaps about historical methods. Qualified actinide scientists must have specialized knowledge and hands-on laboratory training. While the number of actinide science programs at universities has increased, most programs do not address the nuclear security enterprise's specific needs, necessitating training and knowledge transfer between existing employees and new hires.

3.1.3 High Energy Density Science and Plasma Physics

HED Science includes the study of matter and radiation under extreme conditions, including the conditions produced in a functioning nuclear weapon. HED experiments provide data required to validate weapon physics models in simulations tools used to assess the stockpile. Focused and integrated HED experiments provide the data needed to support warhead certification for legacy and new weapon systems. Inertial Confinement Fusion (ICF) experiments use the extreme conditions of HED states to generate fusion reactions and further expand the range of conditions accessible in the laboratory. HED experiments support scientists' development and their judgement on weapons-related issues and promote the development of skills in experimentation, design work, fabrication, instrumentation, and other related areas.

ICF experiments compress and fuse light hydrogenic species (deuterium and tritium), releasing large quantities of energy and neutrons. The design and analysis of these experiments builds understanding of thermonuclear burn and plasma properties, while also providing a driver for the development of new cutting-edge technologies in multiple fields. The generation of mega-joule yields at the NIF provides a first-of-its-kind capability across the globe to experimentally measure unique temperature, pressure, and density conditions. Understanding the physics of higher yield ICF platforms and exploring the boundaries of what is possible are key goals for HED Science.

NIF, the world's most energetic laser, conducted the first-ever shot to study a HE sample. The results from the shot will help researchers unlock the mysteries of HE by providing experimental data that quantifies the response of laser-driven HE during reaction. The shot used a non-detonable quantity of an insensitive HE that is used as the main charges in weapons systems.

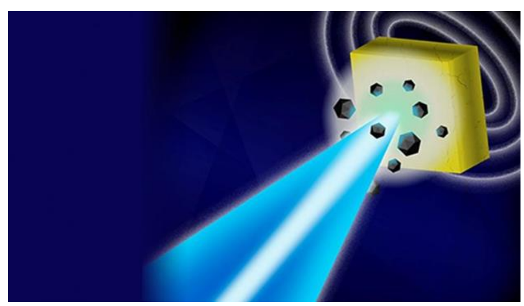
Using HE material at NIF, a radiological facility, required careful analysis and preparation. As with other hazardous or radioactive materials, NIF had to develop and implement rigid, formal operational protocols to ensure that the high-explosive experiments would be conducted safely and within NIF's authorized limits of operation.

Plasma physics is the study of systems containing separate ions and electrons that exhibit a collective behavior. The extremely high temperatures of functioning nuclear weapons generate plasma. Facilities such as NIF, Omega, and Z generate HED states producing data exploring the physical processes that occur in plasma states to validate computational models and improve understanding of matter under HED conditions.

3.1.3.1 Status

Across all three major HED facilities (NIF, Z, and Omega), experimental platforms have produced important data relevant to the performance and stewardship of nuclear weapons. HED facilities have also enabled important advances in determining plutonium properties at relevant pressures and in addressing key questions on aging and remanufacturing. These advances provide immediate mission support in predictive nuclear weapon performance and are crucial to advancing simulation capabilities in energy densities of interest.

One challenge facing the HED and ICF capability is achieving a robust burning fusion plasma, which is the key to enabling technology required to significantly shrink the gap between laboratory experiments and weapons environments. The understanding developed through each stage of experimental performance along the path to a robust burning fusion plasma provides key knowledge and constraining data for simulations, and access to material properties and outputs unachievable anywhere else in the world. In recent years, a focused effort on understanding and scaling all the major HED science platforms will establish a foundation for next-step decisions on investments and program balance needed to realize long-term stockpile goals for a modern, flexible, responsive, and resilient deterrent.



The National Ignition Facility conducted a HED experiment using the first-ever shot with explosives.

The workforce of scientists with training in plasma physics has become stronger over the last decade. A concern for future workforce development and growth is that only a small number of university programs offer relevant training, though several of these institutions are offering these courses online to reach a broader academic community.

3.1.4 Technologies to Study Extreme Conditions (Lasers, Accelerators, and Pulsed Power)

DOE/NNSA uses lasers, accelerators, and pulsed power capabilities to support the stockpile in several ways: (1) generating stockpile-relevant environments to qualify materials, components, systems, and hardened electronics in hostile environments; (2) providing static and dynamic material information for weapon assemblies and components that can inform predictive capabilities; and (3) exploring and implementing new options for the stockpile as external threats evolve.

Lasers and pulsed-power machines deliver intense pulses of energy into microscopic volumes. Within the nuclear security enterprise, these capabilities are used to generate and probe HED conditions similar to those produced when a nuclear weapon is detonated. These technologies support studies that affect design codes enhancement, new components and systems qualification, and improvement of weapon performance assessments. Experiments on the various facilities directly inform material choices for warhead modernizations and resolve stockpile questions.

Laser-driven facilities such as NIF and Omega are complemented by pulsed-power facilities such as Z; they provide important complementary HED data as well as unique HED conditions with distinct characteristics. The combined capabilities from these two approaches to producing HED conditions work together to generate a spectrum of material and physics regimes needed to study the environments' experiences by nuclear weapons upon detonation, including components and materials aging, weapon-relevant materials performance under hostile environments, and components and systems survivability.

Accelerator technology supports the stockpile by providing high-fidelity static and dynamic material information for weapon assemblies and components, imaging subcritical experiments in real time, and providing unique high-energy particle beams for various other activities. Accelerator technology uses high-voltage pulsed power to accelerate charged particles to generate high-energy X-rays, protons, and/or neutrons that probe objects in weapon-relevant experiments. These pulses of high-energy particles can also be used as a radiographic source for dynamic imaging diagnostics. Accelerator technology is a critical component of the Scorpius project at the U1a Complex (U1a), the Dual-Axis Radiographic Hydrodynamic Test facility (DARHT), the Flash X-Ray capability at the Contained Firing Facility (CFF), and LANSCE.

3.1.4.1 Status

Over the past decade, U.S. HED facilities have achieved unprecedented levels of performance and efficiency. Maintaining and enhancing this capability as equipment and facilities reach their intended service lifetime is a challenge. The NIF, Z, and Omega facilities are reaching a point where some subsystems and components are reaching obsolescence, and locating suitable replacements and vendors, is becoming an issue. Recapitalizing these facilities and equipment with minimal pause in operations will be necessary to sustain a key role in maintaining a strong deterrent.

Today, pulsed power accelerator technology is employed to generate data needed to qualify weapon components and assess weapon performance, which was formerly only possible via underground nuclear explosive tests. The Nation's accelerator and pulsed power facilities are aging (e.g., CFF/Flash X-Ray, DARHT, and LANSCE), and cannot provide the full range of test capabilities needed to assure the future viability and reliability of the stockpile. These test capabilities include a combination of the environments that weapons may experience during use.

Additionally, accelerator facilities such as LANSCE are essential to the ability to probe the characteristics and performance of materials for the evolving deterrent. The front end of the LANSCE accelerator is 50 years old and based on technology that is nearly a century old. Further, many of the LANSCE components are reaching obsolescence and becoming increasingly challenging to maintain.

Modernization of LANSCE and investments in national light source facilities tailored to stockpile applications would support obtaining the material and nuclear science data needed for the deterrent.

3.1.5 Advanced Experimental Diagnostics and Sensors

The Advanced Experimental Diagnostics and Sensors capability provides the technology to make detailed measurements of materials, objects, components, system assemblies, and dynamic processes that are critical to weapon performance, other national security applications, and HED science. The data are vital to understanding material and system behavior across requisite environments and in the extreme conditions reached in nuclear weapons. For dynamic material experiments, new diagnostics provide data vital to understanding material behavior in the extreme conditions reached in nuclear weapons. In the HED field, advanced diagnostics are necessary to improve understanding of weapon science experiments and implosions, and to acquire the high-fidelity data required to validate aspects of stockpile stewardship computational capabilities. As HED facilities increase yields, additional diagnostics must be developed to operate at higher yields and study plasma behavior achieved in the laboratory. The breadth of experiments performed at Hydrodynamic and Subcritical Experiments (HSE) facilities is increasing and developing a broader range of higher performance diagnostics is key to generating high-quality data for the weapons programs.

Diagnostic development activities are linked closely to other enterprise mission needs, and individual diagnostic requirements can vary drastically. Time scales can vary from microseconds to picoseconds and length scales can vary from meters to microns. Different technologies need to be developed to investigate this wide range of parameters. Accurate diagnostic measurements of shocked material experiments and HED science experiments are critical to constrain the simulations used to underwrite the nuclear stockpile.

3.1.5.1 Status

DOE/NNSA has developed transformative, next-generation diagnostics across weapons science and engineering capabilities. These diagnostic capabilities now contribute to a better understanding of weapon performance, including the dynamic materials and components response in relevant weapon environments. This response has led to new insights on plutonium aging and is being used to improve models that inform plutonium lifetime assessments. Advances in diagnostics have also enabled recent experiments to determine the effects of new manufacturing processes for components in future warhead systems. With these new techniques, uncertainties can be reduced, and more informed decisions can be made when changes to the stockpile are needed. However, a broader range of higher performance diagnostics are still needed to address the increasing breadth of experiments and provide high-quality data for the weapons programs.

As HED facilities increase yields, new diagnostics must be developed to study new plasma conditions that are being created in the laboratory. Higher fidelity diagnostic measurements, improved calibration capabilities, and new techniques must also be developed to obtain higher spatial and time resolution to better understand the evolution of implosion and shock-driven phenomena. In order to meet these challenges, a National Diagnostics Working Group of over 100 scientists from Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL), together with national laboratory and academic partners Lawrence Berkeley National Laboratory, the Laboratory for Laser Energetics at the University of Rochester, and the Massachusetts Institute of Technology), meet annually to develop and implement multi-year plans to develop advanced diagnostics.

Continual improvement of experimental diagnostics and sensors is an enduring need to ensure advances in stockpile science and drive down and quantify simulation uncertainties. Experimental diagnostics also push the boundary of what is possible and inspire concepts for future experimental advances. To support this, DOE/NNSA continues to invest in four areas: (1) infrastructure to support the continued health of existing diagnostics; (2) hiring and training the next generation of diagnostic scientists who will push the frontier of measurement science; (3) supporting the supply chain of specialized equipment uniquely required for HED and HSE diagnostics; and (4) development of advanced and transformational diagnostics.

3.1.6 Hydrodynamic and Subcritical Experiments

The HSE capability provides data on the behavior of imploding primaries without creating nuclear yield, providing vital data on material behavior under low energy density extreme conditions. The combination of hydrodynamic testing with surrogate materials and subcritical experiments with plutonium provides important data to build and validate weapon design and safety simulation capabilities.

HSE are used to characterize nuclear weapons' primary performance and safety and to assess the effects of findings from stockpile surveillance. The data are used for the stockpile annual assessment and certification decisions before a weapon enters the stockpile. These experiments are also used to assess the effects of aging components and their potential replacements in warhead modernizations and effects on weapon performance and potential design changes, material substitution, and component changes.

3.1.6.1 Status

The National Hydrodynamic Testing Complex consists of open-air, contained, and underground facilities at several NNSA sites to provide the experimental infrastructure for hydrodynamic and subcritical experiments. These specialized facilities are operating at near capacity and the complex is aging. The demand for a higher cadence of experimental data collection required by multiple DOE/NNSA programs stresses the physical infrastructure and the workforce. Additional investments would allow DOE/NNSA to meet a greater demand and to maintain the equipment, facilities, and people underpinning this capability.

The weapon programs supported by the HSE capability require more and higher-resolution data, necessitating increased testing and enhanced or novel diagnostic measurements. Higher-resolution data are needed to validate higher-fidelity, more-predictive computational simulation capabilities used to certify primaries without underground nuclear explosive tests. Because of the high-hazard nature of these integrated experiments, programmatic needs must be met while ensuring the protection of DOE/NNSA's staff, the environment, and the public.

A new, more capable accelerator is being developed for the Enhanced Capabilities for Subcritical Experiments (ECSE) project to deliver images showing the final implosion stages of plutonium, which currently is not possible using existing radiographic capabilities. Complementary neutron diagnostic capabilities are also being developed as part of the ECSE project for deployment in underground subcritical experiments.

The U1a Complex Enhancements Project provides the U1a with the infrastructure to house and field multi-pulse radiography and reactivity diagnostics to support ECSE. This project includes the structures, systems, and components necessary for deploying the ECSE Advanced Sources and Detectors Project's pulsed X-ray radiography equipment and future neutron diagnosed subcritical experiments technology that will provide valuable data on the phenomena associated with the final stages of a weapon implosion.

Future advanced radiographic concepts actively under development include cinematographic radiography ("X-Ray movies") for a potential second axis at the CFF or upgrade to DARHT axis-1. Additional HSE capabilities under development include a multi-axis tomographic system based on laser radiography. Both would deliver enhanced capabilities enabling a responsive assessment of the current stockpile and certification of future systems.

3.1.7 Challenges and Strategies

Table 3–1 provides a high-level summary of the Weapon Science and Engineering area challenges and the strategies to address them.

Table 3–1. Summary of the Weapon Science and Engineering area challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
All		
Developing a robust and diverse workforce trained for the foundational and applied research requisite to DOE/NNSA missions.	Continue current hiring and recruitment efforts to provide opportunities for students. Maintain academic alliances in all capability areas to address current workforce attrition. Continue student internship programs at the national laboratories.	Provide new opportunities for students through increased academic fellowships and grant programs; build new academic alliances in all capability areas to develop next generation of workforce. Conduct workshops and other similar mechanisms to facilitate knowledge transfer and close gaps caused by the absence of ongoing underground nuclear explosive tests. Address the specialized knowledge and experimental skill sets required for the modern workforce through focused training programs. Develop small-scale technology demonstration systems as platforms to engage and recruit the next generation of stockpile stewards.
Maintaining reliable operations in aging facilities where infrastructure and capital equipment are becoming difficult to repair or replace due to obsolescence.	Execute near-term capital and incremental improvements for facility upgrades and replacements to maximize impact on stockpile programs. Reduce deferred maintenance and develop conceptual plans for future experimental facilities. Prioritize current investments for key equipment. Use working groups to evaluate existing experimental gaps and plan and develop new experimental facility capabilities.	Modernize facilities and equipment and develop more capable experimental platforms to support U.S. preeminence in science. Develop long-term investment strategies across the Weapon Science area to address capital planning and mitigate facility aging issues through upgrades or replacements. Work to expand current U.S. vendor base to develop replacements for obsolete components. Prioritize strategic investments in key equipment.
Resolving inconsistencies among data and physics models, certain processes, and properties of materials of interest to increase certainty in simulated outputs	Test accuracy of current complex models with experimental measurements.	Extend state-of-the art complex models to produce more complete and consistent data sets. Develop multi-platform experimental capabilities to validate complex models across the entire range of conditions.
Atomic Physics, Nuclear Physics, Nuclear Engineering, and Radiochemistry		
Addressing uncertainty in the behavior of matter between low and high temperature to enhance certainty in simulated outputs.	Continue advancing fundamental theoretical and experimental research at universities and national laboratories to reduce and quantify uncertainties.	Develop new and innovative experimental platforms with existing capabilities.
Generating sufficient benchmark data to verify certain phenomena that will increase certainty in simulated outputs.	Continue developing and maintaining current experimental platforms to collect data on the properties of high atomic number and mixed materials (e.g., opacity, high-pressure material properties, conductivities, and radiative response).	Develop new capabilities and experimental platforms that close existing gaps to verifying the properties of high atomic number and mixed materials (e.g., opacity, high-pressure material properties, conductivities, and radiative response).

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Increasing demand on computational capacity and capability to run complex radiation models.	Continue developing new computational tools and optimizing models and algorithms for new computing architectures, leveraging simulation, codes, and HPC capabilities.	Evaluate the long-term need and balance of high-performance vs high-capacity computing investments and prioritize more capacity computing if needed. Develop more efficient and integrated workflows to share computational resources across the national laboratories.
Addressing uncertainties in nuclear data and developing new experimental nuclear science capabilities.	Continue conducting fundamental theoretical and experimental research at universities and national laboratories on nuclear data that can reduce uncertainties.	Develop new and innovate experimental capabilities.
Adequately preserving and cataloguing radiochemical data from historical nuclear tests to improve access, creating searchable databases that are easily accessible across weapon laboratories.	Continue current efforts to scan and catalogue all data.	Develop new ways to improve archiving and cataloguing all data and improve data management systems' function and access.
Materials Science, Chemistry, and Actinide Science		
Maintaining and enhancing the ability to assess and qualify material changes in a timely and cost-effective manner, driven by needs associated with aging, manufacturing, obsolescence, and replacement for hazard mitigation in a timely and cost-effective manner. Access to the required experimental capabilities will require recapitalization and modernization investments at LANSCE and investments in tailored functionality at light sources.	Continue R&D in the manufacturing science foundation to predict the effect of material changes (e.g., process, microstructure, and/or impurities) on the material properties affecting performance to accelerate qualification. Develop new experimental techniques to dynamically probe bulk material performance in the mesoscale regime. Use existing experimental platforms and explore the benefits and opportunities of developing new platforms.	Expand experimental and computational abilities that enable more detailed studies of material changes and new material design, enable more rapid qualification through partnerships between national security laboratories and nuclear weapons production facilities, and deliver solutions to emerging materials issues.
Meeting the high demand for dynamic materials properties data to support warhead modernizations and science programs and in-situ diagnostics.	Continue research on existing material science and engineering tools. Use expert cross-functional teams to prioritize using unique capabilities such as plutonium-capable gun facilities. Invest in material and target preparation capabilities and deconflict resources.	Continue the current strategy and develop new cutting-edge material science and engineering tools that will attract the nuclear security enterprise's next generation workforce. Build and sustain pipeline networks with U.S. academic institutes.
Responding to emerging weapons program needs for main charge explosives using expertise and other capability aspects that have not been exercised in recent years.	Exercise the physics laboratory science and engineering HE development process to achieve higher technology readiness levels. Collaborate with DoD and industrial partners to produce HE and preserve in-house production authority, such as for WR detonator powder production.	Develop new strategies for HE development processes with goals reflecting future program requirements.
Improving HE safety by bringing the state of the prediction capability in line with HE performance prediction.	Continue to understand and predict HE deflagration through a combination of bench-scale and full-scale experimentation.	Develop combined new experimental and simulation capabilities to fully address the physical and mesoscale behaviors influencing safety considerations.

Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Predicting chemical compatibility in new systems to reduce the need for expensive core-stack and shelf-life units.	Continue to develop and validate computational chemistry models to understand chemical compatibility.	Develop and validate new computational chemistry models that span length and time scales and address reactivity at interfaces.
Eliminating capability gaps in weapons analytical chemistry and actinide science as DOE/NNSA increases pit production activities.	Simultaneously execute WR analytical technique qualification and the Chemistry and Metallurgy Research facility exit strategy.	Develop new strategies to reduce capability gaps in weapons analytical chemistry and actinide science.
Scaling up new material formulations from the laboratory to industry to provide required materials from commercial material sources.	Continue to partner across the nuclear security enterprise to transition from large numbers of small-scale experiments to fewer informed pilot-scale tests.	Develop new partnerships and focused research programs on new material formulations scalability.
Improving the ability to predict the aging effects on components.	Continue advancing multiscale, validated predictive models of material aging, including the kinetic and thermodynamically aware degradation models of organics, inorganics, energetics, and corrosion of metals. Continue nondestructive tools development and deployment to assess the state of materials in service.	Develop new capabilities for predictive models of material aging. Improve the use of data informatics and artificial intelligence to aid in interpretating large data sets (e.g., mass spectrum data from compatibility and surveillance testing). Develop and deploy new and complementary nondestructive tools to assess the state of materials in service.
Understanding the effects of processing conditions on production consistency and device performance.	Use existing analytical and diagnostic tools combined with process modeling to introduce efficiencies in manufacturing.	Provide new advanced analytical and diagnostic tools for inline monitoring of manufacturing.
Improving flexibility in the current and future stockpile through accelerated qualification methodologies using advanced and additive manufacturing techniques.	Continue research to synthesize new formulations that expand material possibilities for designing new composite, multifunctional materials.	Synthesize new formulations and build confidence in a prediction capability enabling materials made by new processes to become stable over time. Successfully collaborate with design and production agencies to design for manufacturing.
High Energy Density Science and Plasma Physics		
Accessing more weapon relevant ICF regimes for stockpile applications.	Prioritize the fielding of experimental campaigns to address open weapons physics questions and hostile environments on existing HED facilities. Develop diagnostics that provide constraining data for these challenges. Recapitalize and modernize existing HED facilities.	Deliver higher fusion yield HED platforms to answer weapons physics questions and produce higher fidelity hostile environments needed for quantification assessments with accompanying diagnostics to deliver constraining data. Improve computational modeling of hostile environments based on data acquired and assess gaps in capabilities to support future facility investments.

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
Accurately predicting the performance of HED science targets to develop and deliver robust and repeatable burning plasma[2] and ignition platforms.	Execute experiments at the HED facilities to characterize fusion phenomena, then use the results to enhance predictive modeling capabilities and understanding of scaling to next-generation capabilities. Acquire high-fidelity data and improve physics and modeling fidelity to validate 3D models.	Understand the physics and scaling for the balanced development of next-generation capabilities leading to future high-yield platforms.
Accurately understanding the uncertainty in matter's behavior in high-magnetic field and plasma regimes as it pertains to simulated outputs.	Continue conducting fundamental theoretical and experimental research at universities and national laboratories to reduce uncertainties.	Develop new and innovate experimental capabilities.
Resolve inconsistency among tabulated plasma data for certain properties of interested materials to increase certainty in simulated outputs.	Test accuracy of current complex models with experimental measurements.	Extend state-of-the art complex models, and test accuracy with experimental measurements. Improve underlying physics understanding, resulting in improved model accuracy.
Technologies to Study Extreme Conditions (Lasers, Accelerators, and Pulsed Power Technology)		
Waning U.S. preeminence in pulsed power, laser, and optical science, technologies, and facilities.	Execute current research plans for laser technology domestic development for the next generation, including advanced probe and radiography techniques and alternate light sources, to maintain U.S. leadership in this discipline Develop less expensive, more efficient, more reliable, more flexible, and more capable pulsed power architectures for next generation demonstration systems and improve current capabilities. Continue to develop and explore innovative methods to employ pulsed power technology for national security applications.	Develop future research plans to maintain U.S. leadership in this discipline. Develop next-generation laser and pulsed power capabilities that advance the state-of-the-art and attract the world-class scientists.
Generating the necessary experimental conditions and environments to validate weapons codes for the full nuclear weapon life cycle.	Increase investments in laser, driver, and accelerator technology R&D to extend the capability of existing facilities and design new facilities to produce higher-fidelity, weapons-relevant environments	Prioritize investments and plans in new facilities and extension of current facilities to close mission gaps.
Advancing accelerator technologies to provide the necessary time-evolution data for experiments of interest to the stockpile.	Execute current research plans to improve higher spatial and temporal resolutions.	Develop new multiple-pulse technologies that support diagnostic techniques to probe data at higher spatial and temporal resolutions.

[2] *Burning plasma* – A burning plasma is one in which most of the plasma heating comes from fusion reactions involving thermal plasma ions. A plasma enters the burning plasma regime when the self-heating power exceeds any external heating.

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Advanced Experimental Diagnostics and Sensors		
Developing better (higher spatial and time resolution) and novel diagnostic measurements and techniques to decrease simulation uncertainties and challenge physical models in the codes.	Maintain current experimental diagnostic systems. Evaluate measurement needs in the 5-year horizon, determine gaps between current capabilities and needed future development efforts. Develop and execute the National Diagnostic Plan for ICF, and an Integrated Plan for HED experimental diagnostics. Develop and implement plans for hardening existing diagnostics so they can be fielded in more extreme nuclear and radiation environments.	Develop new world-class radiographic and neutron diagnostic capabilities, including proton radiography, X-ray diffraction, and advanced temperature diagnostics. Continuously monitor changing gaps in measurement capability and simulation need. Develop a forward-looking diagnostic strategy for a future high-yield facility.
Hydrodynamic and Subcritical Experiments		
Obtaining multi-frame penetrating radiographs on hydrodynamic experiments with plutonium pits.	Design, build, and install a novel radiographic to close ESCE capability gaps in the mid-2020s.	Continue to closely monitor ECSE program execution. Develop future strategies for new HSE capabilities.
Measuring the reactivity of subcritical assemblies on the experiments.	Implement neutron-diagnosed subcritical experiments in the early to mid-2020s.	Develop photofission methodology to combine neutron reactivity measurement with radiography.
Quickly obtaining the necessary experimental higher cadence operation and time delivery of hydrodynamic and subcritical data needed to support stockpile and certification activities in a timely manner.	Execute current program plans for facility enhancements to provide increased experimental capacity and operational efficiency.	Increase staffing and future investments in facility enhancements.
Designing and procuring new confinement vessels at all firing facilities as existing vessels exceed useful life.	Continue to use vessels and execute current program plans.	Establish an enduring vessel capability and procurement funding strategy with the intention to reestablish a domestic fabrication and manufacturing capability for vessels.
The operational issues associated with the increased capabilities for and cadence of subcritical experiments at the NNSS U1a site are challenging.	Support yet to be developed National plans to address these operational issues.	Complete long-term planning for experimental capabilities at U1a, which support the data necessary to underpin the evolving deterrent.

3D = three dimensional
ECSE = Enhanced Capabilities for Subcritical Experiments
HE = high explosives
HED = high energy density
HPC = high performance computing
HSE = Hydrodynamic and Subcritical Experiments
ICF = inertial confinement fusion
LANSCE = Los Alamos Neutron Science Center
R&D = research and development
WR = War Reserve

[a] The term “mesoscale” refers to the properties and behaviors of materials between the atomic and macro scales. At this scale, a material’s structure strongly influences macroscopic behaviors and properties.

3.2 Weapon Simulation and Computing Area

The Weapon Simulation and Computing area includes high-performance computers, weapons codes, models, and data analytics used to assess nuclear weapons and components' behavior. It must calculate with sufficient resolution and complexity to simulate and assess weapon systems, components, and fundamental science processes that are critical to nuclear weapon performance. The Weapon Simulation and Computing area is closely linked with the Weapon Design and Integration area (Section 3.6) and Weapon Science and Engineering area (Section 3.7) in an iterative fashion, such that capabilities in all three areas are routinely supporting efforts in the other two.

3.2.1 High Performance Computing

High performance computing (HPC) involves software, hardware, and facilities with sufficient capability and power to achieve the dimensionality, resolution, and complexity in simulation codes to accurately model the weapon systems and components' performance and the fundamental physical processes critical to nuclear operation. It also includes R&D in computer architecture design and engineering, data management and analytics, and mathematical sciences to support developing and operating the HPC systems.

For DOE/NNSA, a HPC platform means an integrated system of hardware and software that comprehensively provides the required computing environment, classified and/or unclassified, in which a weapon analyst or designer can run simulations and analyze results. It is not just a computer, it is a host of hardware and software components (e.g., compute and login nodes, networks, file systems, long-term storage, operating systems, compilers, numerical libraries, developer tools, etc.), often developed independently from one another by component vendors and deployed by the HPC system integrator.

Commodity Technology Systems

Commodity Technology Systems are workhorse production, general-purpose systems that provide stable computing power to the nuclear security enterprise's design and analysis community through deployments at each of the three laboratories. These systems run the tri-lab software stack and persistent common software environment, with capability for back-up, data recovery, and remote mission continuation in case any of the NNSA labs' computing centers become unavailable for an extended period.

Advanced Technology Systems

Advanced Technology Systems represent the most significant investments for the Advanced Simulation and Computing (ASC) program in simulation capability. These are leading-edge architectures that are capable of solving the most demanding simulations in DOE/NNSA's mission. They incorporate newer technologies that push the limits of the ASC program in terms of facility requirements, software infrastructure, and applications.

Advanced Architecture Prototype Systems

Advanced Architecture Prototype Systems consist of node-level testbeds, system-level prototypes, and pre-commercial hardware/scaled-up systems. The goal of these prototype systems is to reduce the risk in deploying unproven technologies by identifying gaps in the hardware and software ecosystem and making focused investments to address them moving from small-scale testbeds to potentially large-scale systems production computing.

3.2.1.1 Status

As detail levels increase in simulation codes, especially those with three-dimensional features, run times to reach solution increase dramatically. These heightened run times present an increasing challenge in providing mission and experimental needs support in a timely fashion. DOE/NNSA continues to follow its clearly defined strategy of upgrading HPC platforms at regular intervals to address this challenge. This platform strategy is built around deploying a set of platforms that strike a careful balance among delivering reliable production cycles, pushing the boundaries of current technology, and looking beyond the horizon to what is coming next. This approach to balanced risk has served DOE/NNSA well over the previous decades. As a result, the Weapon Simulation and Computing area will retain the Commodity Technology Systems, Advanced

Technology Systems, and Advanced Architecture Prototype Systems in its platform strategy. All these systems are focused on delivering production computing cycles to the DOE/NNSA mission.

HPC platforms are also evolving in response to the computer industry's movement toward heterogeneous computing in which accelerators, such as graphics processing units, are combined with traditional central processing units to grow computing capacity. In addition to using heterogeneous architectures, the computing industry has evolved new technology models that are more energy efficient. They have also developed artificial intelligence and cognitive simulation capabilities and infrastructure that greatly magnify traditional simulation's capabilities. An integrated approach is key to incorporating advanced technology innovations to support the future mission. Artificial intelligence technologies, for example, have the potential to transform all aspects of this area through coordinated code and platform evolution. Quantum computing,[3] which is even more forward-looking, could have a similar effect but will require more focused attention from DOE/NNSA to explore the potential benefits these new technologies could provide to the weapons missions.

Deploying more advanced platforms also creates increased demand on supporting infrastructure. Power, cooling, and mechanical requirements have grown dramatically with the introduction of exascale computing and are being addressed through minor construction projects and construction line items. The Exascale Computing Facility Modernization project is a construction line item that upgraded the LLNL computing facility with increased power and cooling capability in preparation for DOE/NNSA's first exascale system, El Capitan, to be deployed in fiscal year (FY) 2023, and subsequent exascale-class architectures. Exascale Computing Facility Modernization provides sufficient cooling and power to allow initial installation and necessary systems overlap as they are sited and decommissioned. The nuclear security enterprise will continue to manage and coordinate code development and facility upgrades with system acquisitions to allow HPC platforms use for DOE/NNSA as the technology progresses into the exascale era and beyond.

3.2.2 Simulation Capabilities for Weapon Science, Engineering, and Physics

Advanced HPC and simulation codes, models, and data analytics used to simulate and assess the behavior of nuclear weapons and their components form another important part of the Weapon Simulation and Computing area. Together, these capabilities enable weapon designers to qualify components, certify warheads, and assess the stockpile in the absence of underground nuclear explosive tests. These capabilities support accelerated nuclear weapons design and production, manufacturing process development, and prediction of weapon response to hostile environments, and play a central role in assessing the nuclear explosive package's performance and safety and the reliability of the full warhead system in the stockpile-to-target sequence (STS) environments. These codes must also be sufficiently flexible and adaptable to run on a variety of the latest HPC platforms.

These capabilities underpin DOE/NNSA's ability to resolve challenging stockpile problems using codes that take advantage of increased spatial and temporal resolution, higher dimensionality, and higher-fidelity physical models. Code improvements lead to more predictive simulations that are less reliant on empirical calibration to experimental data. These capabilities are essential to addressing issues associated with an aging stockpile and modernizing the stockpile with new materials in different configurations without resorting to nuclear explosive testing. The nuclear security enterprise also relies on these capabilities to continue developing methods for quantifying critical margins and uncertainties (see Chapter 2,

[3] *Quantum computing* – The area of study focused on developing computer technology based on the principles of quantum-mechanical theory, which explains the nature and behavior of energy and matter on the atomic and subatomic level.

Section 2.1.1). These methods are important for understanding discrepancies between physical measurements and simulated data.

3.2.2.1 Status

Simulation codes include integrated design codes (IDCs) that perform large-scale, multi-physics simulations directly supporting the assessment mission, and weapons science codes that model specific phenomena in more detail and inform the models in the IDCs where experiments are lacking. As the Nation's nuclear stockpile evolves to support a responsive and resilient nuclear deterrent, so must the simulation capabilities underwriting that stockpile.

Simulations with improved predictivity that support stockpile certification and modernization also address significant finding investigations, and safety scenarios relying on large ensembles of multi-physics, three-dimensional calculations with large data movement requirements. Newer generations of IDCs and supporting codes are being designed to respond to evolving requirements. Improved physical models are needed to address responses to hostile environments and analyses of manufacturing, production, and disassembly processes to reduce cost and waste. Future rewrites to accommodate new technologies will be expedited through careful modular design and adaptable programming models.

IDCs and weapons science codes are supported by experimental activities designed through close cooperation between the simulation and experimental communities. Simulations, especially those resolving three-dimensional features, currently require an extended time to complete on petascale machines. As the simulation detail increases into the mesoscale, exascale-class computing will be required to resolve these simulations in a responsive timeframe to support experimental needs (see Appendix C for detailed information on the Exascale Computing Initiative). In response, DOE/NNSA initiated developing a new generation of IDCs, requiring new capabilities in numerical methods, software design, and programming models to optimize the use of these emerging HPC technologies. DOE/NNSA has also introduced an Advanced Machine Learning Initiative to expand the use of artificial intelligence, or Cognitive Simulation capabilities, to better manage the complexity in physics-informed simulations

The DOE/NNSA is also advancing several internal initiatives to leverage developing technologies and capabilities to support the nuclear stockpile sustainment. The Large-Scale Calculations Initiative, which is currently underway, was initiated to determine the limitations and scaling potential of DOE/NNSA's assessment capabilities. The Large-Scale Calculations Initiative is assessing what is achievable with current platforms, codes, and qualified personnel and what cannot be achieved with those capabilities. "Large-scale calculations," as defined by this initiative, are impractical to perform on available capacity computing platforms due to size, run length, or a combination of the two. The initiative directs the national security laboratories to look beyond current computing abilities and ask how calculations on this scale enhance mission delivery.

3.2.3 Challenges and Strategies

Table 3–2 provides a high-level summary of the Weapon Simulation and Computing area challenges and the strategies to address them.

Table 3–2. Summary of the Weapon Simulation and Computing area challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
The evolving stockpile necessitates new physics, engineering, and materials applications that challenge the understanding, modeling, and simulation capabilities.	Work with Stockpile Management, Assessment Science, Engineering and Integrated Assessments, and Weapons Technology and Manufacturing Maturation programs to understand the physics of these changes, establish requirements, and continue efforts to improve modeling.	Current strategy is sufficient.
The evolving threat space requires new and evolving ways for weapons to be certified.	Coordinate with customers through the *Nuclear Posture Review* implementation to understand the new needs for threat response and to respond with credible simulation capabilities.	Current strategy is sufficient.
Improving the rate at which new modeling and simulation capabilities are provided to the Stockpile Major Modernization and Stockpile Sustainment programs. Enhancing the ability to simulate the effects of weapons effects, aging, and manufacturing changes.	Develop and implement a broader range of tools for rapid design, evaluation, and qualification of new materials. Develop models and databases in conjunction with experiments to improve the performance, reliability, and safety of weapons. Adapt weapon science codes to the most advanced computing architectures to reach time and spatial scales of greatest interest. Run IDCs and supporting codes on more powerful platforms to allow quicker time-to-solution for applications of simulation enhancements.	Current strategy is sufficient.
Performing rapid evaluations of new materials and modeling additive manufacturing techniques requires advanced simulations.	Continue current efforts to model additive manufacturing processes and couple these with molecular dynamics and mesoscale modeling to enhance their use. Develop machine-learned techniques that can capture these effects efficiently for routine use in part-scale simulations	Current strategy is sufficient.
Working with IDCs that are not effectively using advances that have emerged in commercial HPC architectures. Maintaining current IDC operations to deliver on near-term needs, while preparing the IDCs for future computing architectures.	Optimize current codes for advanced technology hardware.	Evolve HPC tools for IDCs' next generation to achieve sophisticated programming models, software designs, and numerical algorithms. This development will produce a more responsive simulation capability that responds more rapidly and efficiently to challenges.
Supporting exascale platforms with insufficiently structured and sized facilities and supporting infrastructure (space, power, and cooling).	Continue to execute the ASC platform strategy. Continually survey HPC vendors' facility requirements, identify gaps, and proceed with modernization or new infrastructure solutions to meet HPC utility demands.	Current strategy is sufficient.
High demand in multiple industries for computational skill sets.	Provide innovative work and continue improving career advancement opportunities.	Current strategy is sufficient.

ASC = Advanced Simulation and Computing
HPC = high performance computing
IDC = integrated design code

3.3 Weapon Design and Integration Area

The Weapon Design and Integration area encompasses the capabilities needed to design, test, analyze, qualify, and integrate components and subsystems into weapon systems that will meet all military requirements and endure all predicted environments and to validate and verify they will always work as expected and never work when not intended. The Weapon Design and Integration area is closely linked to the Weapon Science and Engineering and Weapon Modeling and Simulation areas in an iterative fashion, such that capabilities in all three areas routinely support efforts in the other two.

3.3.1 Weapon Physics Design and Analysis

Designing and analyzing the nuclear explosive package is required to assess U.S. nuclear weapons, qualify and certify changes to the stockpile (such as with life extensions and modernization), evaluate proliferant nuclear weapon programs, and respond to emerging threats, unanticipated events, and technological innovation. This capability includes potential concept exploration to satisfy requirements and detailed development of design, production, certification, and development processes. It also encompasses evaluating weapon outputs and effects.

Weapon Physics Design and Analysis efforts are predicated on codes developed through the Weapon Modeling and Simulation area and the nuclear data and material properties that underpin simulation tools. Validating and improving these tools also requires data and knowledge acquired through hydrodynamic, subcritical, and HED experimental facilities and legacy data from nuclear explosive testing. Advances in diagnostics and experimental capabilities are required to obtain suitably high-fidelity data. All these related capabilities underpin and are critical for the Weapon Physics Design and Analysis capability.

3.3.1.1 Status

The Weapon Physics Design and Analysis capability provides the foundational tools and methods necessary to design and analyze nuclear explosive packages and determine the state of constituent materials and components and certify potential future stockpile options with new safety and security features.

Requirements for DOE/NNSA's current systems will evolve in the future due to component aging or remanufacture, the changing threat environment, or the need to transition to alternate materials and technologies. In these future scenarios, Weapons Physics Design and Analysis tools will require expanded predictive capabilities to assess, and certify, system performance without nuclear explosive testing. In addition, the planned warhead modernization requirements over the next decade have expanded. The ability to provide timely analysis to support warhead development timelines is critical.

DOE/NNSA must develop new, highly capable methods for certifying designs that differ from those for which DOE/NNSA has a nuclear explosive test history. The national security laboratories are developing non-nuclear experimental capabilities and evaluation metrics that can quantify predictions and uncertainties for performance and safety without the need for underground nuclear explosive tests.

3.3.2 Weapon Engineering Design, Analysis, and Integration

The Weapon Engineering Design, Analysis, and Integration capability underpins DOE/NNSA's ability to develop, test, qualify, and certify designs to support a responsive deterrent. This capability employs science, technology, and engineering methods so that the integrated solution meets all performance, safety, security, and reliability requirements.

This capability affects several phases of the weapons life cycle, including concept exploration, design, development, and production. It also encompasses systems integration, which includes working with DoD to define the functional, physical, performance and interface requirements between the DOE/NNSA and DoD systems. DOE/NNSA uses that understanding to develop the subsystem-level requirements among the non-nuclear subsystems and the requirements between the non-nuclear components and the nuclear explosives package.

3.3.2.1 Status

While much of the Weapon Engineering Design, Analysis, and Integration capability is being exercised by multiple concurrent life extension programs (LEPs), Modification Programs (Mods), alterations (Alts), and stockpile sustainment, some elements are not being adequately exercised. Because modernization activities prior to the W87-1 Mod have been focused on extending the life of current stockpile weapons, there has been a decline in capacity to develop warhead concepts to address military requirements that differ from those addressed by current stockpile systems. These gaps will be closed through activities supporting the Stockpile Responsiveness Program by exercising the technical capabilities required for all nuclear weapon stages, including design, testing, and production, and working in concert with DoD to recruit, train, and retain the next generation of weapon designers and engineers.

> **Digital Engineering**
>
> *Digital engineering has empowered a paradigm shift from the traditional design-build-test methodology to a model-analyze-build methodology. Instead of expensive and lengthy design-build-test cycles, the goal is to replace the need for repeated build-test cycles with simulation and analysis in a virtual environment. This new methodology requires that simulation models to be calibrated and qualified in small scale tests beforehand. The growing ASC Exascale capability combined with artificial intelligence will accelerate this digital engineering revolution.*

DOE/NNSA is addressing challenges within digital engineering through initiatives to define where specific digital transformation opportunities provide value over time and determine where and how changes should be made in policy and business processes for the use of digital product definition and associated data. Any transformation will require investment decisions in software and information technology (IT) infrastructure.

3.3.3 Environmental Effects Analysis, Testing, and Engineering Sciences

The Environmental Effects Analysis, Testing, and Engineering Sciences capability uses an array of test equipment, modeling tools, and techniques to simulate STS environments and measure the response of materials, components, and systems. Examples of environmental testing and modeling conditions (normal, hostile, and abnormal) include shock, vibration, radiation, acceleration, temperature, electrostatics, and pressure. The engineering sciences that support this analysis include thermal and fluid sciences, structural mechanics, dynamics, aerodynamics, hydrodynamics, radiation transport and disposition, and electromagnetics. This capability influences the design and qualification of planned and future weapon programs, as well as surveillance activities supporting assessment of the safety, security, and reliability of the stockpile.

3.3.3.1 Status

As the vision for a future stockpile takes shape, current engineering sciences, experimental capabilities, and predictive modeling capabilities may not be sufficient to address future needs confidently and comprehensively. DOE/NNSA's facilities, equipment, and the workforce must be ready and responsive to upcoming needs. Modeling and simulation capabilities must be able to predict the effects of the STS environments. Experimental capabilities are necessary to improve the levels of confidence in all modeling and simulation capabilities. DOE/NNSA has been anticipating such changes, and plans are in place to address those needs.

Renewed modernization activities and increasing technical requirements have accelerated the need to recapitalize and modernize experimental facilities. Many environmental test facilities are beyond their projected design life and need major refurbishment over the next decade, especially considering the heavy demand imposed by multiple concurrent weapon programs. The same is true for the programmatic equipment supporting the environmental test and engineering sciences facilities. For example, DOE/NNSA is currently evaluating options for Combined Radiation Environments for Survivability Testing through an Analysis of Alternatives (AoA). This new capability will support DOE/NNSA testing in multiple radiation environments using the same experimental platform, either through recapitalizing existing facilities or constructing new facilities.

3.3.4 Weapons Surety Design, Testing, Analysis, and Manufacturing

The Weapons Surety Design, Testing, Analysis, and Manufacturing capability includes safety and use control system development, analysis, integration, and manufacture to simultaneously minimize the probability of unauthorized use and maximize the reliability of authorized use of a U.S. nuclear weapon while maintaining the highest levels of safety. All these actions are necessary for a safe and secure stockpile. In addition, all aspects of this capability require elevated classification control and secure facilities and equipment for surety feature design and manufacturing. National requirements from Presidential Directives have been implemented through DOE Orders, and performance-based use control requirements introduced by the Deputy Administrator for Defense Programs. These requirements have driven a novel approach to surety designs that are more cost-effective with lower manufacturing complexity while maintaining the stockpile’s high surety standards.

DOE/NNSA performs assessments that integrate weapon and venue security and control capabilities to understand how to best allocate resources to meet evolving threats. This approach includes partnerships across DOE/NNSA and the U.S. Government with stockpile and modernization programs, nuclear counterterrorism and incident response personnel, and other national assets. The Optical Initiation project is one example that incorporates surety technology to meet safety requirements.

3.3.4.1 Status

A variety of surety technologies and approaches have been, or are, currently under development to improve the safety and security of nuclear weapons. The program’s focus is on cost reduction of components and tailoring the technology options to expectations of future systems. Several core technologies have been identified for cost reduction efforts and experiments have proven out the complexity reduction. Close collaboration with the production sites has resulted in greater maturity for cost estimates. Additionally, several novel approaches for various applications are being evaluated for viability and feasibility. The new approaches represent a paradigm shift in how weapons surety is evaluated.

3.3.5 Radiation-Hardened Microelectronics Design and Manufacturing

This capability includes research, design, production, and testing of reliable and robust radiation-hardened microelectronics for use in nuclear weapons. The electronics in nuclear warheads must function when subjected to a range of radiation sources from within the weapon to cosmic rays and hostile sources external to the weapon.

Radiation-hardened microelectronics perform critical sensing and arming, fuzing, and firing functions so weapons work as intended. As operational environments evolve and new requirements emerge, DOE/NNSA R&D resources must evaluate and respond to support the safety, security, and effectiveness of the Nation’s nuclear deterrent. Production must also keep pace with evolving trends in microelectronics production to maintain a trusted supply of hardened microelectronics for nuclear weapon applications.

DOE/NNSA has developed a Microelectronics Capability Development Roadmap that was informed by DOE/NNSA's continued coordination with DoD. DOE/NNSA is engaged with the Strategic Radiation Hardened Electronics Council, the Test and Evaluation, Recruitment and Retention, and Advanced Packaging working groups and is the co-lead for the Trust, Assurance, and Nuclear Surety working group.

3.3.5.1 Status

The Microsystems, Engineering and Sciences Applications (MESA) complex is the enduring lead institution for trusted, strategic radiation-hardened microelectronics. DOE/NNSA is committed to sustaining this capability through 2040 via implementation of the MESA Extended Life Program, which includes facilities and equipment upgrades to maintain and advance capabilities for all active weapons systems, such as the W87-1 Mod and W93 development. The limitations of the existing facilities, together with the current trends in industry tools and products result in residual risks that cannot be fully mitigated through the Extended Life Program. DOE/NNSA is exploring potential solutions to address these risks, working with appropriate institutions to conduct materials research, and collaborating with selected manufacturers to conduct technology evaluation to address sustaining the capability to 2040 and beyond.

3.3.6 Challenges and Strategies

Table 3–3 provides a high-level summary of the Weapon Design and Integration area challenges and the strategies to address them.

Table 3–3. Summary of the Weapon Design and Integration area challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
Developing and exercising design (rather than assessment) skills in physics, engineering, chemistry, and materials science personnel.	Implement activities such as Certification Readiness Exercises, design practicums, and other design studies.	Enhance design experience through design studies and Stockpile Responsiveness exercises, and warhead modernization.
Developing and exercising certification methodologies using recently developed physics performance metrics on device designs for which there is no underground nuclear explosive test data.	Develop metrics and apply methodologies to implement.	Perform subcritical and HED experiments from which metrics can be extracted or validated. Develop and maintain new and existing facilities and capabilities that underwrite qualification and certification.
Managing uncertainty related to DOE/NNSA's design capability for reuse if new component production is unable to meet warhead modernization requirements. Enhancing ability to simulate the effects of aging and manufacturing changes.	Rely on current simulation capabilities (validated by aboveground experiments and non-nuclear testing) to model reuse design options.	Develop certification methodologies for reuse and replacement designs. Close the capability gap regarding plutonium response evaluation in integrated weapons experiments as part of the Enhanced Capabilities for Subcritical Experiments program.
Applying machine learning to weapon physics design problems for current system confidence, future system certification, and increased responsiveness.	Develop capabilities to shorten the design loop through workflow enhancement and surrogate model development for faster parameter space exploration.	Use machine learning as an accelerant capability for data interpretation, simulation results implementation, certification, design, evaluating discrepancies, detecting anomalies, and enhancing current solutions.

HED = high energy density

3.4 Weapon Material Processing and Manufacturing Area

The Weapon Material Processing and Manufacturing Area covers the packaging, processing, handling, and manufacturing of plutonium, uranium, tritium, energetic and hazardous materials, lithium, and other metal and organic materials needed for nuclear weapons. The current stockpile maintenance and modernization programs will continue to demand special nuclear material (SNM), HE, and other energetic materials into the distant future. The nuclear security enterprise must maintain reliable production, science, technology, and engineering capabilities, integrated infrastructure, and logistics (handling, storage, delivery, and supply chain management) for raw materials and War Reserve (WR) products. Components that contain SNM or energetic materials require a special conduct of operations, physical security protection, facilities, and proper equipment to handle, package, process, manufacture, and inspect these components.

SNM-based products must be handled, packaged, processed, manufactured, and inspected and these capabilities require many specialized facilities and programs' support throughout the nuclear security enterprise. The obsolescence, age, or severely degraded nature of many of the facilities required to produce and process SNM presents operational risks to reliably produce nuclear weapon components. The strategies detailed throughout this section for the overall capability are organized by individual materials and supporting programs. Any necessary bridging strategy or solution currently being implemented as capability investments for each type of component is addressed and major programmatic infrastructure projects.

Concurrent to the development of robust strategies for material supply, several collaborative efforts are taking place between production and design agencies to ensure compatibility between design and production capabilities, including material quality and throughput. These include production enclaves such as the polymer enclave commissioned at LLNL's site 200 in cooperation with the Kansas City National Security Campus (KCNSC), or the proposed energetics enclave at Site 300 in collaboration with Pantex Plant (Pantex).

3.4.1 Plutonium Management

Maintaining confidence in the nuclear warheads that compose the U.S. nuclear deterrent requires DOE/NNSA to reestablish a plutonium pit manufacturing capability. Newly manufactured pits are required to enable improved warhead safety and security, mitigate against perceived risk to the nuclear deterrent posed by plutonium aging, and support potential changes to future warheads due to threats posed to the U.S. nuclear deterrent from renewed peer competition.

Working closely with DoD, a requirement to manufacture no fewer than 80 WR pits per year (ppy) was established. This number is driven by the stockpile's size, the desire to minimize the number of existing pits past the age of approximately 80 years, and the need to have a flexible manufacturing capability with the capacity to produce a variety of pits to meet current and planned military stockpile requirements.

DOE/NNSA is implementing a two-site solution with the objective of producing 30 WR ppy at LANL using the existing Plutonium Facility (PF-4) and 50 WR ppy at the Savannah River Site (SRS) by repurposing the existing facility previously referred to as the Mixed Oxide Fuel Fabrication Facility (MFFF) to meet this manufacturing capacity. Both facilities meet the stringent building design standards necessary to support pit manufacturing.

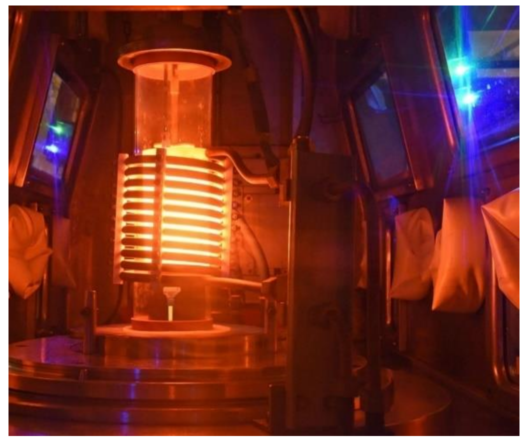
This two-site solution restores a critical production capability central to maintaining the Nation's nuclear deterrent. Operating two geographically separated plutonium pit production facilities provides resilience and adaptable options to mitigate shutdowns, incidents, or other factors that may affect operations at a single site.

Plutonium processing and component manufacturing capabilities are also used for radioisotope thermoelectric generator production,[4] pit surveillance, plutonium science and aging studies, subcritical experiments, National Aeronautics and Space Administration space exploration, materials recycle and recovery, and nonproliferation programs.

3.4.1.1 Status

Based on progress in operations and the maturation of line-item capital asset acquisition projects that support the two-site solution for pit production, NNSA's current assessment of pit production milestone status follows:

- DOE/NNSA is on a path to make at least 30 ppy at LANL and 50 ppy at the Savannah River Plutonium Processing Facility (SRPPF). DOE/NNSA continues to assess risks to implementing its plutonium pit production plan and is implementing mitigation options while studying additional trade space to recover schedule.
- The SRS assessment is based on the ability to meet three key requirements to produce WR pits at rate: (1) completion of line-item construction and Critical Decision (CD)-4, *Approve Start of Operations*; (2) demonstrate a WR-quality pit manufacturing capability; and (3) demonstrate the ability to manufacture at full-rate capacity while maintaining WR quality control. The total time duration for achieving steps two and three is several years, based on experience.
- Because PF-4 is already conducting plutonium operations at LANL, these three key efforts, to a large extent, are being overlapped in time. Since the SRPPF must undergo commissioning to startup plutonium operations, the three key pit requirements to achieve 50 WR ppy will occur sequentially.



A vacuum induction furnace safely melts, and casts, plutonium metal, a part of the pit production process at Los Alamos National Laboratory.

In addition to dedicated infrastructure efforts at LANL and SRS, DOE/NNSA is recapitalizing other existing facilities through a series of reinvestment projects, including several line-item projects, to replace the current aging capability to provide supporting functions and processing infrastructure for pit production qualification processes, risk-reduction, and increased reliability activities. The Chemistry and Metallurgy Research Replacement project maintains continuity in analytical chemistry and material characterization capabilities by transitioning these activities from the nearly 70-year-old Chemistry and Metallurgy Research Facility to newer facilities. The Material Recycle and Recovery program is conducting risk reduction activities by removing the nuclear material inventory currently housed in the Chemistry and Metallurgy Research Facility.

[4] *Radioisotope thermoelectric generators* – A type of lightweight, reliable nuclear battery with no moving parts that uses an array of thermocouples to convert the heat released by the decay of plutonium-238 into electricity.

3.4.1.1.1 Approach at Los Alamos National Laboratory for 30 War Reserve Pits Per Year

DOE/NNSA will establish a reliable capability at LANL to deliver 30 WR ppy. There are several key steps to delivering 30 WR ppy:

- Advance the science and mature the engineering to meet the LLNL design agency specifications in support of delivering a first production unit.
- Maintain and update PF-4 to ensure reliability and continued compliance with all relevant safety requirements.
- Reconfigure PF-4 for efficient pit production by completing the ongoing equipment installations and facility modification to optimize the pit production process flow and establish the capacity for a reliable 30 WR ppy production rate.
- Increase the workforce required for the pit production mission to manufacture pits; maintain and operate facilities; provide security for pit production activities and materials; and provide a broad range of support functions.
- Provide acceptable components and support for the experiments and evaluations specified by the LLNL in the Pit Certification Plan Under the guidance of the Pit Production Realization Team.

Plutonium metal purification, casting, machining, and assembly are all currently performed at LANL's PF-4, while the Radiological Laboratory/Utility/Office Building houses plutonium chemistry operations that support plutonium component production, surveillance, and science missions. DOE/NNSA will transition PF-4 to be available 24/7 for scheduling programmatic work, facility maintenance, equipment installation, and construction activities to accommodate increased operations. DOE/NNSA also will use a waste management program at LANL to maintain efficient and continuous off-site shipments to the Waste Isolation Pilot Plant.

3.4.1.1.2 Savannah River Site Approach to Producing a Minimum of 50 War Reserve Pits Per Year

DOE/NNSA will reach 50 WR ppy production as close to 2030 as possible by repurposing the former MFFF as SRPPF.

SRPPF will be a Security Category 1/Hazard Category 2 structure that provides an opportunity to achieve pit production in a facility designed to meet stringent security and safety requirements for plutonium operations.

Initial modernization activities include repurposing and transitioning the MFFF into a safe, secure, compliant, and efficient pit production facility, the planned SRPPF. Developing new facilities and security infrastructure and establishing a new program office at SRS to sustain an enduring pit production goal of 50 plutonium ppy are also underway. Preliminary and final design efforts for the SRPPF project are in progress with knowledge gained from LANL, LLNL, and other sites.

There are several key steps to completing the SRPPF project and establishing an enduring production mission:

- Complete five interrelated construction subprojects.
- Hire and train the workforce necessary to establish and sustain the SRS pit production mission.
- Begin production operations upon CD-4 to enable delivery of a first production unit pit.

- Establish the institutional systems at SRS necessary to build WR pits.
- Establish and manage SRS pit production interfaces across the nuclear security enterprise.
- Re-establish a secure supply chain to support the SRS pit production mission.

Further design activities conducted supporting CD-2, *Approve Performance Baseline*, will identify multiple opportunities to accelerate achieving the required production capacity. One opportunity already down-selected is the use of a High Fidelity Training and Operations Center, which will reduce the time required from CD-4 to delivery of first production unit pit by facilitating operator training and qualification and supporting certification activities in cold environments. Establishing required SRPPF pit production capacity as close as possible to 2030 remains a high priority and is required for sustaining the Nation's nuclear deterrent's effectiveness.

The proposed pit production mission will need a skilled workforce at the site. Estimates indicate design and construction activities will require approximately 3,000 staff. Sustained production of 50 WR ppy at SRS will require nearly 2,000 production and support staff. These estimates will continue to be refined as the project's design matures. LANL is actively supporting a knowledge transfer program for the SRS pit production mission with subject matter expertise.

DOE/NNSA will undertake a multi-year training and qualification process to ensure the necessary people, processes, procedures, and commodities are in place to meet the minimum 50 ppy requirement at SRS. Essential to this process will be transitioning an existing facility into the SRS High Fidelity Training and Operations Center expected to be completed prior to the SRPPF main process building. The Center will enable unclassified and classified training in a non-nuclear environment, aimed to qualify the personnel and procedures ultimately used to build and handle pits in the SRPPF main process building. The Center will also advance final design by serving as a proving ground for selected engineering equipment and a test bed to demonstrate systems integration. LANL and LLNL are supporting the training rotation pipeline for the SRS pit production mission through a knowledge transfer program initiated in FY 2020 with Savannah River National Laboratory. This knowledge transfer program will form the foundation of the High Fidelity Training and Operations Center knowledge and experience base.

3.4.1.1.3 Status of Other Plutonium Activities

Many other production, surveillance, and research activities involving plutonium must be conducted throughout the nuclear security enterprise, including radioisotope thermoelectric generator production and surveillance, subcritical plutonium experiments, pit certification, environmental testing, and material processing. Conducting these activities requires close coordination between the sites to execute the disassembly activities, evaluations, experiments, analysis, and recovery.

A responsive plutonium infrastructure requires proper storage facilities, safe and secure disposal pathways, and unique equipment and facilities for R&D activities.

3.4.1.2 Challenges and Strategies

Table 3–4 provides a high-level summary of plutonium handling, packaging, and processing challenges and the strategies to address them.

Table 3–4. Summary of plutonium handling, packaging, and processing challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Timely integration of infrastructure and workforce investments in alignment with W87-1 program needs to reestablish required pit production capabilities and capacity.	Continue to invest in LANL plutonium facilities and workforce needs to meet pit production milestones – achieving the first production unit milestone, then completing the Los Alamos Plutonium Pit Production Project to increase production capacity to 30 WR ppy.	Drive continued improvement in executing equipment installation projects and workforce investments to support future pit production needs.
Repurposing the former MFFF at SRS to achieve a production rate of 50 WR ppy.	Implement a tailored approach for the SRPPF project to achieve CD-2/3, and execute engineering, procurement, and construction activities through multiple subprojects to support producing 50 WR ppy. Use knowledge transfer from LANL and LLNL SMEs to support workforce development at SRS to achieve pit production mission objectives.	Reestablish the supply chain for weapons-related components and commodities needed to support the 50 WR ppy mission.
Executing environmental testing/surety/qualification of plutonium pits without nuclear explosive testing.	Use and expand thermal and mechanical testing capabilities to evaluate newly manufactured and legacy pits in the STS sequence normal environments. Establish equipment, experimental platforms, and systems to evaluate additional normal and abnormal environments that pits could experience.	Leverage the ongoing investment in the Enhanced Capabilities for Subcritical Experiments Program to demonstrate the certification uncertainty achieved with one-point and multi-point safety.

CD = Critical Decision
MFFF = Mixed Oxide Fuel Fabrication Facility
ppy = pits per year
SMEs = subject matter experts
SRPPF = Savannah River Plutonium Processing Facility
STS = stockpile-to-target sequence
WR = War Reserve

3.4.2 Uranium Management

Uranium is a strategic national defense asset with different assays and enrichments, including highly enriched uranium (HEU), low-enriched uranium (LEU), and depleted uranium (DU). Uranium has a variety of defense and other applications, including weapon components and fuel for naval reactors, commercial power reactors (for tritium production), and commercial and research reactors (medical isotope production).

3.4.2.1 Highly Enriched Uranium

HEU is needed to support stockpile programs, Naval Reactors, and Nonproliferation programs. Uranium Modernization supports these efforts through modernizing the infrastructure around HEU processing, purification, machining, and other operations. Particularly, the program is working to phase out mission dependency on Building 9212 at the Y-12 National Security Complex (Y-12). The program is working toward completing the following actions to ensure the success of this transition:

- Relocating HEU capabilities from Building 9212 into the Uranium Processing Facility and other enduring facilities.

- Leveraging these relocations to develop and deploy new technologies that will improve safety, reduce costs, and enhance throughput to meet future needs.
- Investing in key systems such as casting, machining, metal purification systems, assembly, and analytical chemistry capabilities to ensure long-term reliability.

3.4.2.2 Status

DOE/NNSA manages and operates the Nation's primary uranium processing and storage capabilities at Y-12, and several laboratories for R&D capabilities at Y-12 and other locations across the nuclear security enterprise. Building 9212 at Y-12 houses the most hazardous of the HEU processing capabilities; however, at more than 75 years old, the facility is deteriorating and does not meet modern nuclear safety and security standards. DOE/NNSA is decreasing mission dependency on this facility by relocating certain uranium purification and processing capabilities to existing facilities at Y-12, and through construction of the Uranium Processing Facility. In addition to relocating these capabilities, DOE/NNSA is modernizing them to increase safety and efficiency, ensuring future material needs can be met.

The Uranium Processing Facility will replace Building 9212 capabilities for HEU casting, special oxide production, chemical recovery, decontamination, and assay. HEU casting and special oxide production will be housed in the Uranium Processing Facility's Main Process Building, while chemical recovery, decontamination, and assay will take place in the Uranium Processing Facility's Salvage and Accountability Building. A third building, the Uranium Processing Facility's Mechanical/Electrical Equipment Building, will provide utilities and other support systems.

While the Uranium Processing Facility is constructed and undergoes startup activities, DOE/NNSA will relocate capabilities for HEU purification and chip processing, deploying new technologies that will fully enable phasing out mission dependency on Building 9212 and meet future mission needs. Ongoing projects include electrorefining, calciner, and direct chip melt (recovery of enriched uranium machine tool chips and turnings by collecting and melting them in a furnace), which will reduce cost and improve manufacturing processes for nuclear weapon materials. These capabilities will replace the hazardous HEU processing capabilities, improve safety, and reduce risk. Technology maturation, such as for electrorefining and direct electrolytic reduction, is funded and monitored by the Uranium Modernization Program. When the technology is sufficiently mature, the equipment development and deployment is pursued through capital line-item acquisition and major item of equipment processes, as appropriate. This process has generated three current major items of equipment acquisitions to enable the following processes:

- Electrorefining is the electrochemical purification process for HEU metal. This capability, located in Building 9215, along with the calciner process in Building 9212 (see below), will replace the current high-hazard wet chemistry process located in Building 9212.
- The calciner process uses a dry thermal treatment process to convert low-equity HEU liquids to a dry stable form for storage. This capability will process material remaining in Building 9212, ensuring all material is recovered, aiding in shutdown activities. This process, along with the electrorefining capability in Building 9215 (see above), will enable the shutdown of the current high-hazard wet chemistry process in Building 9212.
- Direct Chip Melt is the process by which HEU machine tool chips/turnings are recovered and melted in furnaces. This capability, located in Building 9215, will replace the current high-hazard practices where chips are transferred to Building 9212, then cleaned, briquetted, and stored there.

DOE/NNSA will perform its enriched uranium metal purification in Building 9215 using the electrorefining process, which will achieve CD-4 in 2023. Uranium Modernization will continue to fund the hazardous wet chemistry metal purification process in Building 9212 until the electrorefining process is fully operational, at which point wet chemistry in Building 9212 will be shut down.

Uranium Modernization currently uses Y-12's Building 9212 resources to supply the stockpile with purified HEU metal. The program provides a comprehensive storage capability to support a steady material supply stream through peak production periods. It also enables HEU material de-inventory activities to increase safety, establish target working inventory levels for the production facilities, and optimize inventory composition. The program, partnering with DOE/NNSA's Office of Infrastructure, is sustaining existing and enduring uranium facilities with an Extended Life Program. These efforts allow safe and secure operations to continue, including those relocated from Building 9212, in existing facilities through 2040 and beyond.

Uranium Modernization is proactively removing equipment that is no longer needed from these enduring facilities through its Flexible Production Capacity Initiative to improve Y-12's responsiveness and resiliency.

3.4.2.3 Challenges and Strategies

Table 3–5 provides a high-level summary of highly enriched uranium handling, packaging, and processing challenges and the strategies to address them.

Table 3–5. Summary of highly enriched uranium handling, packaging, and processing challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Bringing new processes online and shutting down hazardous processes.	Verify equipment meets all requirements and use Operational Release Plans to streamline the transition to operations.	Support past project closure, ensuring the transition to production is successful.
Developing processes to bridge capability gaps as Building 9212 is phased out.	Closely monitor and work with the site to advance technology development and plan how to move projects forward.	Closely monitor project schedules and prepare fallback options to ensure mission demand is met.
Preparing Building 9212 for disposition and demolition.	Shutdown high-hazard processes as new processes are brought online and begin material removal, maintaining a 15+ year schedule.	Current strategy is sufficient.
Continuing operations in aging facilities with increasing safety, security, and environmental requirements and maintaining them until operations transition to newly deployed facilities.	Make short- to medium-term recapitalization investments where reasonable. Find adaptive solutions to maintain facilities past their useful lives.	Execute future projects including electrical, utility upgrades, and other identified structural life-extending efforts, as identified in the implementation plan.
Growing and maintaining SMEs across the nuclear enterprise.	Increase hiring to plan for multi-year training and clearance requirements. Transfer knowledge from SMEs near retirement age to new SMEs. Collaborate with national laboratories and industry to develop next generation of subject matter expertise.	Gather and collate knowledge from SMEs through documentation programs targeting critical knowledge areas.

SME = subject matter expert

3.4.2.3.1 Depleted Uranium Modernization

DU, a HEU enrichment process byproduct, has a lower concentration of the fissile isotope uranium-235 and a higher concentration of the fissionable isotope uranium-238 than natural uranium. DOE/NNSA must have the capability to produce certified components made from high purity depleted uranium metal (HPDU) and DU-niobium alloy (binary) to fulfill mission requirements.

DU and binary are required for nuclear component production to maintain and modernize the stockpile through LEPs, Mods, and limited life component (LLC) exchange programs. DU and binary are processed into precision components through complex processes that must meet stringent requirements. Key processes include alloying, casting, rolling, swaging, forming, forging, machining, assembly, welding, and inspection.

3.4.2.3.2 Status

The Depleted Uranium Modernization Program was established in FY 2021 by consolidating the DU portions of the previous Uranium Sustainment Program and other related programs. DU capabilities include feedstock procurement, restarting and maintaining legacy Vacuum Induction Melt-Vacuum Arc Remelt alloying and manufacturing processes, and investing in new key technologies. In the early 2000s, these capabilities lapsed due to materials reuse, low-demand signals, and prioritizing other activities. The Depleted Uranium Modernization Program is restarting these capabilities to meet imminent mission requirements.

DOE/NNSA has a long-term requirement to reestablish a reliable supply of HPDU before the current inventory is exhausted. DOE/NNSA is working toward an AoA study to determine the best approach to meet the mission need for HPDU supply. One concept is to develop a uranium hexafluoride (DUF_6) to uranium tetrafluoride (DUF_4) conversion line and establish a capability to convert DUF_4 to HPDU metal. DOE/NNSA is also evaluating if recycling DoD DU munitions to mitigate schedule risks associated with establishing a DUF_4 conversion line is feasible or not.

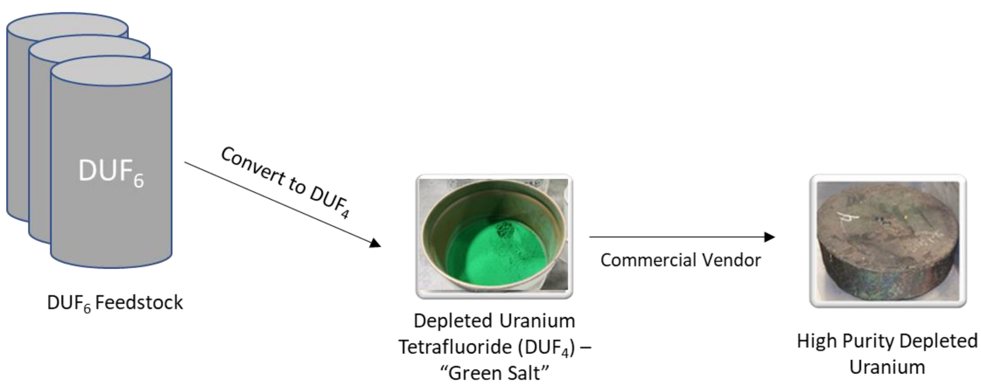


Figure 3–3. High Purity Depleted Uranium supply chain

DOE/NNSA is developing new technologies to replace and augment aging capabilities and to provide a more efficient and cost-effective means of producing binary components, allowing DOE/NNSA to meet future production demands while reducing feedstock demand. For example, Direct Casting is a technology being developed to supplement current wrought activities that would significantly reduce equipment failure risk, decrease material waste, and improve process efficiency. The Depleted Uranium Modernization Program is also pursuing new technologies for material reuse and recycling, such as electron beam cold hearth melting of binary. These new technologies have the potential to significantly reduce risks to production and DU and binary components material feedstock in the future stockpile.

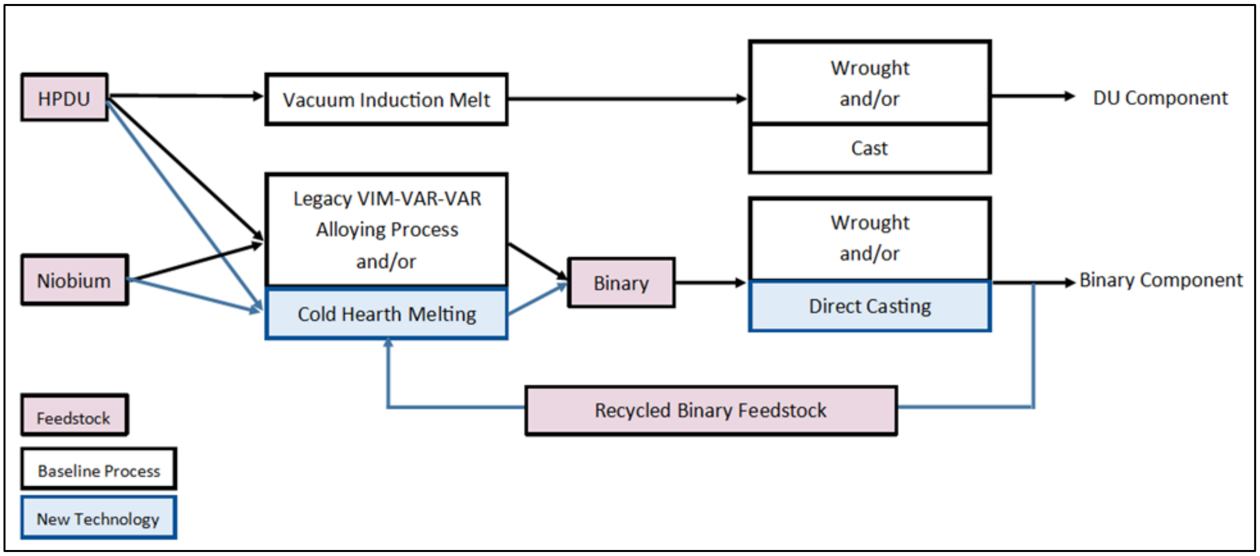


Figure 3–4. Depleted Uranium Modernization Process flow chart

DOE/NNSA's Manhattan Project-era facilities continue to experience age-related failures that present significant risk to mission delivery and personnel safety. Short-term stockpile demands require dedicated resources to restart and modernize legacy-DU processing capabilities. Ultimately, to meet long-term stockpile demands, DOE/NNSA will invest in a new dedicated DU facility.

3.4.2.3.3 Challenges and Strategies

Table 3–6 provides a high-level summary of depleted uranium modernization challenges and the strategies to address them.

Table 3–6. Summary of depleted uranium modernization challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
HPDU inventory insufficient to meet long-term demands.	Purchase existing, limited HPDU supplies from commercial vendors. Scaling up DU munitions recycling to convert to HPDU. Conduct AoA study to inform alternatives for creating DUF_4 feedstock.	Invest in EBCHM and direct casting to reduce overall HPDU demand.
DU alloying capabilities have lapsed and need to be restarted and modernized to support future stockpile needs.	Invest in the restart and maintenance of the legacy alloying processes. Purchase additional equipment to reduce the strain on legacy equipment and processes. Coordinate across production and design agencies to expedite binary qualification. Use the NNSA Binary Working Group to manage existing and future binary supplies and set NNSA priorities.	Deploy EBCHM alloying production technologies to improve efficiency and recycling capabilities. Integrate direct cast technology into production to reduce binary material demands and waste due to increased efficiencies and decrease process risk.

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Current component manufacturing capabilities rely on aging equipment and have limited capacity to meet future stockpile needs.	Identify bottlenecks and develop bridging strategies to fulfill near-term mission requirements should new technology not be employed in the immediate future.	Purchase wrought critical spare parts to sustain the process. Invest in direct casting technology to produce component technologies more efficiently and reliably.
Current DU facilities experience age-related failures and have insufficient floor space to support future stockpile demand.	Identify opportunities to meet capacity within existing space using process improvements, upgraded equipment, and future needs and capacity modeling. Invest to recapitalize the aging physical infrastructure, thus reducing risk to produce strategic materials and components. Establish a combination of on-site and off-site storage capabilities to store required HPDU feedstock quantities to meet future mission demand.	Evaluate long-term DU facility options to meet future stockpile demands. Sustain existing DU facilities with a DU/binary strategy to ensure safe and secure operations in existing facilities through 2040 or until a replacement facility is constructed.
Continuing operations in aging facilities with increasing safety, security, and environmental requirements and maintaining them until operations transition to newly deployed facilities.	Make short-term to medium-term recapitalization investments where reasonable. Find adaptive solutions to maintain facilities past their useful lives.	Execute future projects including electrical, utility upgrades, and other identified structural life-extending efforts, as identified in the implementation plan.
Growing and maintaining SMEs across the nuclear enterprise.	Increase hiring to plan for multi-year training and clearance requirements. Transfer knowledge from SMEs near retirement age to new SMEs. Collaborate with National Labs and industry to develop next generation of subject matter expertise.	Gather and collate knowledge from SMEs through documentation programs targeting critical knowledge areas.

AoA = Analysis of Alternatives
DU = depleted uranium
DUF_4 = uranium tetrafluoride
EBCHM = electron beam cold hearth melting
HPDU = high purity depleted uranium
SME = subject matter expert

3.4.2.4 Domestic Uranium Enrichment

Enriched uranium contains higher concentrations of the fissile uranium-235 isotope than natural uranium. DOE/NNSA requires enriched uranium at varied enrichment levels for tritium production, nonproliferation, and the Naval Reactors Program. The Domestic Uranium Enrichment Program is responsible for ensuring a reliable supply of enriched uranium is available to support U.S. national security needs. Since the 2013 closure of the Paducah Gaseous Diffusion Plant, near Paducah, Kentucky, the United States has lacked the capability to produce enriched uranium free of peaceful use obligations (i.e., unobligated). While commercial LEU sources exist, they carry peaceful use obligations and are therefore unusable for defense missions. Mission needs for enriched uranium are currently fulfilled via the United States' existing HEU inventory (including downblending HEU to produce LEU where needed), which is a finite and currently irreplaceable source.

3.4.2.4.1 Status

The Domestic Uranium Enrichment Program is implementing a three-pronged strategy to supply current enriched uranium needs and reestablish a domestic uranium enrichment capability for long-term enriched uranium needs:

- **Downblend HEU to LEU to extend the tritium fuel need date to 2044**. DOE/NNSA has identified existing unobligated and unencumbered material to power the Tennessee Valley Authority (TVA) reactors through 2044. Much of the material is HEU "scrap," which is unattractive for use by other programs. This effort maintains continuous vendor downblending operations, which would otherwise close in the absence of feed material. However, because the HEU inventory is finite, and at present, irreplaceable, downblending is a temporary solution.
- **Develop enrichment technology options.** Following an analysis of available enrichment technologies, DOE/NNSA determined that centrifuge technologies have the highest technical maturity and lowest risk. DOE/NNSA is funding centrifuge R&D efforts at Oak Ridge National Laboratory to ensure a centrifuge technology is available in time to be deployed in a domestic uranium enrichment capability.
- **Execute the acquisition process to deploy an enrichment technology.** Because the HEU inventory has a finite nature, the United States will eventually need a new uranium enrichment capability. DOE/NNSA approved CD-0 for this capability in December 2016 and expects to make a final technology down-select and deployment decision in the mid-2020s.

3.4.2.4.2 Challenges and Strategies

Table 3–7 provides a high-level summary of domestic uranium enrichment challenges and the strategies to address them.

Table 3–7. Summary of domestic uranium enrichment challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Enrichment technologies are complex and difficult to develop and deploy.	DOE/NNSA has invested in two centrifuge technologies to provide optionality and contingency. DOE/NNSA continuously assesses its inventory to identify unobligated enriched uranium that may provide additional development time or margin to the LEU need date.	Continue developing centrifuge technologies to reduce long-term deployment risks.
Sources of unobligated LEU are finite and limited.	DOE/NNSA continuously assesses its inventory to identify any additional unobligated enriched uranium.	Establish a reliable source of unobligated enriched uranium.

LEU = low-enriched uranium

3.4.3 Lithium Management

3.4.3.1 Lithium

Lithium handling, packaging, and processing is a capability that is key to the nuclear weapon production mission. It continues to have increased focus due to supply, production, and infrastructure issues. DOE/NNSA requires specialized, weapon-specific forms of lithium for stockpile sustainment and is the sole source provider for these materials. DOE/NNSA manufactures lithium materials into precise nuclear weapon components that meet stringent specifications to support warhead modernization programs and joint test assembly requirements, and to support tritium-producing burnable absorber rod (TPBAR) production for the tritium production, handling, and processing program.

Lithium metal from technology maturation efforts

3.4.3.2 Status

Lithium for the weapons program is currently provided via a recycling process that relies on dismantled weapon feedstock to supply material for processing. Nondestructive and destructive testing is performed for lithium components in full assembly and part forms as part of surveillance data collection for ensuring confidence in the stockpile. Additional material is provided to the Department of Homeland Security and DOE Office of Science for various needs, and to other customers through the Strategic Partnership Program process.

Restored electrolytic cell at Y-12

DOE/NNSA is actively pursuing alternate, advanced lithium purification techniques. Technology Readiness Assessments are conducted as needed to assess the strengths and weaknesses of identified technologies.

Currently, aging infrastructure and antiquated equipment present risks to mission delivery that, if realized, will affect the ability to meet stockpile requirements. The 79-year-old facility where lithium is processed has structural issues due to chemical degradation, which poses safety and environmental concerns, and a replacement facility is needed. DOE/NNSA continues to execute and revise a lithium strategy to maintain sufficient lithium processing capabilities (from raw materials to finished assemblies) to meet near-term and long-term requirements. The strategy includes the design and construction of a new Lithium Processing Facility by 2031 to house modernized lithium processing capabilities. The Lithium Processing Facility F has received CD-1, *Approve Alternative Selection and Cost Range*, approval and is on track for CD-2/3 approval first quarter of FY 2026.

DOE/NNSA will continue to work with stakeholders to develop tailored, long-term staffing plans that anticipate critical skills shortfalls within this capability and properly forecast staffing levels based on the current program of record. Subject matter expert (SME) growth and sustainment will require SMEs undergo continued training and development to produce lithium components and resolve technical issues associated with these complex production processes.

3.4.3.3 Challenges and Strategies

Table 3–8 provides a high-level summary of lithium handling, packaging, and processing challenges and the strategies to address them.

Table 3–8. Summary of lithium handling, packaging, and processing challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Meeting manufacturing deliverables using existing aging and degraded facilities.	Sustain current operations in the legacy lithium facility to meet near-term stockpile needs. Reestablish a small-scale purification capability and restart some legacy processing capabilities to supplement recycling activities. Plan and prioritize recapitalization projects and risk reduction activities to keep facilities and process equipment functional until the Lithium Processing Facility is qualified.	Design and construct the Lithium Processing Facility. Continue to maintain legacy processing efforts through the identified facility life cycle extension project until the Lithium Processing Facility is fully qualified.
Sustaining the supply of recycled lithium during potential shortages.	Restart a small-scale purification capability and legacy processing capabilities in the legacy lithium facility to provide additional feedstock material. Deploy/recapitalize new equipment (production cleaning station glovebox, backup pressure vessel, backup crusher/grinder) to increase capacity and provide redundancy to reduce likelihood of single-point failures. Monitor and optimize weapons dismantlement schedule to provide feedstock as needed.	Develop and prioritize new process technologies and equipment to maximize efficiency and reliability in meeting stockpile needs. Complete the qualification for the production parts cleaning station glovebox. Identify, plan, and schedule future weapon system qualifications for direct material manufacturing feed material. Complete the qualification for the refurbished purification and legacy processing capabilities. Develop, update, and sustain program management tools to optimize the feedstock production schedule.
Sustaining lithium production with current inefficient processes.	Develop and mature lithium process technologies to introduce efficiencies into the current process and prepare for insertion in process facilities.	Further develop small-scale wet chemistry to purify legacy material not suitable for the direct materials manufacturing process. Mature process improvements for legacy processes (e.g., next-generation electrolytic cell and improved purification).
Continuing operations in aging facilities with increasing safety, security, and environmental requirements and maintaining them until operations transition to newly deployed facilities.	Make short-term to medium-term recapitalization investments where reasonable. Find adaptive solutions to maintain facilities past their useful lives.	Execute future projects including electrical, utility upgrades, and other identified structural life-extending efforts, as identified in the lithium implementation plans. Optimize the purification processes design for the Lithium Processing Facility.
Grow and maintain SMEs across the nuclear enterprise.	Increase hiring to plan for multi-year training and clearance requirements. Transfer knowledge from SMEs near retirement age to new SMEs. Collaborate with national laboratories and industry to develop next generation of SMEs.	Gather and collate knowledge from SMEs through documentation programs targeting critical knowledge areas.

SMEs = subject matter experts

3.4.4 Tritium Management

Tritium, a strategic material used for national security purposes, is placed in gas transfer system (GTS) reservoirs, and used to meet weapon system military specifications, increase system margins, and support weapon system reliability. Due to the rate of radioactive decay, tritium must be replenished periodically in these components. DOE/NNSA produces tritium for this purpose and others using TPBARs that are irradiated in the Watts Bar Unit 1 and Watts Bar Unit 2 nuclear reactors (WBN 1 and WBN 2) operated by TVA. Because this is defense-purposed tritium, WBN 1 and WBN 2 require unencumbered and unobligated LEU use as fuel (i.e., LEU that is free of any peaceful use restrictions). Once the TPBARs are irradiated, the bars are transported to SRS, where the tritium is extracted, stored, and loaded into GTS reservoirs. In addition to tritium production at TVA, tritium supplies from previously filled reservoirs are recycled to maintain required inventories. Most of DOE/NNSA's tritium capability activities focus on stockpile requirements, but activities also include tritium gas processing R&D, GTS life storage, helium-3 recovery, and stockpile surveillance.

3.4.4.1 Status

DOE/NNSA has a multi-year plan of producing and recycling tritium to meet national security requirements and demonstrating a highly reliable supply chain. DOE/NNSA continues to deliver the requisite supply by using TVA's WBN 1 and WBN 2 reactors. The goal to reach maximum tritium production in each of the two Watts Bar reactors by FY 2025 is on schedule. Extraction of tritium from irradiated TPBARs at SRS is ongoing in accordance with the multi-year plan.

The SRS Tritium Extraction Facility performs a cask receipt, enabling TPBARs to be moved safely from shipping casks to basket.

DOE/NNSA manages numerous facilities at SRS that support tritium handling, processing, and storage functions, including recovery, nondestructive analysis, and surveillance, and is implementing a plan to replace, or recapitalize, aging facilities. This plan focuses on facilities maintenance and the need for supply chain management (e.g., vendors, tritium R&D capabilities, etc.).

The Tritium Finishing Facility line-item project, along with several minor construction projects and equipment replacement/upgrade projects, will replace the critical capabilities occurring at the existing 60-year-old manufacturing building that operates 24/7 for GTS production and surveillance.

Examples of these required smaller projects include:

- Replacing large, obsolete distributed control systems for the gas processing equipment
- Replacing and electronic refurbishing mass spectrometers to analyze gas associated with processing equipment
- Installing a hydrogen/tritium separation capability in the Tritium Extraction Facility
- Replacing the deuterium/tritium separation equipment, including support systems and valves
- Several minor construction projects to address end of life, safety, and space requirements

Some of the scope described above will require significant processing downtime, particularly replacing the deuterium/tritium separation equipment. Maintaining the equipment replacement sequence and timing will be critical to minimize downtime.

3.4.4.2 Challenges and Strategies

Table 3–9 provides a high-level summary of the tritium production, handling, and processing challenges and the strategies to address them.

Table 3–9. Summary of the tritium production, handling, and processing challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Maintaining a reliable tritium supply chain to meet tritium inventory and availability requirements to load GTSs on schedule.	Assess supply chain risks and opportunities. Investments are being made that will provide high-level reliability, flexibility, and resiliency to the program.	Continue to monitor risks and opportunities to identify cost-effective solutions and retain high reliability.
Planning for alternative tritium production technologies or methods due to the uncertainties associated with Nuclear Regulatory Commission approval of operating license renewal applications in 2055 for Watts Bar Units 1 and 2.	Invest in studies that identify and monitor viable and emerging replacement methods and technologies as risk mitigation for long-term tritium production.	Monitor evolving technologies and invest in existing or new technologies as appropriate.
Maintaining facilities and equipment to support stockpile deliverables and future Alts, Mods, and LEPs, and reduce GTS delivery risks.	Construct the modern Tritium Finishing Facility on schedule to replace infrastructure critical to stockpile deliverables at SRS by 2031. Continue long-lead procurements and other activities needed to support replacement of aged tritium isotopic equipment and support systems in CY 2025.	Monitor emerging needs and implement strategies and actions to mitigate risks.
Developing technologies that further enhance stockpile maintenance and evaluation and increase efficiency of processes throughout the tritium production life cycle.	Invest in fundamental tritium science, including material property interactions and scientific research into the material properties and behaviors of TPBARs, GTSs, and tritium gas processing technologies.	Develop a strategy to acquire dedicated radiological tritium capabilities to address future technology needs without compromising mission schedule.
Planning for long lead times to hire, clear, and train personnel.	Examine multiyear staffing needs appropriate to ensure a continuous knowledge, skills, and abilities influx to sustain capabilities.	Implement additional strategies to maximize knowledge retention and minimize workforce turnover.

Alt = alteration
CY = calendar year
GTS = gas transfer system
LEP = life extension program
Mod = modification
TPBAR = tritium-producing burnable absorber rod

3.4.5 High Explosives and Energetics Management

Energetics development and production, including the associated manufacturing processes and infrastructure, are required to meet legacy material demands and to modernize stockpile applications. Energetics are materials that provide instantaneous energy through an exothermic chemical reaction. Energetics include specific end products, such as HE that include conventional HE and insensitive HE, low explosives (e.g., pyrotechnics and propellants), their respective energetic ingredients, and various inert ingredients required for manufacturing (e.g., polymers, reactants, catalysts, plasticizers, oxidizers, fuels, ballistic modifiers, stabilizers, surfactants, and bonding agents). Across the enterprise, DOE/NNSA laboratories and production sites handle energetic material as part of the nuclear weapon sustainment and warhead modernization missions.

The current stockpile maintenance and modernization programs will continue to demand energetic and hazardous materials. Ensuring DOE/NNSA has the capability to properly handle, package, process, and manufacture energetic and hazardous materials is essential to supporting the nuclear deterrent.

This capability depends on the ability to perform HE and energetic scientific and engineering activities, and is united with the ability to handle, package, and process SNM (plutonium and uranium) (Section 3.4.1 and 3.4.2).

The nuclear security enterprise must maintain reliable production; science, technology, and engineering capabilities; an integrated infrastructure; a robust domestic supplier base; and logistics (handling, storage, and delivery) for raw materials and WR products. Most of the current facilities were built over 70 years ago, lack the electrical infrastructure to meet mission requirements, and have safety and security limitations because infrastructure is failing. New facilities construction and existing energetic facilities recapitalization across the nuclear security enterprise are needed to improve the capability and capacity required by increased modernization efforts, continuing challenges associated with a limited vendor base, and advancements to energetic manufacturing.

DOE/NNSA completed the Nuclear Explosive Package Engineering Test's functional test phase in January 2022.

HE processing, production, and manufacturing are currently performed externally by a vendor and internally at the Pantex. This capability encompasses the ability to supply raw material, procure HE from the vendor, and perform safe HE processing into precision parts meeting tight specifications. The current stockpile planned warhead modernization programs, LLC exchanges, and future modernization programs will continue to demand HE and energetic materials.

In each weapon, DOE/NNSA uses either one of the two types of HE produced in the main charge of a nuclear weapon: (1) insensitive HE, which provides greater safety and security of the stockpile by reducing the risk of low-likelihood but high-consequence accidents from initial build through retirement and disassembly, and/or (2) conventional HE, which provides enhanced performance for a lower volume and weight. The type of HE used changes depending on the weapon type and purpose.

3.4.5.1 Status

The facilities and equipment that support this capability pose mission risks due to their aging and declining condition and must be maintained through rigorous corrective maintenance, preventive maintenance, and calibrations.

Experienced and knowledgeable personnel are needed to properly care and handle energetic and hazardous materials. Also, recruitment of skilled professionals and extensive safety training are imperative for safe operations. With an increased workload and the attrition/retirement of senior personnel, DOE/NNSA must focus on building and training a workforce that can safely perform these operations well into the future.

DOE/NNSA is currently planning three major programmatic line-item construction projects for HE. The High Explosives Science and Engineering Facility will consolidate 15 aging facilities into 3 new and more efficient facilities to conduct science, technology, engineering, and production activities in weapons assembly/disassembly and HE. The High Explosives Science and Engineering Facility received CD-2/3 approval in the third quarter of FY 2022 and commenced construction immediately. CD-4 is planned for FY 2027. The HE Synthesis, Formulation, and Production project will address challenges at the supplier's production facility and address the difficulties in meeting DOE/NNSA production requirements. It plans to receive CD-3A approval for the first quarter of FY 2024 and CD-4 approval fourth quarter of FY 2030. Areas that will be addressed include explosive and mock formulation operations to support multiple weapon programs, technology development for future programs, and support for strategic partners. Finally, the Energetic Materials Characterization project will provide the capability to perform energetics material characterization, analysis, and testing, and will replace obsolete facilities that pose risks to workforce safety.

Future infrastructure enhancements may include consolidating and modernizing existing facilities critical to meet the stockpile's HE production capabilities for energetic components (main charges, boosters, actuators, igniters, rocket motors, timers, and detonators) in a modern and enhanced safety and security environment. DOE/NNSA also will continue to implement minor construction to mitigate known issues with the limited commercial component vendor base to provide on-site production of energetic components in the stockpile (actuators, igniters, detonators, timers, rocket motors).

3.4.5.2 Challenges and Strategies

Table 3–10 provides a high-level summary of the high explosives and energetics management challenges and the strategies to address them.

Table 3–10. Summary of the high explosives and energetics management challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
Nuclear security enterprise infrastructure for energetics face aging critical facilities and equipment (many past their life expectancies), increasing demands for capability and capacity, and uncertainty in material production due to a single-source vender base.	Coordinate with the Infrastructure and Operations Program and the Programmatic Recapitalization Working Group to improve energetic readiness. Keep aging equipment available for warhead modernization and current stockpile systems through rigorous maintenance programs and integrated equipment refinancing planning across the nuclear security enterprise. Find creative solutions to maintain facilities past their useful life. Make short-term to medium-term refinancing investments where reasonable. Engage and enable sites to reduce dependency or better enable external suppliers.	Construct the HE Synthesis, Formulation, and Production building, the HESE Facility, and the Energetic Materials Characterization facility. Identify and invest in equipment requirements through input from the sites and link them to defined risks and capability gaps. Employ creative methods to mitigate obsolescence issues, such as using additive manufacturing to produce parts. Stand up production enclaves at design laboratories to enable more efficient response to the emerging deterrent. Prototyping Capabilities, funded at the production agencies, would better serve this need by not only addressing emerging needs, but by also providing early visibility and involvement that would accelerate transitions from development into production. See Section 3.5.23.5.4.

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Dependence on a small and shrinking vendor base to supply the explosives, constituent components, and specialized equipment needed to produce its energetic end products.	Establish clear requirements for Nuclear Enterprise Assurance. When necessary, use in-house capabilities to restore mission schedules at risk. Respond to situations by acting to stabilize suppliers or fund management and operating partner activities to qualify new ones. Support cooperative arrangements with DoD and Holston to improve Holston's ability to deliver product requirements.	Sponsor capital acquisition projects and coordinate efforts among sites and HQ elements to shepherd projects from business case to beneficial use. Construct the HE Synthesis, Formulation, and Production Facility for a nuclear security enterprise capability, capacity, resources, and equipment to supply HE for WR energetics.
Developing sufficient supply chain capacity for energetic materials in current and future LEPs and Alts.	Exercise initiatives within the Defense Programs for Energetic Materials. Refresh HE formulation, synthesis, and machining capabilities at Pantex. Identify, assess, and perform risk-informed activities to understand, characterize, and develop better methods to produce and qualify materials more fully.	Analyze and apply lessons learned from Defense Programs initiatives for energetic materials for broader implementation across the enterprise along lines of effort such as design for manufacturing, and requirements and capacity integration.
Ensuring requirements for energetic materials are adequately identified, preserved, and documented.	Document the detailed processes necessary for the synthesis and formulation of energetic materials for a repeatable material specification that yields the required engineering and performance requirements through efforts with the NNSA Energetics Coordinating Committee.	Document the technical basis for future process parameter choices and rationale for specific requirements in the specifications. Improve understanding and control over material specifications and manufacturing to improve reliability and repeatability and increase lot acceptance. Develop techniques to computationally assess manufacturing with computational fluid dynamics, computational chemistry, machine learning, and artificial intelligence. Develop techniques to reprocess out-of-spec material to meet requirements.
Planning for material shortfalls for legacy WR HE due to a lack of robust plans and processes to control inventories.	Collaborate with DoD and industrial partners to institute a more routine process to exercise synthesis and form energetic materials. Complete triaminotrinitrobenzene/ PBX-9502 specifications will improve plans and processes to enhance inventory control.	Preserve and enhance in-house production for items such as WR detonator powder production.

Alt = alteration
HE = high explosives
HESE = high explosives science and engineering
LEP = life extension program
WR = War Reserve

3.4.6 Additional Material Needs

Specialized components and materials that are not commercially available must be produced within the nuclear security enterprise. This production may require organic materials and processing production, manufacturing, and metallic and organic products inspection, based on knowledge of material behavior, compatibility, and aging. This would include, but is not limited to, polymer material and part manufacturing.

3.5 Weapon Component Production Area

The Weapon Component Production area includes multiple capabilities for producing all the non-nuclear components and the arming, fuzing, and firing system, and for designing, developing, engineering, and integrating other materials, from components to prototype high-quality and full-scale nuclear explosive packages and/or their major assemblies. This area also includes the advanced manufacturing capabilities that apply modern technologies to advance NNSA legacy and existing processes for making and producing weapons components and systems. The capability area involves internal and external manufacturing and maintenance and of a broad supply base for parts. It also includes identifying and verifying trusted suppliers to provide materials and parts within the weapon product realization process.

3.5.1 Non-Nuclear Component Modernization and Production

The Non-Nuclear Capability Modernization Program manages projects and executes strategies to modernize, monitor, and ensure DOE/NNSA's non-nuclear capabilities and capacities. The Non-Nuclear Capability Modernization Program provides funding to modernize and strengthen capabilities required for full product realization, including design development, qualification, and production of non-nuclear components for multiple weapon systems. Non-nuclear components and subsystems make up more than half the cost of each warhead modernization activity. This program consolidates management and oversight of strategic investments in technology, equipment, infrastructure, tools, and materials.

Non-Nuclear Capability Modernization activities include:

- Procuring equipment
- Meeting non-nuclear component design, qualification, and manufacturing capacity requirements
- Increasing non-nuclear component manufacturing in capacity and capability within the nuclear security enterprise and extending and strengthening the trusted supplier base
- Sustaining DOE/NNSA's capability to produce trusted microelectronics
- Re-establishing critical capabilities for the design, production, and qualification of nuclear weapon electrical and mechanical systems
- Modernizing capabilities with a fragile vendor base such as Power Sources program deliverables
- Reducing component manufacturing costs through introducing modernized processes and technologies
- Developing a pre-qualified and trusted commercial parts inventory to avoid delays in integrating commercial off-the-shelf components into DOE/NNSA systems

Production sites work with the national security laboratories early in the design phase to provide production perspectives on material selections and designs to enhance components producibility. The national security laboratories define the component testing requirements for acceptance through a variety of specialized procedures to ensure materials meet design specifications, parts are manufactured within acceptable tolerances, and assemblies function as intended.

3.5.1.1 Status

DOE/NNSA has made progress in developing rapid prototyping and advanced manufacturing capabilities that have the potential to accelerate production, reduce production issues, and deliver better overall products at lower costs.

Production sites are facing capacity shortfalls in production and components development due to increased weapon modernization requirements and scope. The increased workload has resulted in a growth in the KCNSC management and operating partner's workforce that has more than doubled since 2014. DOE/NNSA is adding additional production capacity through leasing at KCNSC and shifting production to other DOE/NNSA sites while simultaneously increasing the supplier base for commercial component production. Off-site office space has been leased to meet the increased office employment. KCNSC is leasing an additional 275,000 square feet of space for manufacturing to meet the near-term weapon modernization mission. Additional space will be needed for long-term manufacturing requirements. LLNL and KCNSC jointly developed and implemented the Polymer Enclave to help ensure production capacity for the W80-4 and W87-1. Further, the Enclave has enabled advanced Direct Ink Write (DIW) technology research and production process development to better integrate and increase cycles of learning for the technology, resulting in more rapid product development for the programs.

All modernization programs and future planned nuclear weapon systems require power sources, and DOE/NNSA has concluded there is an unacceptable risk to power source development and production due to failing and inadequate power source facilities and an unreliable supplier base. DOE/NNSA is investing in the development of new power source technologies across the nuclear security enterprise to expand the option space for safe and reliable long-term power sources that can meet evolving system architectures. Currently, the mission assignment for design and production agencies for power source is assigned to SNL. DOE/NNSA completed an AoA Study in 2020 and identified a preferred alternative for pursuing capital acquisition of a line-item construction project to address this risk. Current stockpile stewardship plans are forecasting sustained high workload for power sources production over the next decade.

Similar issues hold true for radiation-hardened microelectronics at SNL's MESA complex; the MESA facilities and existing equipment face obsolescence and are becoming less suitable for mission use. MESA has an ongoing extended life program to sustain MESA's capabilities through 2040. In addition, plans are being developed for sourcing and manufacturing these microelectronics well past 2040.

Aging equipment poses reliability and obsolescence issues, resulting in greater operations continuity risks. The Capabilities Based Investments program helps mitigate these risks and related ones through projects which refinance high risk failure test, measurement, and production equipment. In addition, DOE/NNSA is pursuing efforts to better understand current and future equipment needs across the nuclear security enterprise for all aspects of the nuclear weapons mission, including non-nuclear production, through the Programmatic Recapitalization Working Group. This working group is a combination of participants from the Office of Defense Programs and the Office of Infrastructure, and has full participation from each of the DOE/NNSA sites. The concern with aging capabilities extends to major environmental test facilities used to qualify and assess non-nuclear components in their extreme environments to high reliabilities not required for commercial products. The majority of these facilities, including the Annular Core Research

Reactor, are decades old and, similar to production facilities, have suffered from technology obsolescence and deferred maintenance over the years. These facilities must remain operational to assure qualifying non-nuclear components does not become critical path for the modernization programs.

DOE/NNSA is becoming increasingly dependent on internal production due to difficulty finding trusted sources for non-nuclear weapon components such as power sources, cables, and radiation-hardened microsystems. This insourcing may require additional facilities, equipment, and infrastructure for certain product lines. In the long term, capital reinvestment will be crucial to maintaining DOE/NNSA's manufacturing and testing capabilities suite. Developing additional qualified commercial suppliers will help this effort, although commercial demand for these products, with less stringent production requirements, is posing challenges throughout the supplier base.

3.5.1.2 Challenges and Strategies

Table 3–11 provides a high-level summary of non-nuclear capability modernization challenges and the strategies to address them.

Table 3–11. Summary of non-nuclear capability modernization challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Increased Scope and Complexity: Workload projections to produce non-nuclear components for the program of record exceed existing equipment and infrastructure capacity. Manufacturing space was sized for fewer, less-complex weapon systems.	DOE/NNSA will develop options for additional space or more efficient use of existing space. Planning is underway to determine the most prudent solutions to provide increased production capacity at SNL (for Power Sources) and KCNSC. Additionally, production enclaves enable increased production at production sites.	The MESA complex at SNL fulfills an enduring need for radiation-hardened microelectronics. A Federal Management Plan will implement processes to validate sustainment and modernization needs, identify potential funding gaps, and develop mitigation strategies to ensure MESA capabilities continue to meet stockpile sustainment and modernization needs through 2040.
Integration of New Technologies: As new manufacturing techniques are developed, qualified, and accepted, new production capabilities are required to support manufacturing involving different materials, multi-function machines, additive manufacturing, and other new approaches. Space for the new capabilities is required in addition to current equipment until legacy technologies can be retired.	The Capability-Based Investments program is providing interim relief for some of the critical equipment needs related to these key product lines. Investments in multiple Advanced Manufacturing technologies are being made across several NNSA sites and are expected to be used by FY 2023. Additionally, production enclaves at design laboratories enable new manufacturing techniques to transition smoothly to production by encouraging early DA-PA interactions.	The Non-Nuclear Capabilities Program will continue to collaborate with the Research, Development, Test, and Evaluation Program Office to identify promising technologies that could/would be committed to future modernization programs if sufficiently mature and fund them to higher technology readiness levels and manufacturing readiness levels. [5] These technologies) will enable improvements in stockpile safety, security, use control, and reliability, while minimizing the schedule, performance, and cost risk to the identified modernization program.

[5] Technology readiness level (TRL) is a measurement system to assess the maturity level of a particular technology that includes nine levels, where TRL 1 is the lowest (the associated scientific research is beginning) and TRL 9 is the highest (a technology has been proven through successful operation). Manufacturing readiness level (MRL) is a means of communicating the degree to which a component or subsystem is read to be produced. MRLs represent many attributes of a manufacturing system (e.g., people, manufacturing capability, facilities, conduct of operations, and tooling). There are nine MRLs, with the lowest being product development and the highest being steady-state production.

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Material Availability: Some material supplies are limited to only those quantities remaining from legacy programs yet continue to be in demand by weapons programs. Vendors have lost the capability, capacity, or interest to produce more of these materials.	Current efforts for managing these critical materials consist of establishing a central database for at-risk materials and providing a transparent supply chain network and associated risks by industry experts.	Supply chain analysis and studies will examine supplier network risks for non-nuclear components and provide recommended policy actions, production activity practices, and material solutions to improve supply chain resiliency. These efforts also coordinate across DOE/NNSA to prioritize supplier risks, develop enterprise-wide mitigation strategies, and leverage available policy tools such as the Defense Production Act, and leverage existing partnerships such as with DoD.
Vendor Implications: Risks in the available supplier base and the need to produce more classified components is driving a need for additional in-house production capability while continuing to identify and qualify additional suppliers.	The program will support non-nuclear component material development and replacement identified for use. The program will then engage in activities to modernize DOE/NNSA's industrial capacity for its implementation.	Early engagement with design requirements to research potential new qualified sources. Baseline capabilities at the design agencies to quickly fulfill unexpected needs.

DA-PA = design agency-production agency
MESA = Microsystems Engineering, Science and Applications

3.5.2 Weapon Component and Material Process Development

The Weapon Component and Material Process Development capability is focused on research, development, engineering, and integrating technologies into production operations to improve cycle time, cost, safety, security, reliability, and performance. This capability entails improving required manufacturing, scientific, and engineering capabilities in the production environment, while also meeting DOE/NNSA production requirements.

Weapon Component and Material Process Development capabilities must include the ability to rapidly develop and mature manufacturing processes and technologies. Advanced manufacturing technologies and digital-based processes are needed to reduce cost and support mission success. Historically, these processes and technologies have been matured late in the process, with limited time to produce viable component and material options to support production. The expanding scope of the weapon modernization programs is driving increased complexity and diversity of production demands, which inherently slows process and technology maturating.

Weapon Component and Material Process Development Accomplishments

In the absence of a suitable commercial solution, a custom software package for DIW was developed and deployed. LayerUp uniquely combines capabilities to generate complex toolpaths for 5-axis printing, corrects for substrate surface variations and handles high precision multi-material dispensing and flow control. LayerUp also provides a user-friendly interface and quality control capability to support rigorous nuclear security enterprise qualification needs. Compared to the previous scripting R&D solution, LayerUp reduces the toolpath computation time from 3 hours to 7 minutes. Notably, LayerUp has been selected as the baseline software for W80-4 LEP polymer DIW components and is being adopted by the W87-1 program for both polymer and thermoset DIW components.

The Weapon Component and Material Process Development capability develops innovative manufacturing processes, technologies, and materials that are necessary to address obsolescence due to sunset availability, regulatory safety, or security requirements, and to reduce schedule and cost risks.

3.5.2.1 Status

DOE/NNSA must achieve higher technology and manufacturing readiness levels and buy down risks, enabling faster insertion of new technologies into weapon systems for the modernization programs to succeed in reducing costs and increasing agility. Programs associated with the Weapon Component and Material Process Development capability continue to develop and improve multi-system component and manufacturing processes, reducing costs, and improving schedule execution for the nuclear security enterprise.

Current processes and infrastructure are inadequate to meet goals for rapid design, production, testing, and qualification of equipment and technologies to meet modernization needs. These inadequacies are hampering focus on development efforts separate from production demand, which has reduced the ability to innovate new solutions that could help assure responsiveness to future needs.

Advances in the Weapon Component and Material Process Development capability are currently constrained by aging infrastructure and associated reliability risks. Aging manufacturing equipment is leading to increased downtime and reduced product yield. At the same time, sustaining or restarting legacy processes is affected by equipment and material obsolescence. DOE/NNSA must also address facility capacity issues due to the increased production demand from multiple concurrent modernization programs. DOE/NNSA is performing AoA studies to seek ways to mitigate any potential adverse effects to existing and future programs caused by insufficient facility capacity and emerging production needs.

> ***Weapon Component and Material Process Development Accomplishments***
>
> *The capability to print high performance thermoset epoxy composites using existing DIW tools has been established. The Additive Manufacturing Thermosets team has rapidly on-boarded the technology and printed different prototype iterations for analysis and consideration for use on the W87-1. These materials and processes provide additive manufacturing technologies that are readily adaptable to design changes and potentially more manufacturable than conventional technologies.*

3.5.3 Weapon Component and System Prototyping

The Weapon Component and System Prototyping capability supports efforts to develop, test, analyze, and manufacture high-fidelity, full-scale prototype weapon components and systems to reduce the cost and cycle times required to develop modern designs and technologies prior to production. This capability includes the ability to design, manufacture, and employ mock-ups with sensors to support laboratory and flight tests that will provide component functionality evidence with DoD delivery systems in realistic environments. Identifying, developing, and sustaining process expertise and prototyping is crucial to scientific understanding, production agility, responsiveness, and efficiency in the ever-changing threat environment.

The Weapon Component and System Prototyping capability supports DOE/NNSA to replace sunset technologies and obsolete materials and use technological advances from industry and academia. This approach provides weapon designers the opportunities to take prudent risks before use in stockpile warheads, facilitates rapid/accelerated learning cycles, and integrates multidisciplinary, multi-site teams to support laboratory and flight tests to provide evidence that components will function in relevant environments.

Weapon Component and System Prototyping facilitates an effective nuclear deterrent through proactive design and innovative weapon technologies development. Such activities may include:

- Developing technology insertion options to prepare the nuclear stockpile for changing global security environments, such as advanced hardware design for nuclear explosive packages, energetics, microelectronics/microprocessors, mechanisms, GTSs, initiation systems, and neutron generators.

- Partnering with DoD's Science and Technology community to mature and demonstrate integrated system architectures to accelerate innovation and reduce risks in the nuclear weapons development life cycle.

3.5.3.1 Status

Aging facilities and legacy processes are not easily, or economically, modifiable to new technologies. DOE/NNSA requires capabilities to provide rapid development cycles through modular systems, rapid prototyping, integrated simulation, and realistic combined environments testing to develop components and systems. The ability to realize designs quickly and receive rapid feedback will promote innovation as risks and barriers to participation are lowered.

Advancements in science and technology improve warhead performance and manufacturing. Recently, innovatively applying additive manufacturing and model-based systems engineering have created new approaches for weapon technology prototyping. These new technologies will provide options to solve warhead issues that can be implemented more quickly, cost less, and/or provide greater performance than is possible with existing technologies and processes.

3.5.4 Advanced Manufacturing

The Advanced Manufacturing capability advances novel manufacturing processes to enable a responsive and resilient nuclear security enterprise. These innovations simultaneously open component design space while reducing component R&D costs. In addition, benefits from advanced manufacturing capabilities include a reduced manufacturing footprint, waste, and facility operating costs and increased production throughput and improved manufacturing safety basis.

This capability underpins innovation in future nuclear weapons systems and allows the enterprise to quickly respond to emerging issues in the current stockpile and respond to future weapons requirements resulting from an evolving geopolitical landscape. Many advanced manufacturing capabilities are available for the future production capabilities, including additive manufacturing for metals and polymers, injection molding, standing up internal materials production capabilities and new materials with better properties, and manufacturing simulation capabilities.

3.5.4.1 Status

All new advanced manufacturing technologies require stringent R&D to ensure the components produced by these new methods can meet or exceed the requirements of legacy components. This requirement allows the enterprise to field new concepts for the entire life cycle of a weapons system without needing underground nuclear explosive testing. DOE/NNSA created a long-term Advanced Manufacturing Strategic Program Plan linked to the Nuclear Weapons Council strategic guidance, and the Technology Development Strategic Plan to implement this requirement.

The plan covers objectives including continuous improvement on processes, securing materials and component supply chains, adopting modern, risk-based manufacturing qualification methods, developing efficient and cost-effective manufacturing technologies, reducing time to deploy advanced manufacturing technologies, and discovering the "art of the possible." Efforts across these themes will directly affect the agility and responsiveness of DOE/NNSA's manufacturing infrastructure and will continue to develop the required manufacturing capabilities prior to a future weapon program's development engineering phase, producing confidence in the schedules and cost estimates for those programs.

Emerging advanced technology solutions will enable a flexible, digital-based enterprise that will use a common set of trusted models and simulations throughout the entire product life cycle. Benefits include reduced and errors; ability to simulate and predict outcomes for critical manufacturing processes, thereby reducing the iterations needed for manufacturing development, rapidly incorporating requirements modifications, and enhanced producibility, agility, and responsiveness.

The DOE/NNSA sites are working collectively to rapidly advance additive manufacturing, an emerging technology, for nuclear deterrence applications. DOE/NNSA established a multi-site Additive Manufacturing Coordinating Team to coordinate activities across the enterprise. There are many benefits the enterprise is realizing from additive manufacturing including customized tooling and fixturing, weapon component weight reduction, and rapid prototyping.

Technology maturation for advanced manufacturing must be aligned with current and future warhead modernization schedules to become responsive to future challenges and execute the current program of record.

3.5.5 Challenges and Strategies

Table 3–12 provides a high-level summary of the Weapon Component Production area challenges and the strategies to address them.

Table 3–12. Summary of the Weapon Component Production area challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
Cross-program Integration: Extensive interactions are necessary across program elements, to ensure the full suite of advanced manufacturing capabilities are matured in time for future programs of record. These maturation activities are multi-disciplinary and often very broad in scope because engineering and material science functions are required throughout the life cycle of a weapon system.	Program managers meet regularly to identify opportunities and effect coordination. Additionally, regular meetings with Management and Operating managers help to inform and discuss emerging issues and maturation progress.	Earlier and more frequent communication across federal program managers and Management and Operating managers to ensure early collaboration and consensus on necessary activities.
Identification of Risks: Lack of high-fidelity risk assessment contributes to missing insertion opportunities for advanced technology and engineering into the stockpile or adding new or enhanced manufacturing capabilities for production. Risks identified later in a technology or manufacturing process maturation leads to additional unforeseen R&D scope that needs additional resources and time to buy down. The resultant schedule slip increases the likelihood the technology will not be ready in time for insertion to the stockpile.	Maturation of advanced manufacturing capabilities is strengthened by using product business cases and partnerships across programs to understand the risk extent for inserting the new capability into the stockpile.	Ensure early stakeholder engagement in the technology development cycle to best understand the full range of risks to inserting a new technology. Capturing these risks in a business case and using the R&D phase of a technology to buy down these risks and discover additional risks with more than enough time to explore solutions before stockpile insertion.

R&D = research and development

3.6 Weapon Assembly, Storage, Testing, and Disposition Area

After weapon components are produced, each requires assembly into complete warheads and temporary storage before delivery to DoD. Some of these warheads are removed from the stockpile on a yearly basis for surveillance to provide data to evaluate the stockpile's health. These surveillance activities (such as inspections, laboratory and flight tests, nondestructive tests, and component and material evaluations) provide data over time to predict, detect, assess, and resolve aging trends and any observed anomalies. This process requires disassembly and sometimes reassembly. Nuclear weapons undergo disposition at their end of life, or due to other reasons. This area covers all these capabilities.

3.6.1 Weapon Assembly, Storage, and Disposition

The Weapon Assembly, Storage, and Disposition capability involves assembly, disassembly, and inspection of nuclear weapons systems, including lower-level subassembly of components and final assembly of the nuclear and non-nuclear components. All these activities require special conduct operations, equipment, facilities, and quality control, and special safety and security processes and protocols.

3.6.1.1 Status

DOE/NNSA maintains extensive infrastructure to assemble, disassemble, store, and dispose of weapons at a central site, and R&D capabilities throughout the enterprise. Storage, disassembly, and assembly of components occurs at the production facilities, depending on the mission. Much of this specialized infrastructure is aging, with some facilities exceeding 50 years of age. Capital investments are essential to the overall strategy for modernization of this capability.

Programmatic equipment that supports this capability is also degrading due to age and condition, and some pieces are becoming obsolete due to unavailable parts and emerging new technology. Sophisticated measurement devices, vacuum chambers, gloveboxes, ovens of many types, lathes of varying sizes, environmental chambers and rooms, and various types of nondestructive testing such as radiography, laser gas sampling, and computed tomography that all contribute to the viability of this capability and depend on this specialized equipment remaining robust. Some new equipment has been installed, but many additional equipment replacements are needed to meet mission requirements. As part of the overall strategy, DOE/NNSA is investing in upgrading obsolete items of equipment and the facilities in which the equipment is used.

3.6.2 Weapon Component and System Surveillance and Assessment

This capability evaluates weapons and components across weapons-relevant environments to demonstrate that stockpile systems continue to meet design and performance requirements. Such evaluations occur through inspections, laboratory and flight tests, destructive and nondestructive tests, and component and material appraisals. Comparing surveillance results over time provides the ability to detect, assess, and resolve aging trends and abnormal changes in the stockpile, potentially predict phenomena before the stockpile is affected, and address or mitigate issues or concerns.

3.6.2.1 Status

The Weapon Component and System Surveillance and Assessment capability is essential to surveillance and assessment activities and depends on a broad array of specialized equipment. DOE/NNSA possesses a flexible and dynamic evaluation plan that responds to emerging issues and new information, thus enabling adjustments as conditions change and key priorities remain met. This planning includes identifying issues with the aforementioned equipment and mitigating them accordingly.

3.6.3 Testing Equipment Design and Fabrication

The Testing Equipment Design and Fabrication capability includes special test equipment design, fabrication, and deployment to simulate environmental and functional conditions and collect performance and diagnostic data to evaluate against requirements. Data from test equipment provide evidence for process qualification, weapon certification, reliability, surety, product acceptance, and stockpile evaluation and are used to evaluate performance at all assembly levels.

3.6.3.1 Status

Due to the age of current testers and associated equipment, it is becoming increasingly difficult to obtain replacement parts, acquire software upgrades, and maintain test equipment for production and surveillance. As a result, operational quantities of some test equipment are diminishing. Furthermore, data quantity and complexity requiring collection and processing has challenged the sites' ability to handle, analyze, store, and transfer data. Efforts continue to enhance the common tester architecture, improve trusted, robust test solutions, and develop the next-generation foundation bus that will improve connectivity, interchangeability, and multi-use compatibility with components and systems in the future. A surveillance tester sustainment effort has been initiated and surveillance testers (and potential risk) are regularly assessed through stockpile evaluation program planning.

3.6.4 Challenges and Strategies

Table 3–13 provides a high-level summary of Weapon Assembly, Storage, Testing, and Disposition area challenges and the strategies to address them.

Table 3–13. Summary of Weapon Assembly, Storage, Testing, and Disposition area challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
It is difficult to obtain replacement equipment and infrastructure provisions (facilities, infrastructure, and utilities) to adequately perform weapon assembly storage and disposition.	Identify aging facilities and infrastructure in advance and corresponding plans and campaigns for upgrades and replacements.	Current strategy is sufficient.
It is difficult to obtain replacement equipment, testers, software, and related infrastructure provisions necessary to adequately perform testing and component and system surveillance.	Identify aging equipment and sunset technologies in advance and mitigation strategies to compensate for gaps and diminishing quantities of hardware.	Current strategy is sufficient.
Numerous capabilities and resources have strained or insufficient capacity to meet sustainment and modernization demands.	Cross-complex working groups prioritize activities to minimize impacts.	Current strategy is sufficient.
Aging testers supporting surveillance are becoming unreliable and unsupportable due to sunset technologies.	Sites partner with Headquarters to migrate surveillance test capability from old and unsupportable testers to modern, common platform testers to support components that are common across multiple programs. This migration not only makes the common platform tester sustainable for the future and reduces. Required floorspace for surveillance testing.	Tester refresh/migration to a common platform for components that will be surveilled as those components approach last production unit.

3.7 Transportation and Security Area

The Transportation and Security area involves DOE/NNSA's capabilities for protecting the people, places, information, and other aspects critical to the nuclear security enterprise's function. The Secure Transportation capability provides safe, secure transport of the Nation's nuclear weapons, weapon components, and SNM throughout the nuclear security enterprise to support DOE/NNSA operations. The Safeguards and Security capability protects all nuclear materials, infrastructure assets, information, and the workforce at DOE/NNSA sites involved in Weapons Activities programs and operations. The IT and Cybersecurity capability supports secure electronic connectivity across the enterprise and guards against threats to data integrity.

3.7.1 Secure Transportation

Nuclear weapon warhead modernization, LLC exchanges, surveillance, dismantlement, nonproliferation activities, and experimental programs rely on transporting weapons, weapon components, and SNM on schedule and in a safe and secure manner. The Secure Transportation capability supports DOE/NNSA's goals, including to consolidating nuclear material storage and reducing the dangers and environmental risks posed by domestically transporting nuclear cargo. This capability includes design and fabrication or vehicle modification, leading edge communication systems, and Federal Agents training.

Weapons Activities missions receive the highest priority, but the Secure Transportation capability also provides secure transport for other DOE/NNSA programs and offices, such as the DOE/NNSA Nuclear Counterterrorism and Incident Response Program, the DOE/NNSA Office of Naval Reactors, and DOE Office of Nuclear Energy, as well as DoD and other U.S. Government agencies. The capability also supports nuclear materials recovery from partner nations.

The Secure Transportation Asset (STA) Program, which provides this capability, has a record of 100 percent safe and secure shipments without compromise, loss of components, or release of radioactive material. STA is U.S. Government owned and operated due to the control and coordination required and the potential security consequences of material loss or compromise.

3.7.1.1 Status

STA must maintain assets to sustain convoy safety and security to support missions based on changing customer needs and current and future threats. These assets include vehicles (trailers, armored tractors, escort vehicles, and support vehicles), aircraft, and a highly trained Federal Agent workforce.

The process of identifying, designing, procuring, and manufacturing vehicles takes several years. The Safeguards Transporter (SGT) fleet vehicles reached the end of the projected design life cycle in 2018. STA is sustaining this capability by implementing risk-reduction initiatives to extend the life of the SGT until the replacement, known as the Mobile Guardian Transporter (MGT), is fully integrated into mission operations. The MGT will assure weapon-related cargo and containers' safety and security, protect the public, and meet nuclear explosive safety standards.

A business case analysis to review options for replacing STA aircraft fleet was performed in FY 2018. The analysis supported a McDonnell Douglas DC-9 replacement and a long-range replacement plan for the current fleet of two Boeing 737 aircraft. STA procured a 737 (replacement for the DC-9) in FY 2021 and is planning for the first 737 life cycle replacement in 2027 and the second in 2032.

As with other capabilities, STA is committed to a robust human resources strategy that recruits and retains people with the requisite skills to meet priorities and mission requirements. This strategy considers the many years it takes to achieve growth in the Federal Agent workforce due to the stringent hiring process, security clearances, and attrition. During the Coronavirus Disease 2019 (COVID-19) pandemic, STA's mission has not ceased—STA's ability to effectively meet customer requirements proved STA to be highly dynamic and adaptable to the ever-changing environment.

3.7.1.2 Challenges and Strategies

Table 3–14 provides a high-level summary of Secure Transportation Asset challenges and the strategies to address them.

Table 3–14. Summary of Secure Transportation Asset challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
The SGT fleet is beyond its design life and sustaining it involves challenges such as unavailable or obsolete parts, difficulty finding new manufacturers, the high cost of limited-run production, and meeting Nuclear Explosive Safety Study requirements.	Support SGT risk-reduction program and continue design and production activities toward development of the MGT. Work with partners to identify mitigation strategies, address Nuclear Safety Study requirements, and sustain the required readiness posture of the STA fleet.	Continue to evaluate, update, and replace STA assets as required to meet mission. Incorporate MGT into mission operations as fleet becomes available (beginning in FY 2027).

MGT = Mobile Guardian Transporter
SGT = Safeguards Transporter
STA = Secure Transportation Asset

3.7.2 Safeguards and Security

The Safeguards and Security (S&S) capability protects NNSA personnel, facilities, nuclear weapons, and SNM from a full spectrum of specified threats at its national laboratories, production plants, processing facilities, and security sites. This capability protects the enterprise from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile or noncompliant acts that adversely affect national security. The S&S program achieves this capability by ensuring integration amongst several components including protective forces, physical security systems, information security, personnel security, material control and accountability, and security program operations and planning.

3.7.2.1 Status

DOE/NNSA must maintain the safety and security of the nuclear security enterprise and its workforce despite changing mission needs and ever-evolving threats. The following outlines the status of each S&S component and how it supports the entire NNSA mission.

DOE/NNSA is projecting an unprecedented increase in protective force personnel through FY 2027 in support of known mission growth across the nuclear security enterprise, including the pit production mission. DOE/NNSA's standardization initiative for life cycle replacement of its aged rifles will achieve 100 percent completion during FY 2022.

DOE/NNSA continues to employ proprietary state-of-the-art physical security systems to protect key sites. A modernized security system is currently under development, with testing projected to occur in FY 2022 and 2023. Planned counter unmanned aircraft systems projects are at various stages of installation, and testing efforts continue at several sites. For specific system and site information refer to the classified Annex.

DOE/NNSA eliminated the personnel security clearance inventory backlog and continues to upgrade the web-based Clearance Action Tracking System, develop policy, and update training that supports federally mandated Trusted Workforce requirements.

DOE/NNSA, in partnership with the National Training Center, initiated the contractor *Material Control and Accountability Technical Qualification Program Pilot*. More than 135 individuals have received training during eight separate sessions. The Material Control and Accountability Technical Qualification Program is critical to addressing significant attrition and turnover of material control and accountability personnel across the enterprise, and the program will continue into FY 2023.

DOE/NNSA supports mission growth by prioritizing programs and projects based on prudent risk management and acceptance. DOE/NNSA continues to implement the Design Basis Threat (DBT) policy, specifically, the DBT's Change 1 requires a security posture assessment against new threats, followed by the appropriate adjustments. DOE/NNSA continues to refine and implement a comprehensive risk management framework to inform nuclear security decisions.

Growth within Weapons Activities programs requires increases to the S&S capabilities including additional personnel in the various security disciplines along with corresponding investments to maintain and modernize security infrastructure and technologies.

3.7.2.2 Challenges and Strategies

Table 3–15 provides a high-level summary of Safeguards and Security challenges and the strategies to address them.

Table 3–15. Summary of Safeguards and Security challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Rapidly evolving threats	• Complete CUAS deployment at remaining planned sites • Engage other government agencies on the UAS threat and furthering CUAS technologies • Analyze UAS threat as part of the DBT[a] process	• Continue to collaborate with other government agencies to address the ever-evolving UAS threat • Analyze and incorporate of future CUAS technologies
Modernize security systems and leverage new technology	• Develop a modernized security system for future deployment • Collaborate through CSTART[b] to identify advancements in technologies, to include artificial intelligence, and integrate into future system designs and installations	Assess and deploy future technologies through formal efforts (e.g., testing and evaluation, etc.) with multiple collaborators
Aging security infrastructure	Prioritizing security infrastructure recapitalization efforts through the Security Infrastructure Revitalization Program and West End Protected Area Reduction project at Y-12.	Use the *Physical Security Technology Management Plan* to update the current plan
DVE threat	Partner and liaise with FBI Joint Terrorist Task Forces and the Department of Homeland Security to provide information regarding DVE activity in the vicinity of NNSA equities	Develop dedicated DVE analysis function with advanced tools for threat and social media analysis capability
Enhance cybersecurity protection solutions for security systems	In partnership with DOE/NNSA OCIO, develop and deploy security systems and technologies to defend against cyber threats and resilient to intrusions	Ensure all systems are modernized to mitigate cyber vulnerabilities
eConversion of Personnel Security Files to electronic media	Contract awarded to vendor to complete scanning and validation of files, monitoring and tracking tasks, productivity, and trends	Realign eConversion of Personnel Security Files project focus on Human Reliability Program actions

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Implementation of Trusted Workforce	Develop policy and implementation plans for investigation and adjudication	Adjust to real-time vetting and adjudication model

CUAS = counter unmanned aircraft systems
DVE = Domestic Violent Extremist
OCIO = Office of the Chief Information Officer
UAS = unmanned aircraft systems

[a] DBT-DOE Order 470.3C, *Design Basis Threat (DBT)*.
[b] CSTART-Center for Security Technology, Analysis, Response and Testing - Established under Section 3116 of the FY 2014 *National Defense Authorization Act*.

3.7.3 Information Technology and Cybersecurity

The DOE/NNSA Office of the Associate Administrator for Information Management and Chief Information Officer (NNSA OCIO) is responsible for Federal information management, IT, and cybersecurity for NNSA. The NNSA OCIO has implemented an organizational structure that supports its functions under three organizations: the Office of Information Technology, the Office of Cybersecurity, and the Office of Mission Integration to effectively achieve its mission.

The IT and Cybersecurity program provides information management, IT, and cybersecurity support to the nuclear security enterprise through investments in cybersecurity capabilities, cloud-based technologies, and IT infrastructure. The NNSA OCIO enhances the nuclear security enterprise's information management through using a combination of technology, policy, and risk management practices. NNSA OCIO leverages new and existing technologies to assist and protect DOE and NNSA nuclear missions in an increasingly complex cyber environment. It also collaborates and coordinates with the DOE's Office of the Chief Information Officer on IT and cybersecurity solutions development and deployment to protect DOE information and information assets.

The major elements of the IT and Cybersecurity program, supported by Mission Integration, are illustrated in **Figure 3–5**.

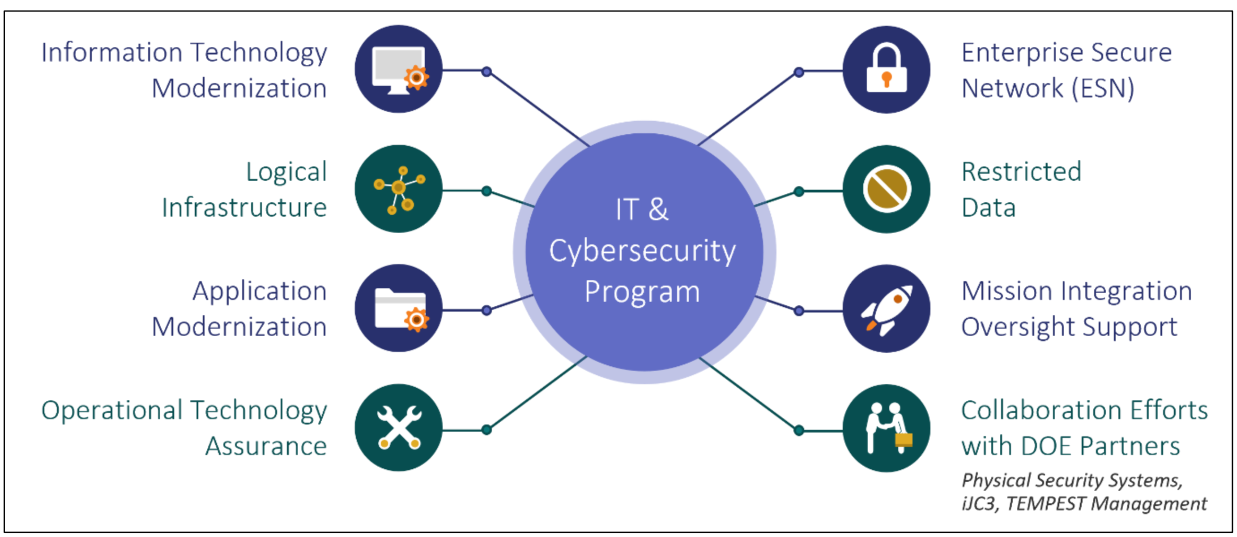


Figure 3–5. Information Technology and Cybersecurity major elements and initiatives

3.7.3.1 Status

3.7.3.1.1 Significant Changes Since the Last Stockpile Stewardship and Management Plan

The NNSA OCIO continues to make enhancements to the Enterprise Secure Network infrastructure, and additional IT modernization, with an emphasis on addressing risks related to software assurance, operational technology (OT) assurance, and supply chain management. Due to the COVID-19 pandemic, the IT and Cybersecurity program has expanded its support boundary to be able to continue accommodating working from home and for extensive videoconferencing, including classified videoconferencing for a large portion of the workforce.

3.7.3.1.2 The Current and Future Anticipated Mission Requirements

The need for agility is critical, as the required responses to the cyber environment necessitate constant monitoring and response and demand increasingly advanced technology to protect information.

3.7.3.1.3 Current State of the Infrastructure

The NNSA OCIO is currently modernizing the infrastructure to provide the best possible protection of information at the best level of service.

3.7.3.1.4 Current State of the Workforce

The NNSA OCIO acknowledges the challenges of recruiting and retaining top talent due to competition for IT and cybersecurity resources, especially in a pandemic situation. It will continue its efforts to meet current and future workforce needs by analyzing job requirements to meet the mission's evolving needs. By doing so, the NNSA OCIO will continue to be a competitive employer that can recruit, develop, and retain top talent in the IT and cybersecurity workforce.

3.7.3.2 Challenges and Strategies

The highly complex and global nature of NNSA and its nuclear security enterprise, coupled with limited resources, makes it critically important that information and information assets are secured, managed, and protected using a risk-management approach. As the cybersecurity threat landscape constantly evolves, it is critical for NNSA OCIO to keep up and adapt to the ever-changing IT, OT, and cybersecurity landscape and to respond rapidly to the evolving and most sophisticated threats. **Table 3–16** provides a high-level summary of Information Technology and Cybersecurity challenges and the strategies developed to address them.

Table 3–16. Summary of Information Technology and Cybersecurity challenges and strategies

	Strategies	
Challenges	*Current Strategy Being Implemented*	*Future Strategies Needed*
Ensure purchased equipment is from the manufacturer, as designed, without modification.	Move toward centralized purchasing and equipment review before issuing equipment to the field will address current supply chain and software assurance issues.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.
Insider Threat	Work with counterintelligence on implementing an insider threat program, concentrating first on the classified arena.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.

Challenges	Strategies	
	Current Strategy Being Implemented	***Future Strategies Needed***
Network Aging Infrastructure/IT Support	• Improve network infrastructure by updating and enhancing networking equipment through public/private cloud services, managed services, software, and hardware enhancements. • Mature capabilities of aging infrastructures enterprise-wide to identify and alert concerning emerging threats. • Ensure faster capabilities development and implementation to counter such threats.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.
Identify, inventory, and ensure proper cybersecurity hygiene is applied to OT such as Industrial Control Systems and wireless technologies across all spectrum bands.	• Collaborate early with program managers, operations, and engineering teams to plan for IT and cybersecurity requirements during the planning stage. • For legacy OT and Industrial Control systems, perform analysis to identify and inventory systems, devices, and all assets. • Ensure applicable cybersecurity hygiene is applied to OT and industrial control systems.	The current strategy is evolving and these processes' maturity will need to adapt to the constantly changing threat/risk environments.
Current network monitoring services restrictions	• Upgrade sites across the enterprise through deploying new cybersecurity solutions. • Ensure all networks, IT, and OT systems are monitored by the new demilitarized zone.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.
Not all buildings support network speeds are fast enough for today's scientific computing, and with technology's reliance on computers, capacities are being exceeded across the NNSA complex.	Continued investment is needed in network communications systems and in the central networking and telecommunications facilities.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.
Program effects from 2022 *Nuclear Posture Review* Implementation	• Resource requirements for IT and cybersecurity that are required to support the nuclear security enterprise mission will vary directly with any increases in weapons program workloads. • Adding work locations, increasing workforce numbers, and adding shifts will result in additional demand for IT and cybersecurity resources to ensure a secure, protected, and innovative work environment.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.
Fill critical cybersecurity and IT vacancies across the enterprise.	Hire a workforce that has the skillsets needed per NNSA's OCIO 2020–2023 Strategic Plan Principle 6: Invest in employee development to cultivate a high-performing workforce that will support NNSA's mission today and into the future.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.

Challenges	Strategies	
	Current Strategy Being Implemented	***Future Strategies Needed***
Fulfill OMB guidance to consider and use cloud solutions in a secure manner.	Modernize current services by capitalizing on cloud technology to increase performance and strengthen security.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.
Fully adopt cybersecurity improvements identified in Executive Order 14018 (Improving the Nations Cybersecurity Infrastructure).	• Conduct baseline inventory and state of existing threats, risks, and mitigations associated with current enterprise IT systems. • Work with IT and program offices to implement a strategy to migrate to zero trust across environments.	The current strategy is evolving and these processes' maturity will need to adapt to the constantly changing threat/risk environments.
Accommodate current and future teleworking needs across the NNSA complex.	Developed and implemented services and solutions to provide operational connectivity during COVID-19.	Continue planning efforts to ensure services and solutions are available to enable operational connectivity beyond COVID-19.
Artificial Intelligence/Machine Learning	• Develop an artificial intelligence/machine learning strategy. • Improve supply chain security processes using business intelligence. • Unlock the power of data to make risk-based decisions. • Set policy for artificial intelligence and machine learning for the enterprise. • Seek technical applications to meet business/mission requirements.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies are needed.

IT = information technology
OCIO = Office of the Chief Information Officer
OMB = Office of Management and Budget
OT = operational technologies

Chapter 4
Infrastructure and Operations

Infrastructure modernization is essential to the Department of Energy's National Nuclear Security Administration's (DOE/NNSA) mission to ensure a safe, secure, and effective stockpile, reduce mission risk, and improve employee, public, and environmental safety. Demand on the existing infrastructure is increasing due to multiple concurrent stockpile modernization programs and the need to advance science, technology, and engineering activities at DOE/NNSA's labs, plants, and sites. These factors present many complex challenges, particularly given DOE/NNSA's aging infrastructure. Despite these challenges, and with congressional support, DOE/NNSA has increased the resources allocated to and made significant progress in modernizing its infrastructure, eliminating excess facilities, and improving management practices.

This chapter provides a broad view of infrastructure and operations across the nuclear security enterprise and shows how DOE/NNSA conducts infrastructure planning and management to capture infrastructure activitivies that support multiple capabilities, such as mission enabling construction, minor construction, and sustainment activities. This chapter also addresses how infrastructure supports the Weapons Activities capability areas discussed in Chapter 3. Infrastructure is an essential element of each capability, as shown in Figure 3–2, and as mentioned in the capability sections of each key capital project in Chapter 3.

Infrastructure and Operations Major Accomplishments

- *Completed construction of the New Albuquerque Complex providing 333,000 square feet of modern office space for 1,200 employees.*
- *Completed construction of the Lawrence Livermore National Laboratory (LLNL) B225 Manufacturing Science Building providing a new polymer manufacturing capability supporting the W80-4 Life Extension Program (LEP) and W87-1 Modification Program.*
- *Executed NNSA's first-ever "option to purchase" acquisition providing a timely and cost-effective solution with high-bay, lab, and office space to support the Y-12 National Security Complex (Y-12) Development mission.*
- *Completed construction of a modern, state of the art new Data Center (Building C902) providing a high-capacity and resilient facility supporting growing operations across Sandia National Laboratories (SNL)-California.*
- *Completed construction of the LLNL Emergency Operations Center.*
- *Completed construction of the TA-5 Substation providing increased electrical capacity to Los Alamos National Laboratory (LANL).*
- *Completed construction of the Exascale Computing Facility Modernization project at LLNL to accommodate the increased infrastructure demands of exascale computing platforms.*

Figure 4–1 illustrates the size and scope of DOE/NNSA's nuclear security enterprise infrastructure that drives the challenges and strategies discussed in this chapter. Comprehensive enterprise asset management requires continuous, multi-level planning across the full spectrum of asset types, resulting in balanced enterprise investment decision-making across the entire asset management life cycle, as shown in **Figure 4–2**. Planning initiates an asset's life cycle, followed by acquisition through new construction, lease, or purchase. The majority of an asset's life is spent in continuous sustainment through maintenance, repairs, and replacements-in-kind, with periodic recapitalizations to upgrade and extend the asset's service life prior to disposition. This chapter describes these life cycle asset management activities.

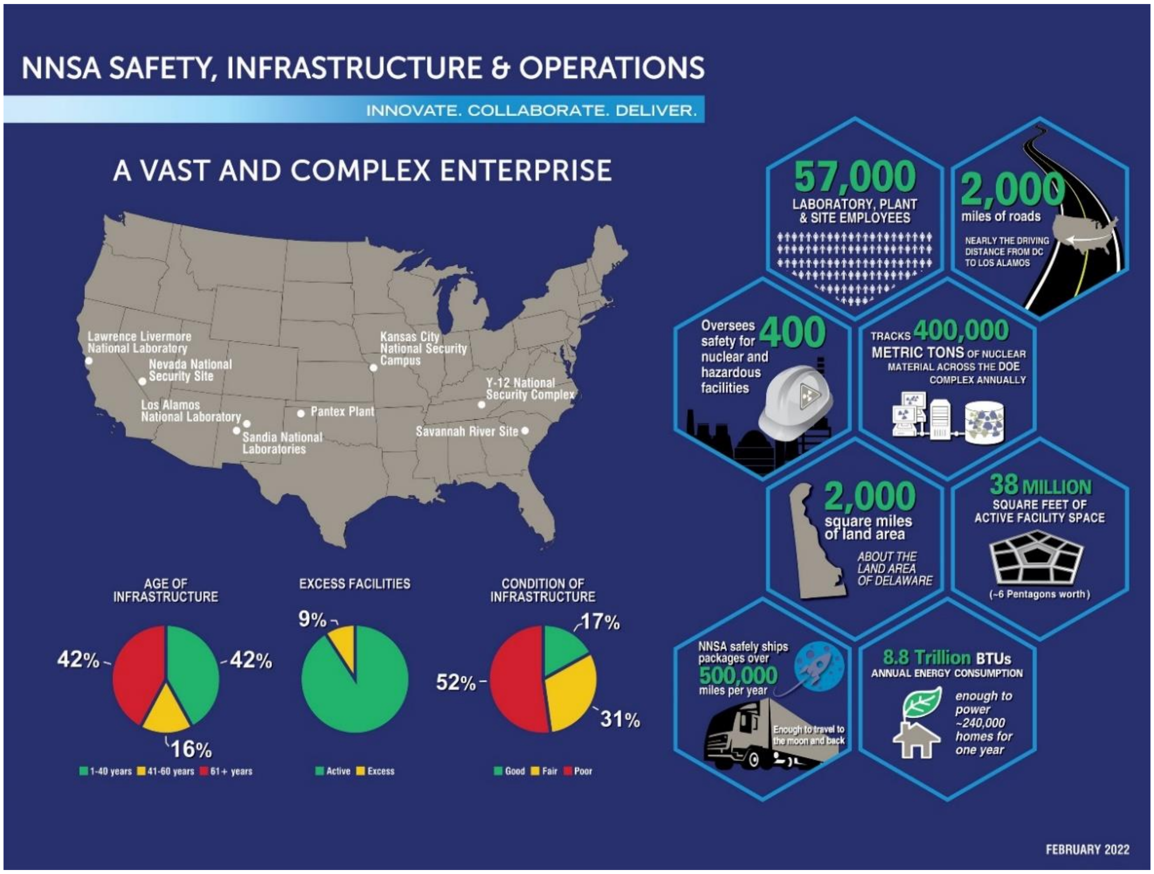


Figure 4–1. DOE/NNSA infrastructure size and scope

Figure 4–2. Asset management life cycle

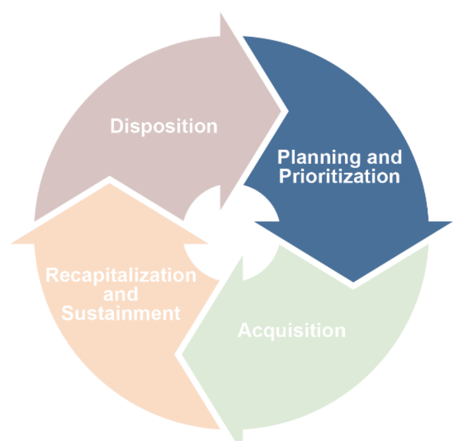
The asset management life cycle model shown in Figure 4–2 illustrates the different types of investments across various funding sources and sponsoring programs. Sections 4.1 through 4.4 describe the activities within the asset management model. Infrastructure planning and asset management, described in Section 4.1, estimates future repair and modernization investments in facilities as they age, forecasting facility replacement schedules, planning for new and replacement acquisitions, and anticipating the disposition needs and excess facilities' costs for completion in a timely manner.

Sections 4.2 and 4.3 describe acquisition strategies as well as modernization and sustainment activities for existing facilities that support capabilities needed to sustain the stockpile. Section 4.2 discusses the plans for programmatic construction by area and the actions being taken to sustain, recreate, and improve the capabilities detailed in Chapter 3. Section 4.4 addresses disposition of excess facilities. Sections 4.2 through 4.4 also discuss a wide range of programs, processes, and funding types, which reflect the complexity of aligning investment needs to funding sources.

Facility acquisition occurs through line-item projects, minor construction, purchase, or leasing. Operating, maintaining, and revitalizing existing facilities are funded through minor construction, recapitalization, maintenance, and other programs. The funding strategy to support any given type of project can vary greatly due to the project's size, scope, and other factors.

In addition to modernizing DOE/NNSA's physical infrastructure that directly supports the Weapons Activities programs, continuous investments are required to sustain and modernize both critical physical security and cybersecurity elements across the nuclear security enterprise.

4.1 Infrastructure Planning and Asset Management



Infrastructure planning and asset management covers the planning phase for operational and capital investment needs. Operational planning involves the maintenance, repair, and operation of facilities, utilities, and equipment at the sites, and strategic investment planning for major system upgrades and replacements. Capital investment planning involves identifying future and anticipated emerging needs in the weapons programs, as well as science and technology investments to support those missions into the foreseeable future. Operational and capital investment planning must work in tandem to achieve the desired balance and cost-effectiveness that reflects capable asset management.

DOE/NNSA has taken considerable action over the last 5 years to better understand the nuclear security enterprise's long-term strategic investment needs. Previous capital planning efforts gave insufficient consideration to the long-term infrastructure needs in sustaining/renewing existing assets, and future needs tied to emerging capabilities and anticipated future workloads. DOE/NNSA's most recent integrated strategic planning efforts have yielded a much more realistic and time-critical view of out-year infrastructure needs to support the mission and long-term sustainment of capabilities. The processes for identifying and planning for these long-term needs are now greatly improved and expanded.

Direct mission needs have been better integrated with routine infrastructure sustainment and renewal processes to create a clearer, more comprehensive plan for long-term investments. Bottom-up planning across the nuclear security enterprise has been improved through area planning, described below, and

> ***Infrastructure Deep Dives***
>
> *DOE/NNSA holds meetings with each management and operating (M&O) partner site to discuss mission requirements, related infrastructure needs, asset condition and life cycle management, and proposed investment plans.*
>
> *Deep dives lay the foundation for prioritized, integrated area plans and a Master Asset Plan for the nuclear security enterprise.*

deep dive reviews. Asset management software has provided accessible data for earlier maintenance and sustainment needs planning. Because of this expanded, more integrated planning, DOE/NNSA has a more comprehensive understanding of the state of its physical assets and the actions needed to acquire, sustain, recapitalize, and dispose of its assets. These processes are also aligned much more closely with industry standards. The asset management life cycle, shown in Figure 4–2, is the basis for all investment planning within DOE/NNSA. It can be applied to a single facility or, if applied to numerous facilities, can be used to organize the way the infrastructure program operates. The elements of the cycle must remain in balance to keep the nuclear security enterprise assets healthy. While the model appears straightforward, the processes employed to achieve balance across multiple facilities for the purpose of meeting multiple competing priorities are not. In the DOE/NNSA environment, decision-making is complicated by multiple funding mechanisms, guidance, and requirements. This section includes definitions of terms and background to aid in understanding these intricacies and the nuclear security enterprise's broad extent of investment planning and execution.

4.1.1 Area Planning

The newest element of DOE/NNSA's planning process is area planning, which connects plans to projects for achieving DOE/NNSA's Strategic Vision for the future nuclear security enterprise. The area plans provide detailed information on the life cycle management strategies of co-located or functionally similar facilities, buildings, and other structures.

Area plans are part of an integrated planning process that flows from high-level requirements to interdependent project plans. Frequent communication among stakeholders at all levels through infrastructure deep dives and other forums keeps the planning process aligned with DOE/NNSA mission needs. Area plans blend multiple funding sources and are regularly updated to reflect the latest developments and priorities.

DOE/NNSA and its M&O partners have been developing area plans, representing assets and associated capabilities across the nuclear security enterprise. These area plans showcase important elements of each capability's long-term infrastructure plans and span direct mission and mission-enabling capabilities. They cover a myriad of topical areas, from flagship experimental facilities and weapon components to utilities and emergency services. When viewed collectively, area plans provide a roadmap for modernizing DOE/NNSA infrastructure to deliver the mission.

4.1.2 Weapons Activities Line-Item Planning Integration

The Weapons Activities line-item planning integration process establishes procedures to consolidate the line-item data collection process and synchronize infrastructure planning across Weapons Activities programs. The integrated planning process is conducted in collaboration with the DOE/NNSA laboratories, plants, and sites to identify and prioritize major line-item construction projects for Weapons Activities programs. This prioritization informs near- and long-term planning efforts for programmatic and mission-enabling construction projects. It also informs the Future Years Nuclear Security Program (FYNSP) programming and budgeting process as projects reach appropriate milestones.

> ***DOE/NNSA Capital Construction Levels***
>
> *Line-item – a capital project greater than $25 million, so-called because it has its own line in DOE/NNSA's budget structure.*
>
> *Minor Construction – a construction project less than $25 million that includes projects also referred to as General Plant Projects, Institutional General Plant Projects, and Accelerator Improvement Projects.*
>
> *Institutional General Plant Project – a minor construction project that addresses an institutional, multi-program, general site need rather than a specific program need, using funding derived from indirect cost pools.*
>
> *General Plant Project – a miscellaneous minor construction project of a general nature, for which the total estimated cost may not exceed the congressionally established limit.*

Programmatic infrastructure investments are linked to mission-specific functions within Weapons Activities, such as plutonium modernization. They address investment needs for direct programmatic infrastructure including facilities, computers, diagnostic equipment, weapon-related production facilities and equipment, or anything else that enables the nuclear security enterprise to carry out research, testing, production, and sustainment activities to meet its national security missions. In contrast, mission-enabling infrastructure provides support for programmatic activities, including general purpose office buildings, site-wide support facilities, utilities, and equipment. Both types of investments are required to sustain Weapons Activities capabilities in the near-term and for the foreseeable future.

Consolidating line-item investment proposals combines multiple current data collection processes and ensures a consistent, repeatable planning process for all line-item construction projects. The program offices' comprehensive review of project proposals ensures all current and proposed line-item construction projects (detailed in Sections 4.2.1–4.2.2) represent necessary investments to support the program of record. The cost estimation process for proposals within capital acquisition is described in Chapter 5, Section 5.9.3.

4.1.3 Critical Decision Acquisition Milestone Process

A basic understanding of DOE's Critical Decision (CD) acquisition milestone process is integral to understanding current and planned line-item construction projects and major item of equipment (MIE) projects. DOE Order 413.3B, Chg 6, *Program and Project Management for the Acquisition of Capital Assets*, outlines a series of staged approvals for line-item and MIE projects greater than $50 million, each of which is referred to as a CD. Each CD stage requires specific deliverables prior to and during the process in order to progress to the next stage. **Figure 4–3** shows the four phases of the CD process (Initiation, Definition, Execution, and Closeout), with their corresponding CD stages.

Activities prior to CD-0 (*Approve Mission Need*) through approval of CD-1 (*Approve Alternative Selection and Cost Range*) constitute the Definition Phase. These activities are prerequisites to commencing the Execution Phase, which includes approval of CD-2 (*Approve Performance Baseline*), approval of CD-3 (*Approve Start of Construction*), and activities up to CD-4.[1] Approval of CD-4 (*Approve Start of Operations or Project Completion*) reflects project completion based on previously determined criteria and the approval to transition to operations. DOE/NNSA Supplemental Directive 413.3 provides further guidance on this process, including that DOE/NNSA typically combines CD-2 and CD-3. The approval of CD-4 is predicated on the readiness to operate and/or maintain the system, facility, or capability. Transition and turnover do not necessarily terminate all project activities. In some cases, it marks a point at which the operations organizations assume responsibility for operating and maintaining the new facility.

---

[1] See DOE Order 413.3B for details regarding projects requiring long-lead procurement. If long-lead procurements are executed prior to CD-3 approval for the project, this is designated as CD-3A and requires an additional stand-alone CD by the Project Management Executive.

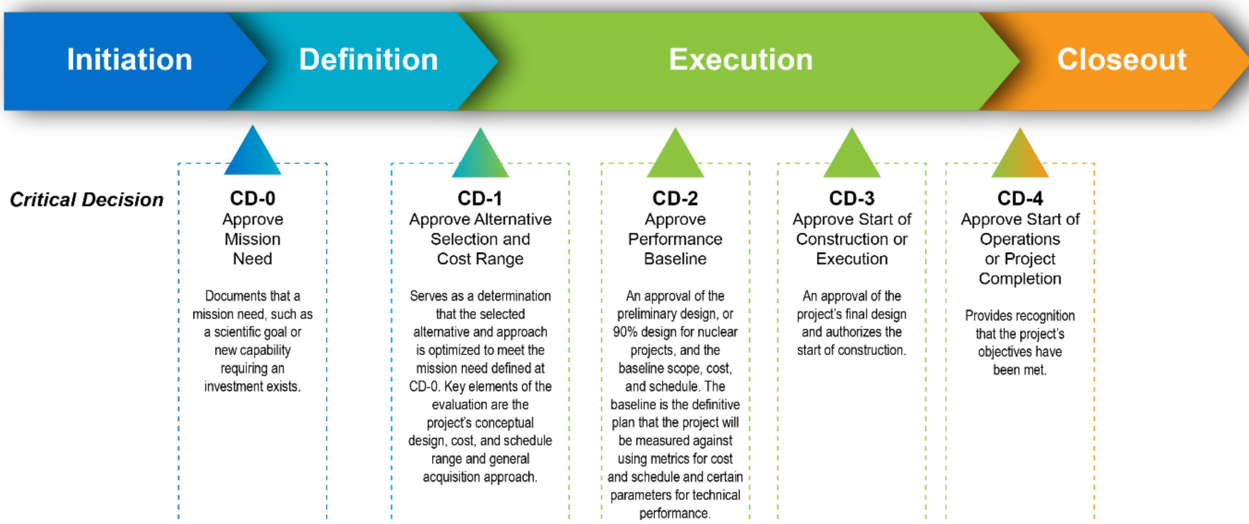
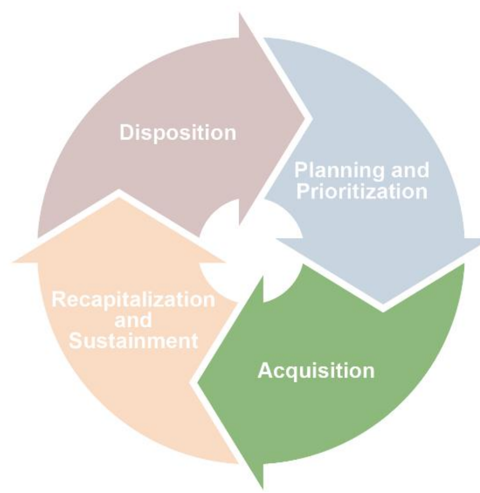


Figure 4–3. Critical Decision process

4.2 Acquisition



DOE/NNSA has more than 5,000 facilities with an average age of 47 years. Many of the largest and most complex facilities will require line-item construction projects to accomplish modernization or replacement. Since aging facilities represent increasing risk to mission execution and line-item projects require significant coordination and funding over multiple years, DOE/NNSA continues to evaluate line-item construction project proposals as a part of the overall 25-year plan for Weapons Activities.

DOE/NNSA's line-item construction portfolio requires consistent, stable, and timely funding. The size and complexities of these projects present several program and project management challenges. However, DOE/NNSA has demonstrated success despite the complexity of the DOE/NNSA acquisition processes and the challenge of meeting enterprise needs in a responsive and timely manner.

Since aging facilities represent increasing risk to mission execution, DOE/NNSA continues to review line-items across the nuclear security enterprise to better ensure infrastructure is in place to meet mission requirements, while improving DOE/NNSA's facility condition and reducing the average facility age to a sustainable level. **Figure 4–4** demonstrates the DOE/NNSA's facilities' historical average age growth and the planned reduction in average age after completing the projects described in the following sections. The average age presented here varies from similar charts in previous Stockpile Stewardship and Management Plans (SSMPs) as the average age calculation was expanded from using a few hundred representative programmatic facilities to all DOE/NNSA facilities.

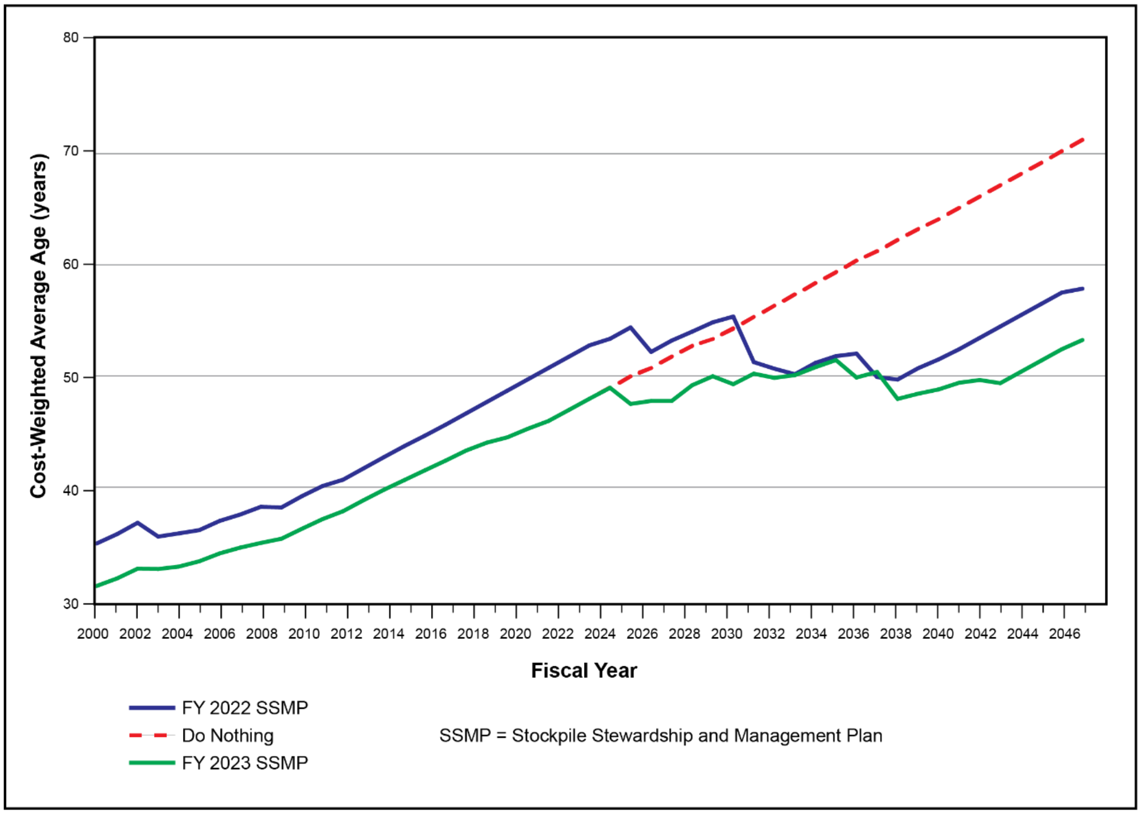


Figure 4–4. Historical and projected average age of all DOE/NNSA facilities

This section discusses the current and planned line-items for the nuclear security enterprise. Programmatic line-items are presented by Weapons Activities capability area (formerly termed portfolio), followed by mission-enabling line-items.

4.2.1 Programmatic Construction

Programmatic construction projects are categorized according to the Weapons Activities capability areas, which are detailed in Chapter 3. Sections 4.2.1.1–4.2.1.7 describe current and proposed line-item projects within each capability area, including their projected schedules and cost ranges. Project proposals (Pre-CD-0) represent potential mission gaps and emerging requirements across the nuclear security enterprise. They require additional vetting before DOE/NNSA moves forward with addressing the gap with a material solution. The projected schedules and cost ranges shown represent one potential planning scenario and may change in future SSMPs as stockpile and enterprise requirements are refined.

4.2.1.1 Weapon Science and Engineering

Line-item projects in the Weapon Science and Engineering area encompass the suite of physical sciences and engineering disciplines that comprise the theoretical and experimental capabilities needed to assess the current nuclear stockpile and design and certify future stockpile weapons. Current planning estimates and schedule dates for projects in this area are listed in **Figure 4–5**. Plans for the sustainment of the Z pulsed power facility (Z) and Omega Laser Facility (Omega) are not included in this figure because they are not proposed as line-item projects.

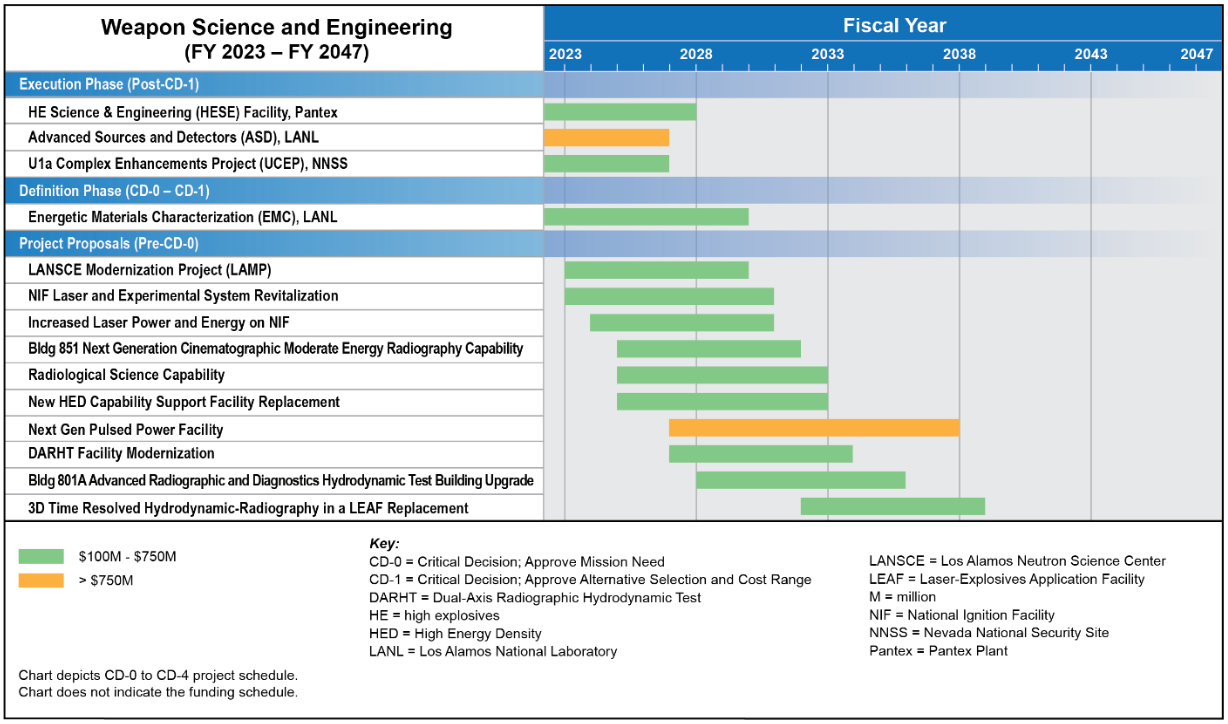


Figure 4–5. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Science and Engineering

DOE/NNSA is currently executing three programmatic line-item construction projects in the Weapon Science and Engineering area that are past CD-1. Cost and schedule estimates for these projects vary from conceptual design-based estimates to baselined project estimates:

- The **High Explosive Science and Engineering (HESE) Facility** will construct three new buildings to provide a technology development laboratory and office space for technical staff. It will replace 15 current Manhattan Project-era facilities at the Pantex Plant (Pantex), support the high explosives (HE) Center of Excellence for Manufacturing mission for DOE/NNSA, and help sustain high-quality scientific staff. The average age of the facilities to be replaced is 68 years old. The HESE facility will be approximately 73,000 square feet. Project design is complete and received CD-2/3 approval in April 2022. Site preparation and long-lead procurement activities started at the beginning of fiscal year (FY) 2021. Main works construction started in May 2022.

- The **Advanced Sources and Detectors** project is an MIE[2] that will fill the pulsed x-radiography capability gap through developing a multi-pulse linear induction electron accelerator. The scope includes design, technical maturation, fabrication, testing, installation, commissioning, and readiness execution at the U1a Complex.

- The **U1a Complex Enhancements Project (UCEP)** will provide infrastructure modifications to the U1a Complex at the Nevada National Security Site (NNSS) to house and field multi-pulse radiography. This project includes structures, systems, and components necessary for deploying

[2] MIEs are capital equipment with a cost that exceeds $5 million. In most cases, capital equipment is installed with no construction cost. However, in cases where the equipment requires supporting construction provision, the associated construction activities must be acquired through a line-item construction project, or a minor construction project if the cost is below the minor construction threshold established by Congress. MIEs follow a similar CD process as line-item capital asset projects. See DOE Order 413.3B for additional details.

Enhanced Capabilities for Subcritical Experiment Advanced Sources and Detectors Project's pulsed X-ray radiography equipment. It also includes support systems for potential future neutron-diagnosed subcritical experiments technology, which will produce valuable data on the neutron behavior of aged plutonium and other phenomena associated with the final stages of a weapon implosion.

The following programmatic line-item project in the Weapon Science and Engineering area is in the Definition Phase of the CD process (CD-0 to CD-1):

- The **Energetic Materials Characterization (EMC)** project will support research and development (R&D) to advance predictive capabilities for safety and performance assessments and qualification and surveillance, evaluate material responses to all phases of the stockpile-to-target sequence, resolve significant finding investigations (SFIs) involving energetic materials, provide technical data on which to base annual weapon assessments, and develop new/replacement materials to support evolving HE technical requirements. The project will consolidate 18 structures into a single modern facility to increase operational efficiency and reduce operating costs.

In addition to projects in the Definition and Execution Phases, DOE/NNSA is considering several programmatic line-item proposals in the Weapon Science and Engineering area (Pre-CD-0). These project proposals are a part of the planning process but should not be considered part of the program of record until they achieve appropriate approvals. Descriptions of scope should be considered illustrative, as alternative selections will not be made until each project completes an Analysis of Alternatives (AoA) and the project achieves CD-1:

- The **Los Alamos Neutron Science Center (LANSCE) Modernization Project (LAMP)** would be a one-time capital investment to replace the front end of the LANSCE accelerator. This would eliminate end-of-life and obsolete components to improve reliability, availability, maintainability, efficiency, and safety, and would allow LANSCE to support assessment and certification, which is required through at least 2050.
- The **National Ignition Facility (NIF) Laser and Experimental System Revitalization** is part of a broader effort of NIF sustainment aimed at refurbishment, recapitalization, and improvement of the NIF facility. This project would support revitalization of the laser systems as part of the 5-year plan to ensure NIF continues to deliver for the Stockpile Stewardship Program.
- The **Increased Laser Power and Energy on NIF** project would upgrade the NIF laser, which is currently operating at its highest sustained levels of energy and power to date, made possible only by continued investments in optics and laser technology. Recent ignition experiments show that small increases in laser energy could substantially increase fusion output. Four energy and power upgrade paths are being assessed within the limitations of the current facility.
- The **Building 851 Next Generation Cinematographic Moderate Energy Radiography Capability** would upgrade the Building 851 open firing site to include a 10 mega-electron volt 20-pulse linear induction acceleration and a dense plasma focus for flash neutron radiography. This project would provide capability for cinematographic x-radiography that would enable X-ray movies for important weapons physics experiments, expand options for in-demand hydro tests, and deliver high-fidelity data for validating simulations.
- The **Radiological Science Capability** project would consolidate and relocate the aging radiological facilities that support Los Alamos National Laboratory (LANL) weapons and global security mission requirements. The planned replacement facility would support critical missions including

weapons programs, nuclear forensics, and nonproliferation programs, as well as broad science capabilities (e.g., actinide separation and synthetic chemistry).

- The **New High Energy Density (HED) Capability Support Facility Replacement** project would support experimental throughput for the national user facility at NIF with a building that would house key functions such as production and fabrication for targets, diagnostics, and optics in support of HED physics experiments. The new building would provide advanced clean room and laboratory facilities for the next generations of targets and diagnostics for HED physics.
- The **Next Gen Pulsed Power facility** is a significant long-term goal of the DOE/NNSA's Inertial Confinement Fusion program to fill a capability gap in the environments currently accessible at facilities such as NIF, Z, and Saturn. The Next Gen Pulsed Power facility would have increased efficiency and effectiveness and would modernize infrastructure dedicated to HED experiments.
- The **Dual-Axis Radiographic Hydrodynamics Test (DARHT) Facility Modernization** would be a series of activities to ensure continued reliable and resilient high-quality data returns at DARHT. These upgrades would sustain delivery of foundational data for stockpile stewardship and global security.
- The **Building 801A Advanced Radiographic and Diagnostics Hydrodynamic Test Building Upgrade** project would build a second-axis with a multi-frame cinematographic capability for imaging weapon physics configurations over a range of densities. The project would use the existing Contained Firing Facility and would add non-bunker laboratory space to house an active reset linear induction accelerator or laser based multi-frame radiographic source.
- The **3D Time Resolved Hydrodynamic-Radiography in a Laser-Explosives Application Facility Replacement** project would build a new facility capable of multi-axis, multi-frame imaging of surrogate nuclear weapon-relevant dynamic experiments to meet a wide range of experimental goals, including tomographic reconstruction. The flexibility, resolution, and information content that would be afforded by this laser-driven X-ray source is not possible in existing facilities.

4.2.1.2 Weapon Simulation and Computing

Line-item projects in the Weapon Simulation and Computing area enable high performance computing (HPC) and development of the weapons codes, models, and data analytics used to design and assess nuclear weapons systems' and components' behavior. Current planning estimates and schedule dates for projects in this area are listed in **Figure 4–6**.

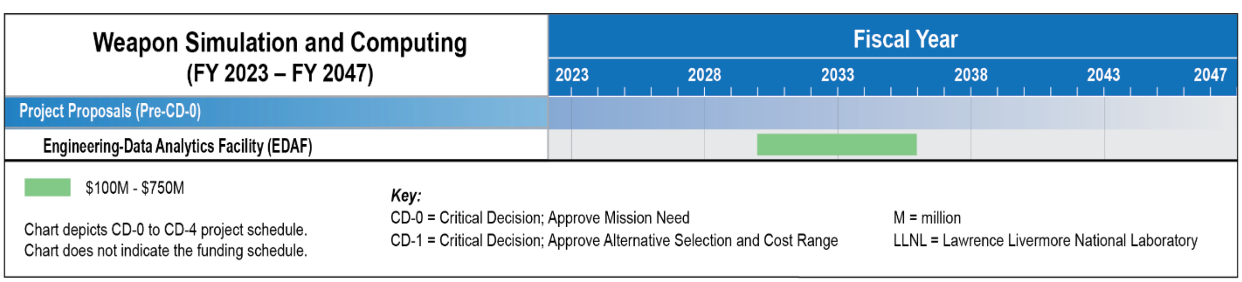


Figure 4–6. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Simulation and Computing

DOE/NNSA recently completed a project in the Weapon Simulation and Computing area:

- The **Exascale Computing Facility Modernization (ECFM)** project modified the existing HPC center at LLNL to accommodate the increased infrastructure demands of exascale computing platforms, including upgrades to the facility's electrical, cooling, and mechanical capabilities. The existing cooling tower complex was expanded for additional cooling, and the electrical system was upgraded to allow additional power for HPC. The project was completed in May 2022.

Upgraded cooling and electrical capabilities upon the completion of ECFM at LLNL

There are no projects in the Execution or Definition Phases in the Weapon Simulation and Computing area. DOE/NNSA is considering one programmatic line-item proposal in the Weapon Simulation and Computing area (Pre-CD-0). This project proposal is in the planning process but should not be considered a part of the program of record until it achieves appropriate approvals. The description of scope should be considered illustrative, as alternative selection will not be made until the project completes an AoA and the project achieves CD-1:

- The **Engineering-Data Analytics Facility (EDAF)** project would construct a new HPC facility that would enable data collection, storage, and analysis capabilities by bringing together HPC systems, high-performance data-analytics systems, a scalable data enclave, and an extreme-speed network-backbone to deploy these capabilities and enable a future of full-system engineering models.

4.2.1.3 Weapon Design and Integration

Line-item projects in the Weapon Design and Integration area support the capabilities needed to research, design, test, analyze, qualify, and integrate components and subsystems into weapon systems that will meet all military requirements and endure all predicted environments. Current planning estimates and schedule dates for projects in this area are listed in **Figure 4–7**.

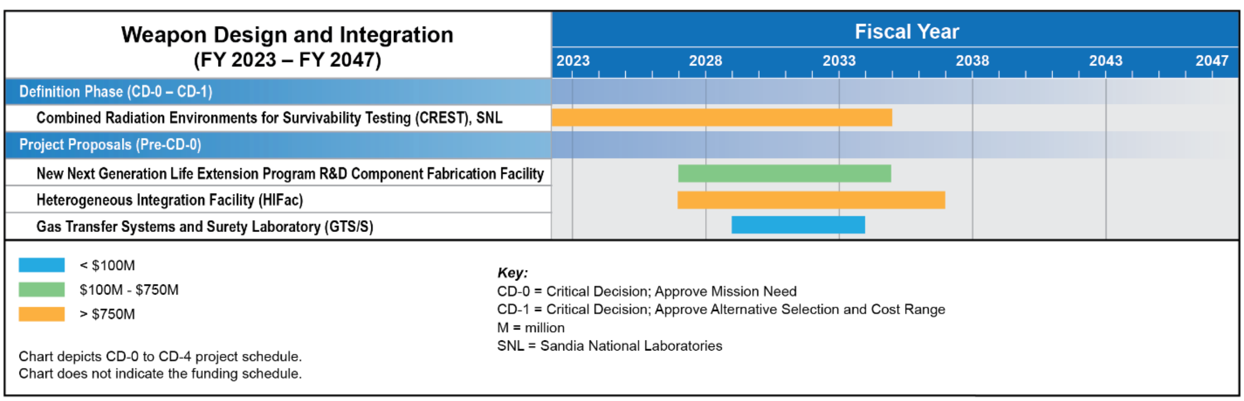


Figure 4–7. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Design and Integration

The following programmatic line-item project in the Weapon Design and Integration area is in the Definition Phase of the CD process (CD-0 to CD-1):

- The **Combined Radiation Environments for Survivability Testing (CREST)** project will provide an advanced radiation environmental test capability to fill a mission gap for R&D, qualification, and certification data in combined survivability/threat environments. The Annular Core Research Reactor's (ACRR) current capability provides high-fidelity neutron and gamma-ray environments that emulate nuclear weapon environments to support weapons development and certification. Every weapon system in the stockpile undergoes testing at the ACRR and demand is increasing. However, ACRR is nearly 60 years old, was not designed to house a nuclear reactor, and does not meet modern codes or standards. The facility's age and condition mean ACRR is unable to keep pace with demand. The proposed CREST project will provide a facility that will replace and enhance the legacy capability. This new facility will combine the current ACRR capabilities with an independent gamma-ray irradiation capability in a purpose-built facility specifically optimized to meet current and future stockpile modernization needs.

In addition to the project in the Definition Phase, DOE/NNSA is considering a number of programmatic line-item proposals in the Weapon Design and Integration area (Pre-CD-0). These project proposals are in the planning process but should not be considered part of the program of record until they achieve appropriate approvals. The descriptions of scope should be considered illustrative, as alternative selections will not be made until the projects complete an AoA and the project achieves CD-1:

- The **New Next Generation Life Extension Program R&D Component Fabrication Facility (NextGen Fabrication Facility)** would be a joint design agency-production agency (DA-PA) pre-production testbed that could assess, develop, tailor, and transition new manufacturing technologies. This would provide DOE/NNSA with a capability to accelerate the development and production of non-nuclear components into the weapon modernization process. This joint DA-PA owned collaborative space would enable faster and more frequent design iterations to mature the definition and production processes for production of non-nuclear components, resulting in accelerated time to first production unit for future modernization programs.
- The **Heterogeneous Integration Facility (HIFac)** capability would provide DOE/NNSA an enduring supply of trusted strategic radiation hardened microsystems to meet future system functional, environmental, and assurance requirements. Meeting these requirements would likely require the integration of a suite of future products, including semiconductor components, microelectromechanical systems, and photonics components. Heterogeneous Integration would improve cost efficiency and reliability through flexibility in combining custom-built and commercially available state-of-the-art technologies.
- The **Gas Transfer Systems and Surety Laboratory (GTS/S)** project would meet GTS and Surety mission requirements in the future. The GTS and Surety project would provide a modern, lower-maintenance structure capable of meeting the expanded, future demands of the program. Work areas and equipment would be upgraded with an efficient layout and state-of-the-art technology to meet current and specific testing requirement needs.

4.2.1.4 Weapon Material Processing and Manufacturing

Line-item projects in the Weapon Material Processing and Manufacturing area are related to the packaging, processing, handling, and/or manufacturing of plutonium, uranium, tritium, energetic and hazardous materials, lithium, and other metal and organic materials needed for nuclear weapons. Current planning estimates and schedule dates for projects in this area are listed in **Figure 4–8**.

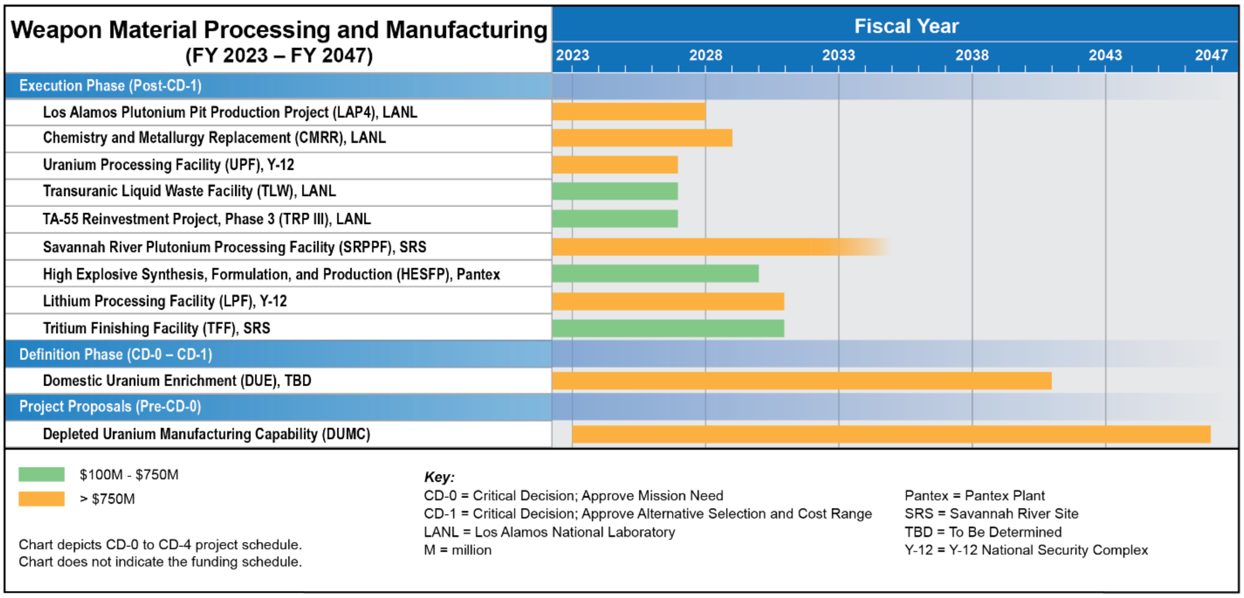


Figure 4–8. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Material Processing and Manufacturing

DOE/NNSA is currently executing multiple programmatic line-item projects in the Weapon Material Processing and Manufacturing area that are past CD-1. Cost and schedule estimates for these projects vary in maturity from conceptual design-based estimates to baselined project estimates.

- The **Los Alamos Plutonium Pit Production Project (LAP4)** will support plutonium pit production at LANL. The LAP4 project replaces aging and outdated equipment with pit manufacturing equipment in the Plutonium Facility (PF-4) at LANL to increase throughput to no less than 30 pits per year (ppy). LAP4 achieved CD-2/3 for the Decontamination and Decommissioning subproject in the first quarter of FY 2022. Additionally, CD-3A and CD-3B were approved for long lead procurement of gloveboxes to support the 30 ppy base equipment installation subproject.

- The **Chemistry and Metallurgy Research Replacement (CMRR)** project will maintain continuity in enduring analytical chemistry and materials characterization capabilities for DOE/NNSA actinide-based missions to support pit production and Plutonium Center of Excellence missions. Active subprojects include reconfiguring space in the Radiological Laboratory Utility Office Building and in PF-4, and installing additional analytical chemistry and materials characterization equipment.

- The **Uranium Processing Facility (UPF)**[3] project will complete the Uranium Mission Strategy's first phase and ensure the long-term viability, safety, and security of DOE/NNSA's enriched uranium capability. It will provide a modernized capability to manufacture weapon subassemblies containing enriched uranium components and convert excess enriched uranium into forms suitable for safe, long-term storage and reuse. The new facility will support Y-12 National Security Complex's (Y-12) enriched uranium processing capabilities currently located in Building 9212, which is an original Manhattan Project-era facility that is degraded, is poorly configured to meet today's strategic needs, and poses multiple risks to meeting the mission.

[3] The original baseline date for the Uranium Processing Facility CD-4 approval of December 2025 is under review.

Manhattan Project-era Building 9212 at Y-12 (left) and construction on its replacement, the Uranium Processing Facility, in April 2022 (right)

- The **Transuranic Liquid Waste Facility (TLW)** will support transuranic liquid waste treatment, which is a key support capability for DOE/NNSA operations at PF-4. The current facility that treats liquid waste is past its useful life and does not meet current codes and requirements. The Transuranic Liquid Waste Facility is designed to receive up to 29,000 liters of liquid waste annually from PF-4 operations, which produces pits for the Nation's enduring stockpile.
- The **Technical Area 55 (TA-55) Reinvestments Project (Phase 3)** has begun and supports design and construction for new fire alarm systems and removal of the old system in PF-4 at LANL. Due to the old system's age, replacement parts are no longer readily available, adding risks to the program.
- The **Savannah River Plutonium Processing Facility (SRPPF)** will support plutonium pit production by repurposing the former Mixed Oxide Fuel Fabrication Facility (MFFF) into a safe, secure, compliant, and efficient pit production facility. The former MFFF is a Security Category I/Hazard Category II[4] structure that provides an opportunity to achieve pit production in a facility designed to meet stringent security and safety requirements for plutonium operations. SRPPF will provide a sustained production capacity of no fewer than 50 War Reserve ppy as close to 2030 as possible at Savannah River Site (SRS). The project achieved CD-1 in FY 2021.
- The **High Explosives Synthesis, Formulation, and Production Facility (HESFP)** project will establish HE production capability within the nuclear security enterprise to address the current domestic supply's inability to meet DOE/NNSA production requirements. This project will consolidate limited legacy facilities that are inadequate for the mission need and will ensure the required capability and capacity is available to meet the future HE workload and mission requirements. Areas to be addressed include explosive and mock formulation operations to support multiple weapon programs, technology development for future programs, and support for strategic partners. CD-1 was awarded in February 2021 and plans for a CD-3A approval in FY 2024.
- The **Lithium Processing Facility (LPF)** will construct a new facility to replace Y-12 Building 9204-2. At 79 years old, the current lithium facility is one of the oldest operating facilities in the nuclear security enterprise. Until the new LPF is operational and qualified, much of the risk to lithium sustainment is associated with the existing facility's age and degradation. A site for LPF has been

---

[4] A Security Category I facility is one designed to contain certain quantities of strategic special nuclear materials that trigger the most rigorous level of security protections. Hazard Category II facilities are those for which a hazard analysis shows the potential for significant off-site consequences in the event of an accident.

selected at Y-12 and the former Biology Building was demolished to make room for this project. Lithium process design is 60 percent complete. Facility design and site civil exploratory boring activities, providing geotechnical information in support of facility design, have commenced.

- The **Tritium Finishing Facility (TFF)** project will construct two new processing buildings and relocate the vulnerable reservoir-related capabilities from the current 65-year-old facility to the newer, centralized facilities. This alternative will significantly reduce operational risk and increase facility reliability when compared to continuing operations in the current facility for an additional 20 years.

The Weapon Material Processing and Manufacturing area has one line-item project in the Definition Phase of the CD process (CD-0 to CD-1):

- The **Domestic Uranium Enrichment (DUE)** project will analyze options for (and if necessary, establish) a reliable and economic supply of enriched uranium to support U.S. national security needs. The U.S. Government does not currently have the capability to enrich uranium.

In addition to projects in the Definition and Execution Phases, DOE/NNSA is considering one programmatic line-item proposal in the Weapon Material Processing and Manufacturing area (Pre-CD-0). This project proposal is in the planning process but should not be considered a part of the program of record until it achieves appropriate approvals. The description of scope should be considered illustrative, as alternative selection will not be made until the project completes an AoA and the project achieves CD-1:

- The **Depleted Uranium Manufacturing Capability (DUMC)** project would support several processes for creating binary feedstock and manufacturing components to meet component deliveries in support of weapons modernization programs. These processes include casting and alloy fabrication, pressing, forging, machining, and inspection. Updating the processing methods and right-sizing the facility for current and foreseeable production needs would result in a significant reduction in the footprint defined by the existing facilities.

4.2.1.5 Weapon Component Production

Line-item projects in the Weapon Component Production area support the research, design, development, qualification, surveillance, manufacturing and production for all non-nuclear components and systems for nuclear explosive package weaponization. Current planning estimates and schedule dates for projects in this area are listed in **Figure 4–9**.

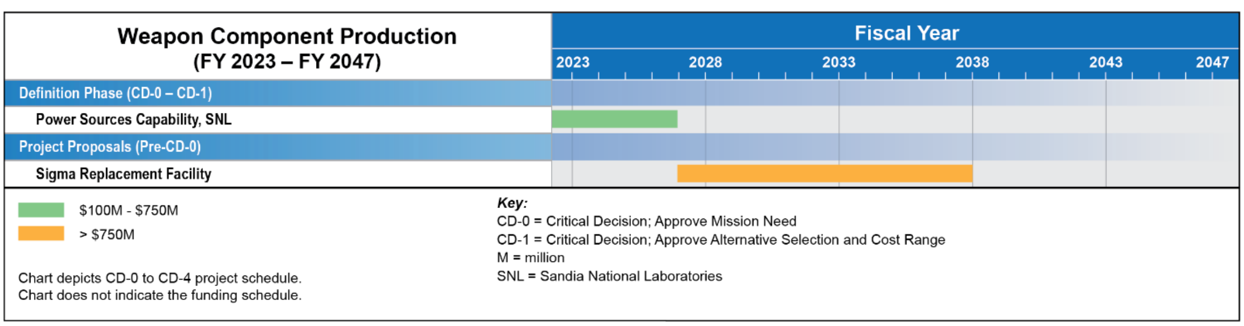


Figure 4–9. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Component Production

The Weapon Component Production area has one line-item project in the Definition Phase of the CD process (CD-0 to CD-1):

- The **Power Sources Capability** project will support all current and planned nuclear weapon systems that require power source research, development, design, qualification, production, and surveillance activities. Requirements for these power sources are stringent and unique to nuclear weapons, and very few commercial suppliers are viable for this work. The current facility cannot meet anticipated mission requirements due to increasing workload and poor facility condition, which poses increasing risks to meeting weapon program deliverables. DOE/NNSA also supplies advanced power sources for other national security mission needs that cannot be commercially sourced. This project will mitigate risk by establishing a new facility that is adaptable to changing needs, enables engagement with supply chain partners, supports technology development, and fosters innovation.

In addition to the project in the Definition Phase, DOE/NNSA is considering one programmatic line-item proposal in the Weapon Component Production area (Pre-CD-0). This project proposal is in the planning process but should not be considered part of the program of record until it achieves appropriate approvals. The description of scope should be considered illustrative, as alternative selection will not be made until the project completes an AoA and the project achieves CD-1:

- The **Sigma Replacement Facility** project would construct new facilities to maintain and enhance capabilities for the many Stockpile Stewardship support roles that Sigma currently fulfills. These facilities would include the Integrated Technology Testbed for Advanced Manufacturing for developing transformative production technologies and three additional facilities that would support uranium foundry operations, replace LANL main shop capabilities for non-nuclear components, and enable beryllium fabrication capability in a building with appropriate ventilation scaled to support the projected size of future mission need.

4.2.1.6 Weapon Assembly, Storage, Testing, and Disposition

Line-item projects in the Weapon Assembly, Storage, Testing, and Disposition area support the safe and secure assembly, storage, testing, and disposition of weapon components. Current planning estimates and schedule dates for ongoing and proposed projects in this area are listed in **Figure 4–10**.

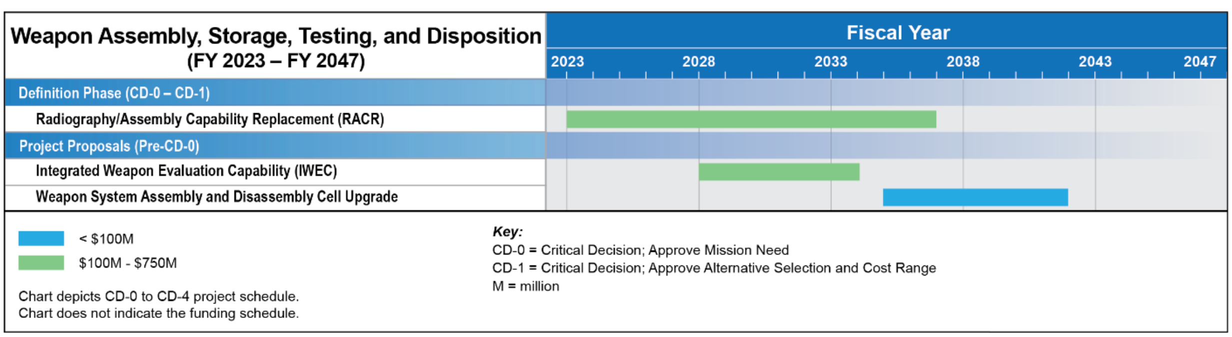


Figure 4–10. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Assembly, Storage, Testing, and Disposition

Two line-items in the Weapon Assembly, Storage, Testing, and Disposition area are in the Definition Phase of the CD process (CD-0 to CD-1):

- The **Material Staging Facility (MSF)** at Pantex was placed on hold in April 2021. The project will provide a new safe, secure, and sustainable below-grade facility adjacent to Zone 12 South Material Access Area that meets weapon and special nuclear material (SNM) component staging capacities for the next 75 to 100 years. The facility will house weapons, pits, SRS surplus plutonium material, as/if needed, and Hanford Unirradiated Fuel Packages. It will include shipping and receiving docks for SNM, and for transporting weapons in the Mobile Guardian Transporter and Safe Secure Transport. This project has been placed on hold so that NNSA can address higher priority infrastructure projects.

- The **Radiography/Assembly Capability Replacement (RACR)** project will consolidate the existing assembly and radiography complex, consisting of over 17 World War II-era buildings. RACR will improve safety, security, schedules, and quality assurance, and decrease risk to the public, workers, and program. RACR will position the DOE/NNSA nuclear weapons program for nuclear explosive package assembly and radiography capability for the next 40 to 50 years for all site and surveillance mission assignments.

DOE/NNSA is considering two programmatic line-item proposals in the Weapon Assembly, Storage, Testing, and Disposition area (Pre-CD-0). These project proposals are in the planning process but should not be considered as part of the program of record until they achieve appropriate approvals. The descriptions of scope should be considered illustrative, as alternative selections will not be made until the projects complete an AoA and the project achieves CD-1:

- The **Integrated Weapon Evaluation Capability (IWEC)** project would consolidate testing facilities for a faster and more efficient testing process and improve NNSA's test development capability at Sandia National Laboratories (SNL). Facility investment would provide secure high-bay, mid-bay, and light electrical laboratories; collaboration space; and general office space. This project would involve co-locating DOE/NNSA's IWEC equipment. Commonality would reduce development cycle time and cost.

- The **Weapon System Assembly and Disassembly Cell Upgrade** project would fill a throughput and capacity mission gap. By modernizing the infrastructure needed to improve production cell capacity, DOE/NNSA would be poised to support the anticipated workload increase during other infrastructure construction projects.

4.2.1.7 Transportation and Security

Line-item projects in the Transportation and Security area support protecting all aspects that are critical to the nuclear security enterprise's function. The Secure Transportation capability within this area has no current or proposed line-item projects. The projects listed below support the Physical Security capability, which protects all nuclear materials, infrastructure assets, and the workforce at DOE/NNSA sites that are involved in Weapons Activities programs and operations. Current planning estimates and schedule dates for projects in this area are listed in **Figure 4–11**.

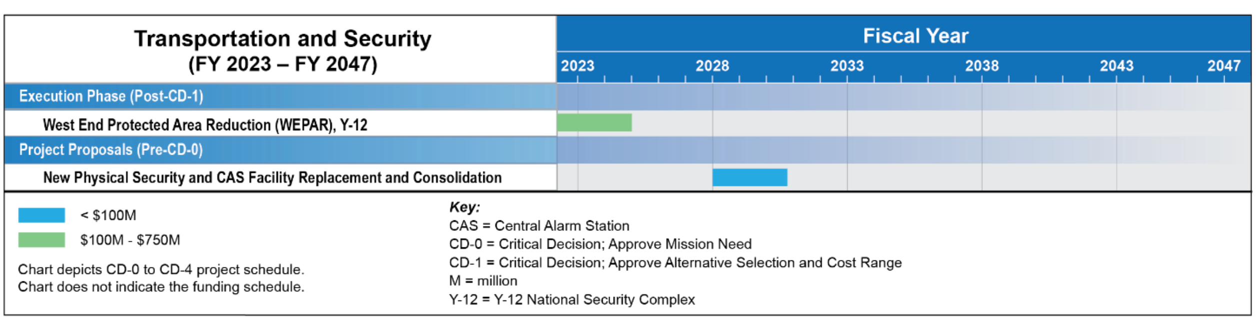


Figure 4–11. 25-year programmatic line-item schedule for ongoing and proposed projects related to Transportation and Security

DOE/NNSA is currently executing one programmatic line-item construction project in the Transportation and Security area that is past CD-1. Cost and schedule estimates for this project vary from conceptual design-based estimates to baselined project estimates:

- The **West End Protected Area Reduction (WEPAR)** project will reduce the size of the protected area at Y-12 from 150 acres to approximately 90 acres. This project will have two beneficial outcomes. First, a new Perimeter Intrusion Detection and Assessment System will protect the sensitive facilities remaining within the now reduced perimeter, which will reduce security and operating costs. Second, DOE Environmental Management cleanup activities for facilities previously encompassed by the larger protected area may proceed more efficiently and cost-effectively because those facilities will no longer be in a protected area. The project received CD-2/3 approval in January 2021 and is anticipated to reach CD-4 in FY 2025.

In addition to the project in the Execution Phase, DOE/NNSA is considering one programmatic line-item proposal in the Transportation and Security area (Pre-CD-0). This project proposal is in the planning process but should not be considered a part of the program of record until it achieves appropriate approvals. The description of scope should be considered illustrative, as alternative selection will not be made until the project completes an AoA and the project achieves CD-1:

- The **New Physical Security and Central Alarm Station (CAS) Facility Replacement and Consolidation** project would provide a new two-story facility that would house multiple security groups including the 24/7 CAS.

4.2.2 Mission Enabling Construction

DOE/NNSA also funds mission-enabling infrastructure line-items that provide site-wide utilities, office and laboratory space, and other services that support the nuclear deterrence mission (see **Figure 4–12**). These projects are required to meet daily operational needs across the nuclear security enterprise.

Three mission enabling line-item projects were recently completed:

- The **Albuquerque Complex Project** provided new office space and was constructed on DOE property in Albuquerque, adjacent to Kirtland Air Force Base. The current DOE/NNSA Albuquerque Office Complex is beyond its design life and does not meet DOE/NNSA's mission needs. Construction was completed on a 333,000-square-foot building to house approximately 1,200 employees. The new building is designed to Leadership in Energy and Environmental Design (LEED) Gold Standards.
- The **Technical Area 3 (TA-3) Substation Replacement** at LANL provides increased distribution capacity, improved reliability, reduced maintenance, support for greater operational flexibility, and increased worker safety. It provides separate power feeds to LANL and Los Alamos County.
- The **Emergency Operations Center** at LLNL provides a new permanent Emergency Operations Center with comprehensive emergency management capabilities for the development, coordination, control, and direction of emergency planning, preparedness, readiness, assurance, response, and recovery actions. The 20,000-square-foot building allows an occupancy rate needed during an emergency event that the previous Emergency Operations Center could not accommodate, provides additional parking, and contains or interfaces with approximately 60 systems, including closed-circuit television, metrology, site fire and life safety alarms, radio communication, emergency services disaster dispatching, etc.

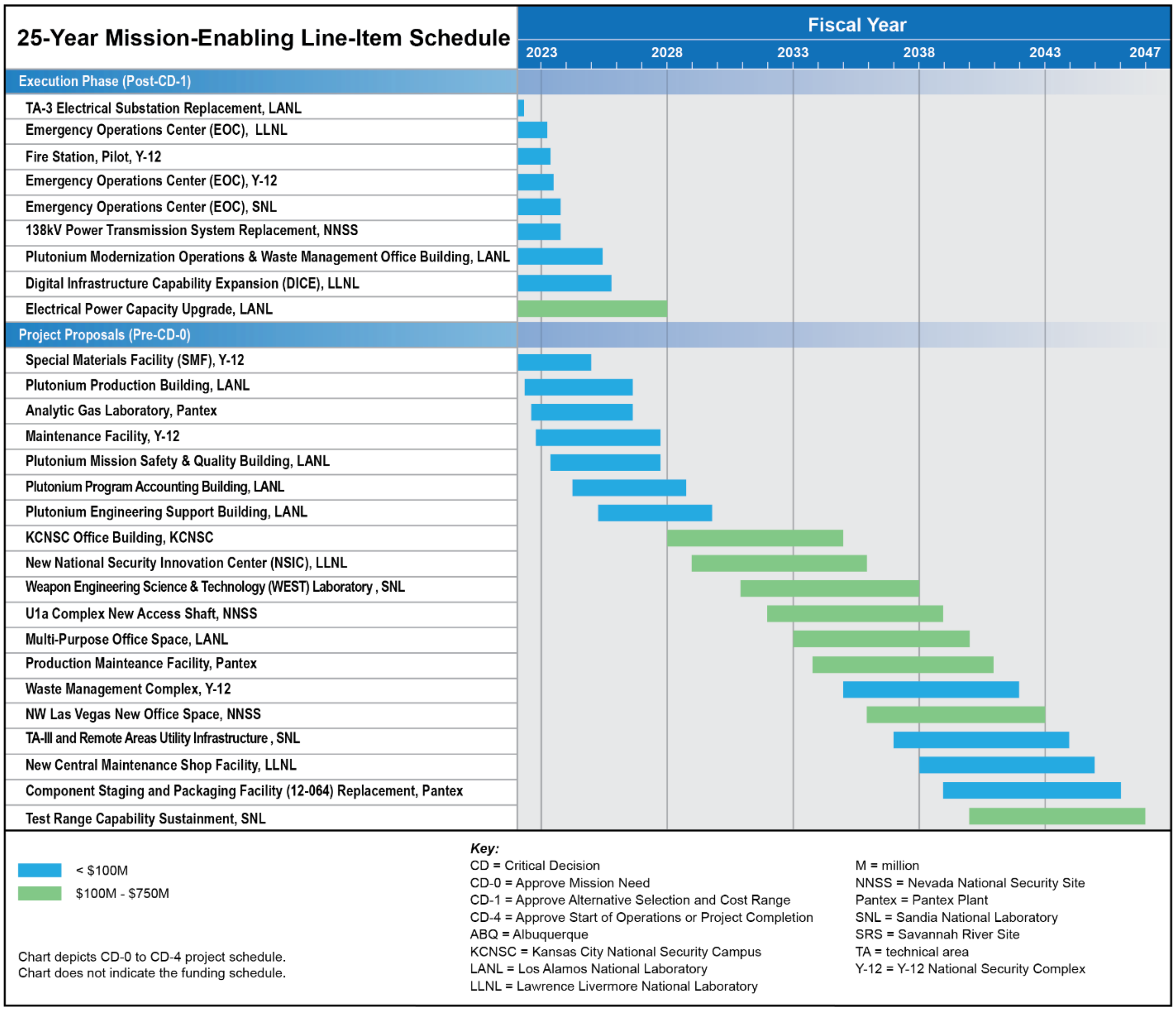


Figure 4–12. 25-year mission-enabling line-item schedule

The Enhanced Minor Construction Commercial Standards pilot is a new initiative to increase buying power and accelerate delivery for non-complex, non-nuclear, commercial facilities line-item construction projects less than $50 million. The pilot aims to attract more competitive bidding and reduce project and contract management costs, while delivering a quality facility that meets the program requirements. There are currently three projects in the pilot, with a fourth, the Emergency Operations Center at LLNL, completed in March 2022.

- The **Fire Station** project at Y-12 provides a single-story building (approximately 35,000 square feet) to meet all emergency response requirements, including firefighting, emergency medical treatment and transport, hazardous materials spill mitigation, and technical rescue responses for all events within the site emergency response boundary at the Y-12 site. The new facility will be built to meet all safety standards and building codes to support 24/7 operations under all environmental conditions. The facility will accommodate a workforce and a fleet that includes large fire apparatus vehicles, ambulances, emergency response vehicles, and other support vehicles. Construction began in FY 2021 and beneficial occupancy is planned for completion in FY 2023.

- The **Emergency Operations Center** at Y-12 will provide a centralized, comprehensive emergency management capability for the development, coordination, control, and direction of emergency planning, preparedness, readiness assurance, response, and recovery actions. The current facility is not compliant with DOE Order 151.1C, *Comprehensive Emergency Management System*. Construction began in FY 2021 and beneficial occupancy is planned for start of operations in FY 2023.
- The **Emergency Operations Center** at SNL will provide a facility that supports DOE/NNSA and SNL emergency operations, the 24/7 Emergency Management Communication Center, dedicated incident management and coordination space, multipurpose training rooms, and fuel and water storage sufficient to mitigate all potential emergency operations and management response capabilities. The center is expected to be operational in spring 2023.

Construction at the Emergency Operations Center at Y-12

Digital rendering of SNL's new Emergency Operations Center

The mission enabling projects listed below are following DOE Order 413.3B CD processes and are currently in the Execution Phase.

- The **138kV Power Transmission System Replacement** project will replace a 55-year-old 138-kilovolt (kV) power transmission system in the NNSS Mission Corridor in Mercury, Nevada. The project will provide the site with reliable power and communications to mission-critical facilities by designing and constructing a new 138-kV power transmission system to replace and upgrade 23 miles of the degraded existing power transmission system. It will also upgrade the collocated fiber optic lines to meet vital national security mission requirements.
- The **Plutonium Modernization Operations Complex** at LANL will provide additional office workstations and associated common space for increased operations within TA-55 and other supporting plutonium modernization capabilities in TA-46, 48, 50, and 63.
- The **Digital Infrastructure Capability Expansion** project at LLNL will provide safe, secure, resilient, reliable, flexible, and sustainable infrastructure for LLNL's networking and telecommunications digital infrastructure needs. The project will expand capabilities to meet growth projections for the next 40 years.
- The **Electrical Power Capacity Upgrade** at LANL will address projected increases in the electrical transmission and distribution system's capacity at LANL to reliably support demand for multiple program activities being performed at the site. By 2024, power demand for all programs is expected to exceed LANL's existing transmission and distribution system's capacity and performance requirements. This electrical upgrade will support critical Weapons Activities requirements for stockpile modernization programs, SFIs, ongoing stockpile stewardship programs, and other work.

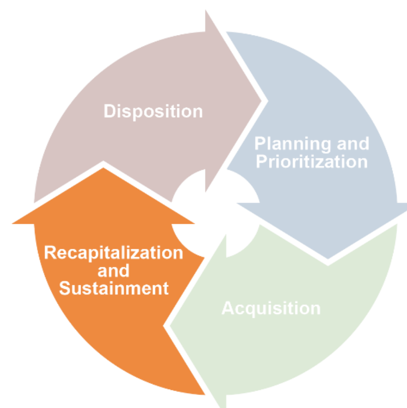
There are multiple proposals for new mission enabling projects that are planned over the next 10 to 25 years, including those listed below. With the exception of the Special Materials Facility, the descriptions of scope should be considered illustrative, as alternative selections will not be made until the projects complete an AoA and the project achieves CD-1:

- The **Special Materials Facility (SMF)** Utilities and Infrastructure Sub-project will provide infrastructure and utility upgrades to Building 9225-03 at Y-12. This repurposed facility is necessary to support special materials processing and production for future mission requirements.
- The **Analytic Gas Laboratory** at Pantex would provide the safe, secure, and reliable infrastructure necessary to perform gas analysis at Pantex. Gas analysis is required to perform the dismantlement, surveillance, stockpile refurbishment, and nuclear non-proliferation missions at Pantex.
- The **Maintenance Facility** at Y-12 would replace the antiquated maintenance facilities that support all Y-12 production missions and would enable preventive, predictive, and corrective maintenance across the site. The new facility would consolidate maintenance processes and eliminate square footage of aging facilities in a more optimized, efficient location.
- The **Office Space** at Kansas City National Security Campus (KCNSC) would provide office space for additional staff supporting increased production capacity for planned requirements. Current facilities do not have the capacity to house the forecasted workforce for the production of non-nuclear components for multiple programs.

- The **National Security Innovation Center** at LLNL would collocate staff in dispersed, end-of-life Weapons Program office buildings into a more centralized location and would enable optimized use of space.
- The **Weapon Engineering Science and Technology Laboratory** at SNL-California would integrate the Materials Science and Engineering capabilities across materials development and engineering design. The primary existing facility is in poor condition, is functionally unfit for advanced materials science R&D, and lacks sufficient capacity to meet the current and projected demand.
- The **Production Maintenance Facility** at Pantex would replace multiple facilities approaching the end of operational life expectancy and not located near critical Production and Production Support facilities. The new facility would consolidate maintenance processes and provide a more efficient location to support Production operations and facilities.
- The **Northwest Las Vegas New Office Space** at NNSS would provide sustainable infrastructure that supports the health, safety, and welfare of NNSS employees, the public, and the environment.

4.3 Modernization and Sustainment

This section describes how DOE/NNSA, in partnership with its M&O partners, modernizes and sustains assets to enable mission success and readiness; ensures operational safety and security; safeguards the workforce, public, and environment; and meets mission needs to support the nuclear security mission.



Modernization can be done through minor construction and recapitalization projects, which are important vehicles for DOE/NNSA to sustain major facilities and replace smaller capital assets below the $25 million minor construction threshold. These projects are an effective method for making improvements to increase DOE/NNSA's mission performance and lower operating costs. They typically can be completed much faster than line-item construction projects, and they enable DOE/NNSA to be responsive to emerging infrastructure issues and changing stockpile requirements.

Security Infrastructure Revitalization Program (SIRP)

SIRP was created by DOE/NNSA's Office of Defense Nuclear Security (DNS) to assure the strength of the physical security infrastructure supporting the DOE/NNSA mission. DNS developed and submitted to Congress a long-range Physical Security Systems Refresh Plan to outline and guide the scope of the SIRP effort. This plan contains a comprehensive condition assessment of the security infrastructure and a nuclear security prioritized listing of required upgrades.

Modernizing the nuclear security enterprise is accomplished through formal recapitalization programs planned and funded at the DOE/NNSA level through General Plant Projects, Institutional General Plant Projects, and other funding mechanisms. These investments improve the condition, reliability, efficiency, and capability of infrastructure to meet mission requirements. The programs plan and execute replacement, installation, upgrades, and minor construction projects to revitalize existing facilities or construct new facilities and additions. This investment method is used in conjunction with line-item construction to provide timely, appropriately sized, and integrated infrastructure solutions.

The following completed projects demonstrate that DOE/NNSA has directed infrastructure investments to address risks identified through facility and mission assessments:


Crystal Lab Revitalization at LANL


Data Center at SNL


Installation of Flame Detection System and High-Pressure Fire Loop Lead-in Replacements at Pantex


New Z and TA-IV Missions Support Facility at SNL

- Building 235 Chemistry Laboratories and Facility Revitalizations at LLNL (Recapitalization)
- Crystal Lab Revitalization at LANL (Recapitalization)
- DARHT Weather Enclosure at LANL (Recapitalization)
- Building 23 Tenant Improvements at KCNSC (Recapitalization)
- Data Center at SNL (Recapitalization)
- Device Assembly Facility uninterruptible power supply Upgrade at NNSS (Recapitalization)
- Provided redundant power to Pantex Data Center under the 12-37 Secondary Electrical Feed Installation project (Recapitalization)
- New Building 225 Manufacturing Science Facility at LLNL (Recapitalization)
- PF-4 High-Risk Variable Frequency Drive Fan Safety Replacement at LANL (Recapitalization)
- Installation of 7 Flame Detection System and 8 High Pressure Fire Loop lead-in replacements at Pantex (Recapitalization)
- New Z and TA-IV Missions Support Facility Building 972 at SNL (Recapitalization)
- TA-72 Outdoor Range Upgrades Project at LANL (Defense Nuclear Security [DNS])
- Range Classroom Facility Replacement at LLNL (DNS)
- Zone 12 Outdoor Floodlight Replacement at Pantex (DNS)
- Zone 12 and 4 Enterprise Standard Booth Installation at Pantex (DNS)
- Building 224 Office Building at LLNL (Site Directed Investments)
- Building 223 Polymers and Engineering Facility at LLNL (Recapitalization)
- TA-33-0066 Building Extension at LANL (Site Directed Investments)
- Building 9117 Data Center Upgrades at Y-12 (Site Directed Investments)
- Roof Asset Management Program (Recapitalization): 27 projects at NNSA sites/1 project at a DOE site
- NM HV 5kV Overhead Feeder Replacements for overhead powerlines in TA-III at SNL (Recapitalization)
- NM Water System Secondary Feed to the 700KG Tank at SNL (Recapitalization)

- 234-H Main Side Diesel Generator Replacement at SRS (Recapitalization)
- Nuclear Facilities Electrical Modernization Portfolio at Y-12 (Recapitalization and Maintenance)


Main Side Diesel Generator Replacement at SRS

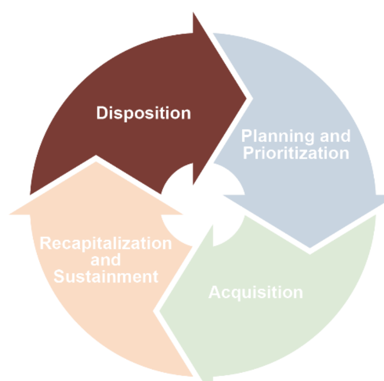

Nuclear Facilities Electrical Modernization Portfolio at Y-12

DOE/NNSA is also modernizing its infrastructure by executing its first option to purchase acquisition at 103 Palladium Way to house Y-12's development capabilities. An option agreement is a contract with the land/facility owner that gives a prospective buyer the exclusive right to purchase the property at a fixed price within a stated time period. The option agreement allows necessary time for DOE/NNSA to perform the due diligence required for any Federally funded purchase. This existing off-site facility, known as the John M. Googin Tech Development Facility, is near Y-12 and will provide a timely and cost-effective home for Y-12's development mission. The facility is located on a secure and fenced 21-acre level campus with approximately 73,000 square feet of interior space. The building has extensive high-bay areas, wet-chemical laboratory areas, office areas, and already has the utilities necessary for a duplicate facility (100,000 square foot expansion) on the adjacent grounds. It was originally built as a secure facility to make medical isotopes in 1999 but was never occupied. With relatively little renovation, the facility can easily be adapted to house the compatibility and surveillance, materials processing, mechanical, control and sensor systems, and the metallurgical engineering and processing operations of Y-12 development. It is anticipated the building will provide a clean, safe, and modern facility for development that will assist in the recruitment and retention of the talented scientific and engineering staff that Y-12 requires for future success if this strategy is pursued.

Sustainment activities include maintenance and repair activities to sustain an acceptable condition of real property assets to perform their designated purpose or to mitigate risks. In some instances, the nature of core mission areas leads to direct programmatic sustainment funding for certain operations. These efforts support the recurring daily work needed to sustain plant, property, assets, systems, roads, and equipment in a condition suitable for its designated purpose. Efforts include required maintenance through surveillance and predictive, preventive, and corrective maintenance activities to maintain facilities, property, assets, systems, roads, equipment, and vital safety systems.

These sustainment activities are executed through a combination of innovative tools that provide data for risk analyses that inform infrastructure management decisions. Decisions dedicate critical resources to maintaining facilities already in good condition and repairing the highest risks in DOE/NNSA assets.

4.4 Disposition



DOE/NNSA infrastructure that is no longer needed must be dispositioned to minimize risks to workers, the public, the environment, and the mission.

Approximately 9 percent of assets located on DOE/NNSA's sites are designated as excess. DOE/NNSA's highest disposition priorities are to stabilize degraded facilities, characterize hazards and conditions, remove hazardous and flammable materials, and place facilities in the lowest acceptable risk condition possible until they can be dispositioned. If a facility is process-contaminated, and the cost estimate for disposing of the facility exceeds $75 million, then DOE/NNSA must stabilize the facility until the DOE Office of Environmental Management can perform the disposition. The DOE/NNSA Disposition Strategic Plan outlines the details of how DOE/NNSA plans to address these excess facilities.

Several completed projects demonstrate that DOE/NNSA has directed infrastructure investments to address risks identified through facility and mission assessments:

- Building 292 Deinventory at LLNL (Disposition)
- Ion Beam Equipment Removal at LANL (Disposition)
- Buildings 11-015A, 12-006B, 12-007, 12-007A, 12-014, 12-017P1, 12-017P2, 12-019P, 12-024E, 12-024S, 12-030, 12-R-034, 12-034, 12-034SS, 12-045, 15-051, and 16-031 at Pantex (Disposition)
- Buildings 9727-04, 9727-04A, 9409-34, and 9949-47 at Y-12 (Disposition)


Building 11-015A at Pantex

The longer an unused facility is left standing before demolition, the more deteriorated it becomes, and the more difficult it is to maintain in a safe shutdown condition. Aging facilities pose risks to human health, the environment, and the mission. DOE/NNSA is committed to mitigating these risks by dispositioning excess facilities as quickly as possible and working with the DOE Office of Environmental Management when its expertise is required.

During the next 10 years, nearly 700 additional assets with 4.2 million gross square feet are planned to become excess at DOE/NNSA sites. Of these assets, approximately 43 percent are process contaminated and may require DOE Office of Environmental Management expertise to demolish.

Chapter 5
Budget and Fiscal Estimates

The Fiscal Year (FY) 2023 President's Budget for Weapons Activities supports the nuclear stockpile and associated modernization programs. The FY 2023 President's Budget provides increase of 8.5 percent[1] for the Department of Energy's National Nuclear Security Administration (DOE/NNSA) and an increase of 7.4 percent for Weapons Activities above the FY 2021 enacted appropriation. Throughout this chapter, the FY 2023 budget request is compared to the FY 2021 enacted budget to maintain consistency with the FY 2023 Congressional Budget Justifications. The FY 2023 Congressional Budget Justifications were prepared under a continuing resolution, prior to the enactment of the FY 2022 budget.

DOE/NNSA developed the FY 2023 Future Years Nuclear Security Program (FYNSP) budget request for Weapons Activities by evaluating the resources necessary to support priority requirements and aligned warhead programs to DOE/NNSA requirements. The assumptions encompassed by this request meet the timeline for DOE/NNSA's warhead deliveries to be synchronized with the modernization of Department of Defense (DoD) delivery platforms.

The first part of this chapter displays budgetary information for the FY 2023 budget request based on the program of record described in the previous chapters of this *Fiscal Year 2023 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (FY 2023 SSMP). Sections 5.4 through 5.8 compare the FY 2023 budget request to the FY 2021 enacted budget by program/budget line and present key milestones, showing progress toward program goals. Key milestones beyond the next 5 years show planned activities to meet DoD requirements and are contingent on future decisions.

The second part of the chapter describes cost projections for selected programs beyond FY 2023, including the basis of those cost projections used to estimate the potential long-term cost of the DOE/NNSA Weapons Activities program. Cost-estimating techniques supporting the budget request are consistent with Government Accountability Office (GAO) best practices and have been updated with current requirements for each weapon system. The chapter concludes with an overview of the 25-year plan and an analysis of the affordability of the Weapons Activities program.

5.1 Planning, Programming, Budgeting, and Evaluation

DOE/NNSA employs a Planning, Programming, Budgeting, and Evaluation (PPBE) process similar to processes in use across the U.S. Government. DOE/NNSA's PPBE process has four major phases for each budget cycle:

- The Planning phase of the PPBE process considers the range of work in a manner that is fiscally informed, but not constrained, to ensure all requirements and mission needs are considered. This phase is guided by strategic goals and objectives specified in Department-level and NNSA-level strategic planning documents. These internal strategic documents are aligned with, and support, the mission priorities in the *National Security Strategy*, *National Defense Strategy*, and *Nuclear Posture Review*. Internal documents are also developed in consultation with the program offices

[1]The percent change does not reflect the mandated transfer of $91.0 million in FY 2021 from Naval Reactors to the Office of Nuclear Energy for operations of the Advanced Test Reactor.

and management and operating (M&O) contractor partners to ensure they reflect a complete set of requirements. This analysis drives the development of a budget that allows timely execution of key mission priorities and enables DOE/NNSA to achieve its mission.

- The Programming phase is the decision-making process that aligns available program resources with priorities, resulting in a balanced, integrated, executable FYNSP to be proposed by DOE to the Office of Management and Budget (OMB) as the basis for that year's congressional budget request. This phase is primarily a Headquarters-driven process that allocates resources and integrates the funded activities to ensure accomplishment of the highest priority efforts.
- The Budgeting phase involves the production of a formal budget request and associated justifications to OMB and to Congress as well as execution of appropriated funds. DOE/NNSA develops OMB budget justification materials for the FYNSP that state work scopes and schedules corresponding with the funding request. Budgeting includes formulation, justification, execution, and control of the budget. This process describes to Congress the resources necessary to execute the mission and then ensures DOE/NNSA spends those resources in accordance with the law. Budget Formulation is the development of funding estimates that support the plans and programs and obtains resources for program execution. Budget Justification includes the development of the budget and supporting documentation that allows the stakeholder to understand the program, or function, and the resources required to accomplish the effort. Budget execution is the phase in which appropriated resources are distributed and controlled to achieve their approved purpose. The OMB apportionment process makes funds available to DOE for obligation and expenditure. Appropriation legislation and accompanying tables are the controlling documents for funds distribution and display the budgetary resources available. Execution is the consistent monitoring of expenditures and obligations.
- Evaluation is the assessment of progress made toward achieving identified performance measures at multiple levels within DOE/NNSA.

At any time, multiple PPBE phases for different budget cycles are ongoing concurrently.

5.2 Portfolio Management

DOE/NNSA employs portfolios which are aligned with the budget, but are scope-based, to optimize its risk-informed, complex, and time-constrained modernization and recapitalization efforts. The President's Budget for Weapons Activities funds a set of programs based on analysis of what actions are necessary to accomplish DOE/NNSA's statutory mission to manage the current and future stockpile without nuclear explosive testing. DOE/NNSA uses a rigorous portfolio management approach to determine the right set of programs and projects to accomplish that mission. During the programming process, funding levels are established at various levels of detail for the FYNSP period to align anticipated resources with DOE/NNSA priorities.

Portfolio management enables DOE/NNSA to make necessary investments to advance existing capabilities and develop emerging capabilities for a strong nuclear deterrent. These capabilities underpin each of the Weapons Activities portfolios and are described in Chapter 3.

5.3 FY 2023 Future Years Nuclear Security Program

Weapons Activities provides maintenance and refurbishment of nuclear weapons to sustain confidence in their safety, reliability, and military effectiveness. In addition, Weapons Activities invests in scientific and engineering capabilities for assessment of the current stockpile warheads, qualification of components for warhead modernization, and certification of warheads upon entry into the stockpile. Weapons Activities also provides maintenance and investment in DOE/NNSA's infrastructure.

The FY 2023 FYNSP budget request supports the current stockpile, warhead modernization activities, recapitalization and modernization programs for infrastructure, and reestablishment of necessary production capabilities. It also supports research and development (R&D) efforts and personnel growth in operations, physical security, and information technology (IT) and cyber security to support expanding program needs. In previous years, line-item construction projects were consolidated under the Infrastructure and Operations program. However, programmatic line-items in the FY 2023 FYNSP now reside under their respective program lines to reflect the Weapons Activities account integrator's request for greater transparency with major construction projects.

Table 5–1 displays the FY 2021 and FY 2022 enacted budgets, and the program budget requests for Weapons Activities for FY 2023–FY 2027. The structure of the budget request in Table 5–1 reflects the major programs, not the capabilities discussed previously in Chapter 3. The figures and narrative that follow describe the FY 2023 budget request in more detail.

Table 5–1. Overview of Future Years Nuclear Security Program budget request for Weapons Activities in FY 2021–FY 2027[a]

Activity	*FY (dollars in millions)*						
	2021 Enacted (Comp)	*2022 Enacted (Comp)*	*2023 Request*	*2024 Request*	*2025 Request*	*2026 Request*	*2027 Request*
Stockpile Management	4,290.2	4,637.7	4,929.1	4,967.2	4,943.5	4,778.6	4,914.3
Production Modernization	3,903.5	4,156.9	4,640.6	5,157.6	5,245.4	5,027.2	4,612.6
Stockpile Research, Technology, and Engineering	3,003.5	2,978.0	2,894.7	3,066.8	2,937.7	2,892.5	2,975.0
Infrastructure and Operations	2,542.1	2,487.4	2,631.0	2,775.0	2,842.7	2,893.9	2,972.1
Secure Transportation Asset	348.7	330.8	344.4	354.7	381.0	389.0	442.1
Defense Nuclear Security	789.1	844.1	882.3	927.6	955.3	991.5	1,049.2
Information Technology and Cybersecurity	366.2	406.5	445.7	494.1	513.9	534.4	587.2
Legacy Contractor Pensions and Settlement Payments	101.7	78.7	114.6	73.5	77.6	79.2	80.9
Adjustments	0.0	0.0	(396.0)	0.0	0.0	0.0	0.0
Weapons Activities Total	**15,345.0**	**15,920.0**	**16,486.3**	**17,816.3**	**17,897.1**	**17,586.3**	**17,633.4**

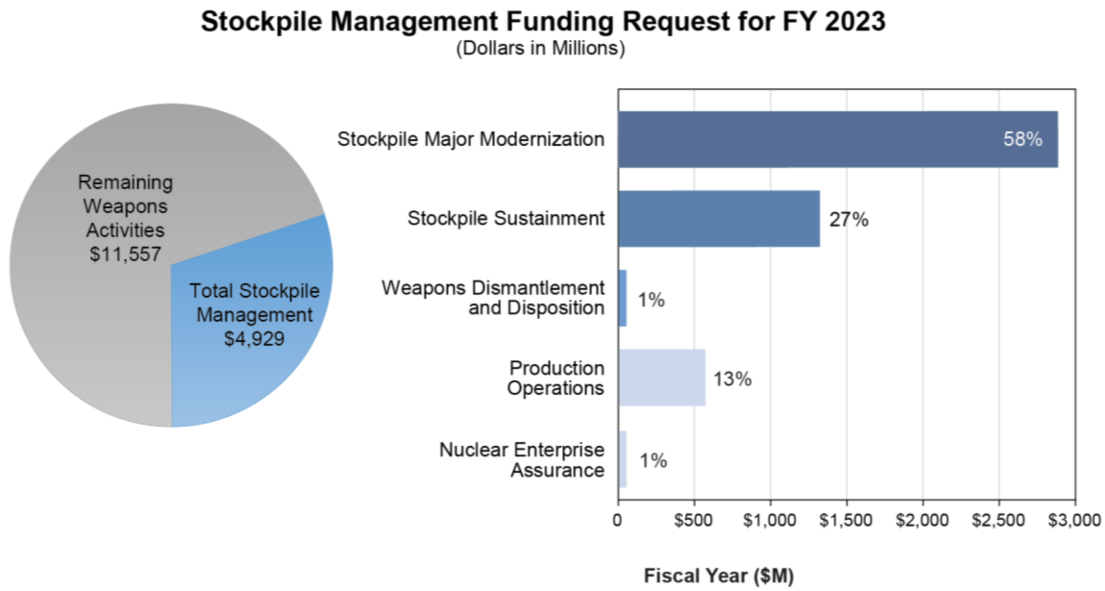
[a] Totals may not add because of rounding.

5.4 Stockpile Management

Stockpile Management encompasses five major subprograms that directly support the Nation's nuclear weapons stockpile: (1) Stockpile Major Modernization, (2) Stockpile Sustainment, (3) Weapons Dismantlement and Disposition, (4) Production Operations, and (5) Nuclear Enterprise Assurance (NEA). NEA, a new subprogram for FY 2023, will prevent, detect, and mitigate potential consequences of subversion to the stockpile and associated capabilities to design, produce, and assess nuclear weapons. Additional information about the Stockpile Management program can be found in Chapter 2, "Stockpile Management."

5.4.1 Budget

The budget request for Stockpile Management increased 14.9 percent from the FY 2021 enacted budget and is illustrated in **Figure 5–1**.



	2021 Enacted	2022 Enacted	2023	2024	2025	2026	2027
Stockpile Major Modernization	2,666.9	2,832.3	2,877.2	2,780.9	2,683.3	2,541.7	2,695.6
Stockpile Sustainment	998.4	1,180.5	1,321.1	1,435.6	1,470.4	1,448.5	1,408.4
Weapons Dismantlement and Disposition	56.0	56.0	51.0	51.0	51.4	52.5	53.6
Production Operations	568.9	568.9	630.9	644.4	668.5	674.6	690.0
Nuclear Enterprise Assurance	0.0	0.0	48.9	55.2	69.8	61.4	66.7
Total Stockpile Management	4,290.2	4,637.7	4,929.1	4,967.2	4,943.5	4,778.6	4,914.3

Note: Numbers may not add due to rounding

Figure 5–1. FY 2023 President's Budget Request for Stockpile Management

5.4.2 FY 2023 Budget Request Compared to FY 2021 Enacted Budget

5.4.2.1 Stockpile Major Modernization

Stockpile Major Modernization extends the lifetime of the nation's nuclear stockpile while addressing required updates; replacing aging, or obsolete, components to ensure continued service life; and enhancing security and safety features. Stockpile Major Modernization includes (1) B61 Life Extension Program (LEP), (2) W88 Alteration (Alt) Program, (3) W80-4 LEP, (4) W87-1 Modification Program, and (5) W93 Program.

The budget request for Stockpile Major Modernization increased to support:

- W87-1 transition from Phase 6.2, *Feasibility Study and Design Options,* to Phase 6.3, *Development Engineering*
- W93 ramp-up within Phase 2, *Feasibility Study and Design Options*
- W80-4 ramp-up of activities as the program transitions from Phase 6.3, *Development Engineering,* to Phase 6.4, *Production Engineering*

5.4.2.2 Stockpile Sustainment

Stockpile Sustainment directly executes maintenance, limited life component exchanges, minor alterations, surveillance, assessment, surety, and management activities for all enduring weapons systems in the stockpile. The program includes the B61, W76, W78, W80, B83, W87, and W88 Stockpile Systems as well as Multi-Weapon Systems.

The budget request for Stockpile Sustainment increased to support:

- The W76 Mk4B development and qualification
- Design, development, qualification, and production of weapon surety capabilities
- Implementation of Integrated Surety Architecture
- Development and deployment of product realization and digital engineering tools and applications
- Transition of the B61-12 into stockpile
- Joint Test Assembly flight test vehicle development and production
- High explosive component development and production
- Special material procurement supporting limited life components
- Activities supporting Air Force transition from Minuteman III to the LGM-35A Sentinel, previously referred to as the Ground Based Strategic Deterrent

5.4.2.3 Weapons Dismantlement and Disposition

Weapons Dismantlement and Disposition dismantles retired weapons and dispositions retired components from the stockpile. It also provides safety studies on retired systems and technical analysis needed to dismantle, and safely store, weapons being removed from the stockpile. It provides an integrated program to safely dismantle and dispose of warhead components that have been retired, while some limited number of components from the dismantled warheads are preserved for potential reuse in stockpile modernization and safety testing programs.

The budget request for Weapons Dismantlement and Disposition decreased due to a reduction in disposition of legacy component inventories.

5.4.2.4 Production Operations

Production Operations is a multi-weapon system manufacturing-based program that drives individual site production capabilities and capacity for the stockpile sustainment and modernization programs, including limited life component production and weapon assembly and disassembly operations. Production Operations also provides programmatic equipment maintenance, and maintenance/calibration services for manufacturing operations to meet DoD War Reserve requirements.

The budget request for Production Operations increased to support:

- Programmatic equipment maintenance activities previously funded under Infrastructure and Operations
- Kansas City National Security Campus (KCNSC) expansion and equipment relocation
- Hiring of critical skilled labor resources to support increase in production activities

5.4.2.5 Nuclear Enterprise Assurance

The FY 2023 budget request provides funding for this new subprogram, which actively manages adversarial subversion risks to nuclear weapons and associated design, production, and testing capabilities. NEA enables the responsible use of digital technologies in the modernization of weapons, facilities, and engineering capabilities by preventing, detecting, and mitigating potential consequences of subversion. Through nuclear weapon digital assurance, NEA enables risk-managed adoption of leading-edge technologies to meet emerging military requirements and to reduce modernization schedules and costs.

5.4.3 Key Milestones

DOE/NNSA must meet the key Stockpile Management milestones in **Figure 5–2**[2] to sustain and modernize the stockpile. There is one major change from last year's plan related to Stockpile Management:

- The FY 2022 milestone, *Begin Phase 6.4 activities for the W80-4 LEP,* is delayed to FY 2023. DOE/NNSA is re-evaluating the W80-4 LEP schedule due to the Coronavirus Disease 2019 (COVID-19), staffing, and technical program delays. Entry into Phase 6.4 will occur after the re-scheduled milestones are completed.
- The FY 2025 milestone, *Deliver first production unit of the W80-4 LEP*, was shifted to FY 2027 due to COVID-19 impacts, slow ramp-up in staff, and component technical delays. Due to the current margin between NNSA first production unit and Air Force Initial Operational Capability, NNSA has high confidence that it will support the Air Force's scheduled Long Range Standoff cruise missile initial and final operational capability dates.

One milestone from last year's Stockpile Stewardship and Management Plan (SSMP) completed in FY 2022 is:

- *Deliver first production unit of the B61-12 LEP*

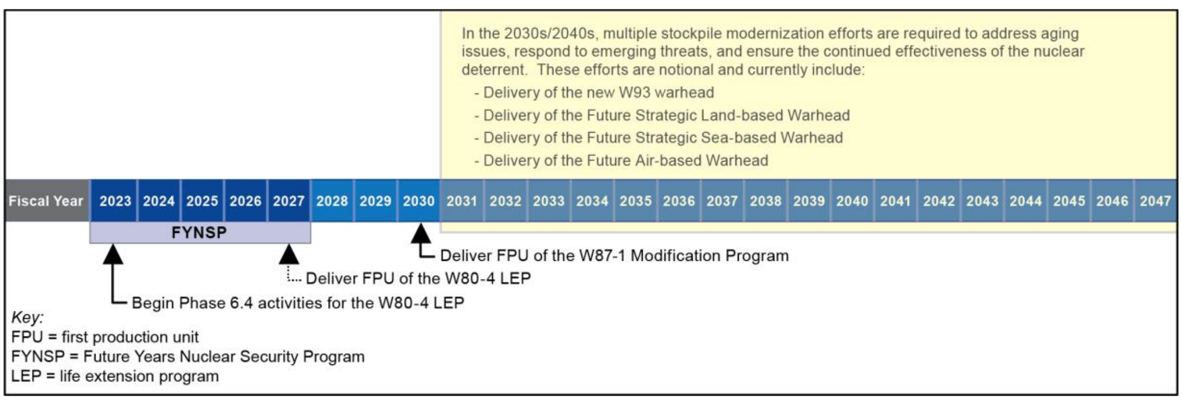


Figure 5–2. Key milestones for Stockpile Management

5.5 Production Modernization

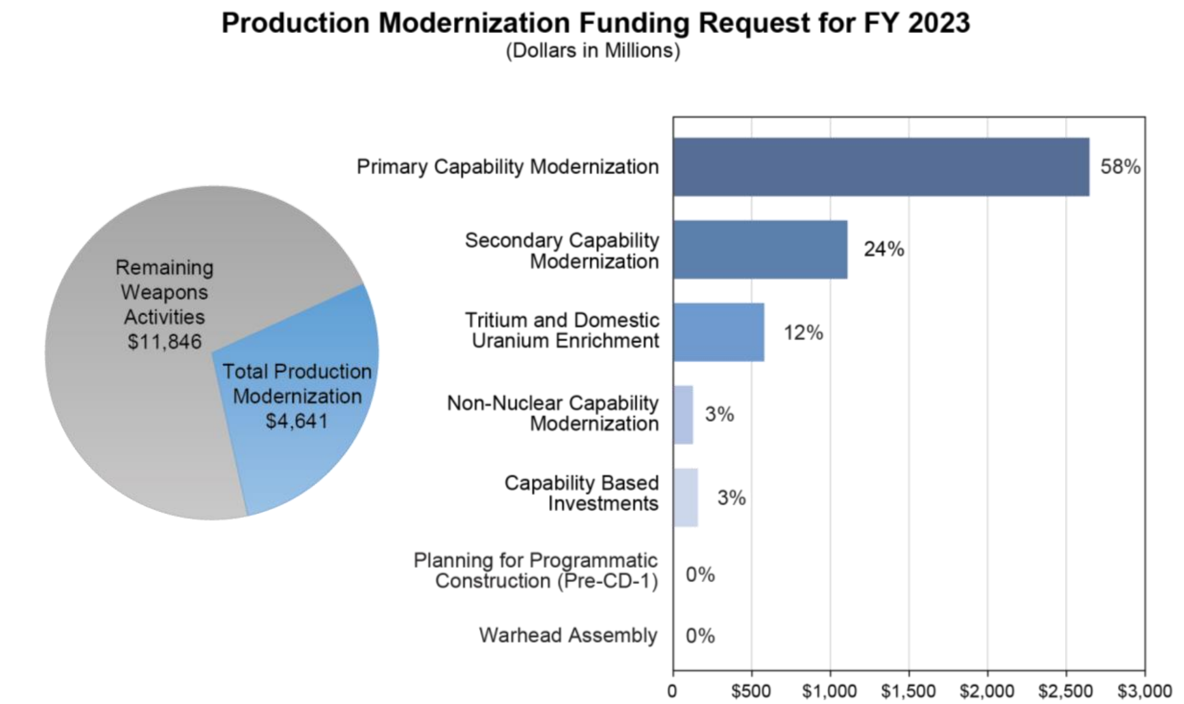
The Production Modernization program is responsible for modernizing the facilities, infrastructure, and equipment that produce materials and components to meet stockpile requirements and maintain the Nation's nuclear deterrent. It consists of five major subprograms that sustain the Nation's nuclear weapons stockpile: (1) Primary Capability Modernization, (2) Secondary Capability Modernization, (3) Tritium Modernization and Domestic Uranium Enrichment, (4) Non-Nuclear Capability Modernization,

[2] These key milestones do not include key annual deliverables, such as completing the Annual Assessment Process culminating in the national security laboratory (Los Alamos National Laboratory [LANL], Lawrence Livermore National Laboratory [LLNL], and Sandia National Laboratories [SNL]) Directors' letters to the Secretaries of Energy and Defense by the end of each fiscal year; meeting Surveillance Program requirements as approved via the surveillance governance model; and updating system reliability estimates and issuing a Weapons Reliability Report.

and (5) Capability Based Investments (CBI). CBI was funded under Infrastructure and Operations in prior year budget requests and now resides within Production Modernization.

5.5.1 Budget

The budget request for Production Modernization increased 18.9 percent from the FY 2021 enacted budget (comparable structure) and is illustrated in **Figure 5–3**.



	2021 Enacted	2022 Enacted	Fiscal Year ($M) 2023	2024	2025	2026	2027
Primary Capability Modernization	1,746.8	2,028.9	2,668.1	3,133.4	3,278.8	3,085.1	2,619.9
Secondary Capability Modernization	1,316.4	1,256.0	1,115.2	996.3	855.4	848.0	807.9
Tritium and Domestic Uranium Enrichment	574.1	516.0	579.9	664.6	744.9	749.0	740.6
Non-Nuclear Capability Modernization	107.1	158.4	123.1	206.2	212.8	165.5	167.4
Capability Based Investments	149.1	187.6	154.2	157.1	153.6	154.7	161.9
Planning for Programmatic Construction (Pre-CD-1)	10.0	10.0	0.0	0.0	0.0	0.0	0.0
Warhead Assembly	0.0	0.0	0.0	0.0	0.0	25.0	115.0
	3,903.5	4,156.9	4,640.6	5,157.6	5,245.4	5,027.2	4,612.6

Note: Numbers may not add due to rounding CD = Critical Decision

Figure 5–3. FY 2023 President's Budget Request for Production Modernization

5.5.2 FY 2023 Budget Request Compared to FY 2021 Enacted Budget

5.5.2.1 Primary Capability Modernization

Primary Capability Modernization consolidates management of primary stage material processing and component production capabilities in the nuclear security enterprise. The program includes (1) Plutonium Modernization and (2) High Explosives and Energetics (HE&E) Modernization. The Los Alamos Plutonium Pit Production Project (LAP4), the Technical Area 55 (TA-55) Reinvestment Project - Phase 3, Transuranic Liquid Waste Facility, Chemistry and Metallurgy Research Replacement, and the Savannah River Plutonium Processing Facility (SRPPF) are now included under Primary Capability Modernization to encompass the full scope of Plutonium Modernization. The HE&E program includes the Energetic Materials Characterization project, the High Explosives (HE) Synthesis, Formulation, and Production project, and the HE Science and Engineering project. As with Plutonium Modernization, these line-item construction projects were captured under Infrastructure and Operations in previous years.

The budget request for the Primary Capability Modernization program increased to support:

- Activities associated with Los Alamos Plutonium Operations, LAP4, and SRPPF
- HE&E modernization through establishing HE production capability at the Naval Surface Warfare Center – Indian Head Division, preliminary design for the Energetic Materials Characterization project, and final design and start of construction for HE Synthesis, Formulation, and Production

5.5.2.2 Secondary Capability Modernization

Secondary Capability Modernization restores and increases manufacturing capabilities for the secondary stage of nuclear weapons in the nuclear security enterprise. This modernization includes ensuring the availability of strategic materials and other sub-component streams necessary for the secondary stage, as well as modernizing the facilities and operations required to process these materials, fabricate them into parts, and assemble the final components. The program includes three subprograms: (1) Uranium Modernization (formerly Uranium Sustainment), (2) Depleted Uranium Modernization, and (3) Lithium Modernization. The Lithium Processing Facility and Uranium Processing Facility projects are now captured within the Secondary Capability Modernization program instead of Infrastructure and Operations.

The overall decrease in the budget request for Secondary Capability Modernization reflects the transition from peak construction activities for the Uranium Processing Facility; however, the budget request for Depleted Uranium Modernization and Lithium Modernization increased to support:

- Re-establishing a reliable supply of High Purity Depleted Uranium metal and investing in key new technologies to modernize production and meet future demands, including modernizing the historical wrought process and investing in critical foundry modernization projects
- Fully funding minor construction projects supporting Lithium Modernization such as the Lithium Lab Area Upgrades, Backup Crusher/Grinder project, and the Lithium Process Equipment Relocation risk reduction activity

5.5.2.3 Tritium Modernization and Domestic Uranium Enrichment

Tritium Modernization and Domestic Uranium Enrichment (DUE) consist of two parts: (1) Tritium Modernization, which produces, recovers, and recycles tritium to support national security requirements, and (2) the DUE Program, which is responsible for providing unobligated, low-enriched uranium for tritium production, and preserving and advancing uranium enrichment technology for potential future deployment to meet national security needs. The Tritium Finishing Facility line-item project now resides within this program and no longer falls under Infrastructure and Operations.

The budget requests for Tritium Modernization and Domestic Uranium Enrichment increased to support:

- Increasing irradiation of tritium-producing burnable absorber rods (TPBAR) to meet multi-year plans for producing tritium, consistent with sustaining a reliable, flexible, and resilient supply chain to meet National Security requirements
- Licensing Tennessee Valley Authority reactors beyond 1,792 TPBARs and Spent Fuel Pool Rerack
- Replacing Hot and Cold Nitrogen and Thermal Cycling Absorption Process equipment at the Savannah River Site (SRS)

- Completing final design activities and the Site Preparation and Warehouse subproject for the Tritium Finishing Facility project
- Down-blending highly enriched uranium (HEU) to extend future tritium need dates, which had previously been funded in a separate HEU down-blend line and is now included in the DUE line
- Increasing centrifuge development scope and maturity as the DUE program advances towards larger-scale R&D demonstrations

5.5.2.4 Non-Nuclear Capability Modernization

Non-Nuclear Capability Modernization consolidates management and oversight of strategic investments to modernize capabilities for design, qualification, and production of non-nuclear components for multiple weapon systems. This program provides increased capability and capacity to produce, and qualify, non-nuclear components to meet scheduled stockpile sustainment and weapon modernization programs. In addition, this program enables development of strategies, processes, and new capabilities and purchasing programmatic equipment for production of non-nuclear components. The Power Sources Capability line-item is now captured within this program instead of Infrastructure and Operations.

The budget request for this program increased to support:

- The transfer of scope for Accelerator and Major Environmental Test Facility programmatic equipment maintenance requirements from Infrastructure and Operations
- Additional support for required qualification and testing capabilities, including modernization efforts for the radiation testing facility Annular Core Research Reactor at Sandia National Laboratories (SNL)
- Tester Transformation Initiative aimed at improving tester requirements by establishing a means for pre-qualifying testers to a common design agency-production agency platform and ensuring designs and hardware meet requirements
- Direct funding for At-Risk Materials, an enterprise-wide effort for early identification of at-risk materials and development of solutions to avoid supply chain interruptions

5.5.2.5 Capability Based Investments

The CBI program executes projects to replace, or enhance, core enterprise capabilities through recapitalization of high risk of failure test, measurement, and production equipment. CBI addresses enduring, multi-program requirements through discrete, short-duration projects. These investments recapitalize scientific and manufacturing capabilities that have degraded due to aging, broken, or outdated equipment and supporting systems. CBI activities primarily include capital equipment purchases and minor construction projects that ensure needed capabilities are available for stockpile stewardship, sustainment, and modernization.

The budget request for this program increased to support the expansion of the Flexible Production Capacity Initiative.

5.5.3 Key Milestones

DOE/NNSA must invest in re-establishing production capabilities and modernizing programmatic infrastructure to properly support the current and future nuclear deterrent mission. Although programmatic construction projects shifted from Infrastructure and Operations to the relevant programs in the FY 2023 budget request, in previous SSMPs, key infrastructure milestones were included in the relevant program areas, so there is no significant change to the milestone sections because of this shift. Key milestones for Production Modernization are presented by program in Sections 5.5.3.1–5.5.3.5.

5.5.3.1 Primary Capability Modernization

Key milestones for Primary Capability Modernization are in **Figure 5–4**. Major changes from last year's plan related to Primary Capability Modernization are:

- The FY 2022 milestone, *Obtain Critical Decision (CD)--1 for Energetic Materials Characterization,* is delayed to FY 2023 to align the project's post-CD-1 activities with appropriated project funding available beginning in FY 2023.
- The FY 2032 to FY 2035 milestone, *Achieve 80 pits per year (ppy) production capability as close to 2030 as possible,* is now shown as *Obtain CD-4, Approve Start of Operations or Project Completion, for SRPPF* to provide clarification that following the start of operations at SRPPF (CD-4 approval), SRPPF will then ramp up to projected pit production capability.
- The FY 2026 milestone, *Obtain CD-4 for High Explosives Science and Engineering*, is delayed to FY 2027 due to a termination of the early works subcontractor, requirement to replan remaining scope, and a delay in awarding the main works construction contract.
- The FY 2028 milestone, *Obtain CD-4 for Energetic Materials Characterization,* is shifted to FY 2030 due to a higher fidelity schedule estimate as a result of additional design and scheduling analysis required prior to CD-1, *Approve Alternative Selection and Cost Range*.
- The FY 2028 milestone, *Obtain CD-4 for CMRR,* is delayed to FY 2029 to prioritize LAP4 and major item of equipment projects within the Plutonium Facility.

One milestone from last year's SSMP is no longer included as a milestone:

- *Complete construction of the Energetics Manufacturing Science and Technology Project*

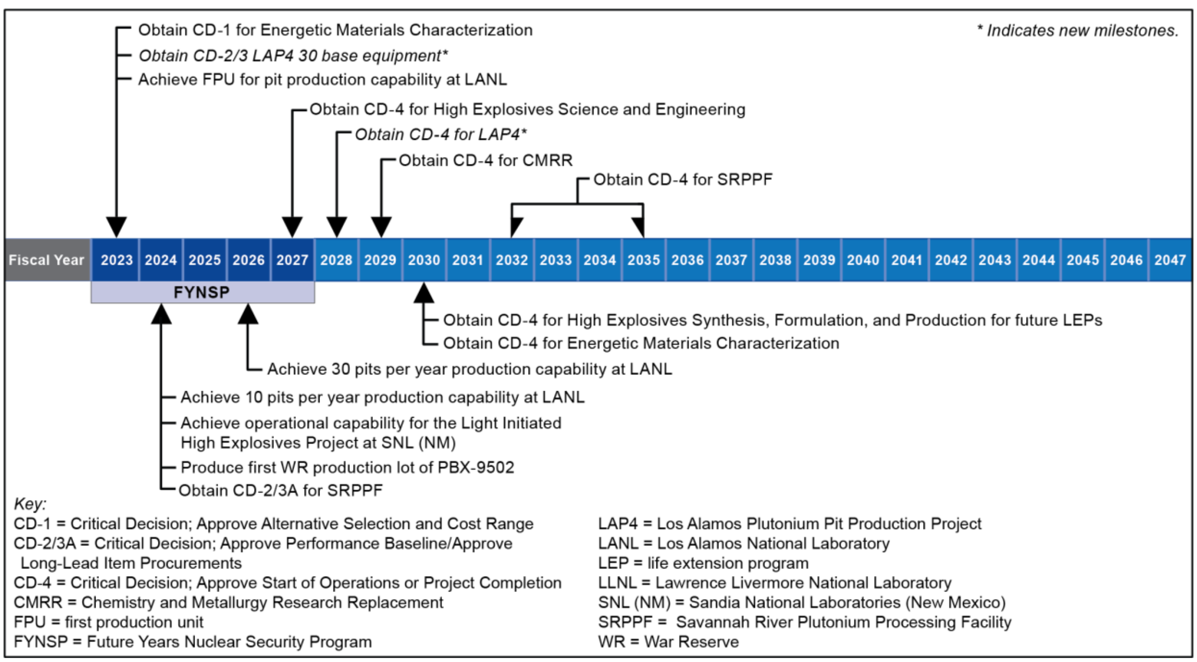


Figure 5–4. Key milestones for Primary Capability Modernization

5.5.3.2 Secondary Capability Modernization

Key milestones for Secondary Capability Modernization are in **Figure 5–5**. There were no substantive changes to the Secondary Capability Modernization milestones from last year's SSMP.[3]

One milestone from last year's SSMP was completed in FY 2022:

- *Qualify lithium small-scale purification, conversion, and reaction capabilities*

One milestone from last year's SSMP that was anticipated to be completed in FY 2022, "*Perform production melts for binary ingot*," is now anticipated to be completed in FY 2023 due to unexpected, prolonged production Vacuum Arc Remelt (VAR) equipment restart activities. Current test and development needs are being met by using development binary ingots from the development VAR at the Test and Demonstration Facility.

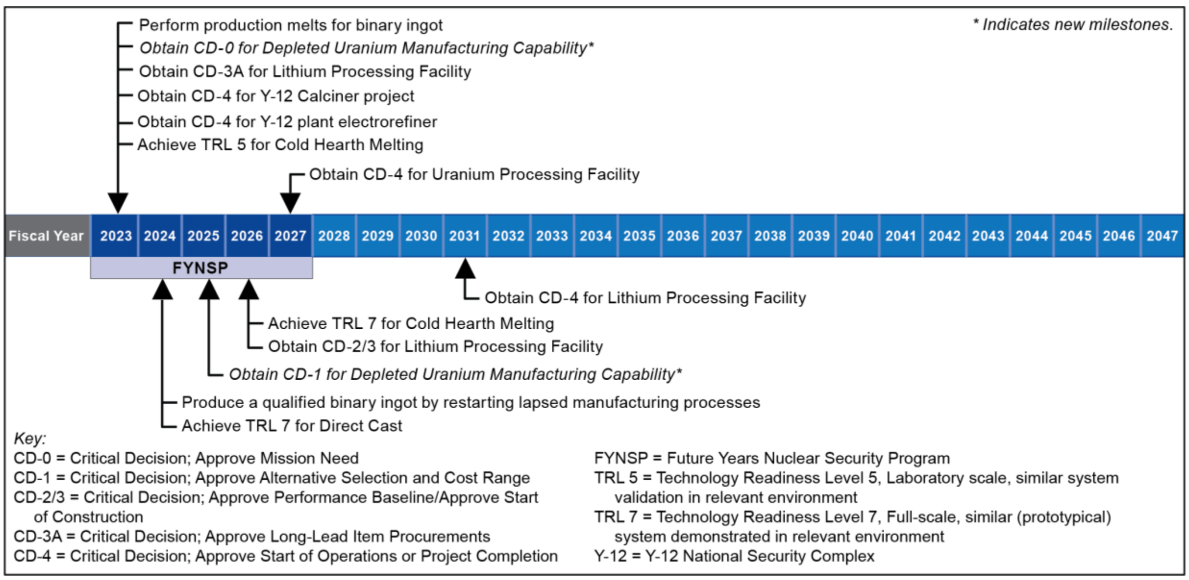


Figure 5–5. Key milestones for Secondary Capability Modernization

5.5.3.3 Tritium Modernization and Domestic Uranium Enrichment

Key milestones for Tritium Modernization and Domestic Uranium Enrichment are in **Figure 5–6**. Major changes from last year's plan related to Tritium Modernization and Domestic Uranium Enrichment are:

- The FY 2023 milestone, *Implement use of new TPBAR Transport Cask for four-fold increase in capacity*, is shifted to FY 2025 due to the current TPBAR irradiation schedules, which allow existing capabilities to meet transportation requirements through FY 2025.
- The FY 2024 milestone, *Obtain CD-2/3, Approve Performance Baseline/Approve Start of Construction, for Tritium Finishing Facility*, is delayed to FY 2026 due to revised Savannah River Nuclear Solutions cost and projected schedule baselines to achieve CD-2/3.
- The FY 2024 milestone, *Obtain CD-3A, Approve Long-Lead Item Procurements, for the Tritium Finishing Facility*, is shifted to FY 2025 after completion of the design performance baseline.[4]

[3] The original baseline date for the Uranium Processing Facility CD-4 approval of December 2025 is under review.
[4] NNSA completed the design performance baseline after completion of the FY 2023 Construction Project Data Sheet.

- The FY 2024 milestone, *Complete facility modifications to prepare for future demonstration of the ORNL small centrifuge*, changed to FY 2023 consistent with the FY 2023 President's Budget Request for the completion of this Minor Construction project.
- The FY 2041 milestone, *Obtain CD-4, Approve Start of Operations or Project Completion, for Domestic Uranium Enrichment Facility*, has a completion range of FY 2041 to FY 2044 to accommodate potential uncertainty in future tritium production requirements.

There were no milestones in last year's SSMP scheduled for completion in FY 2022.

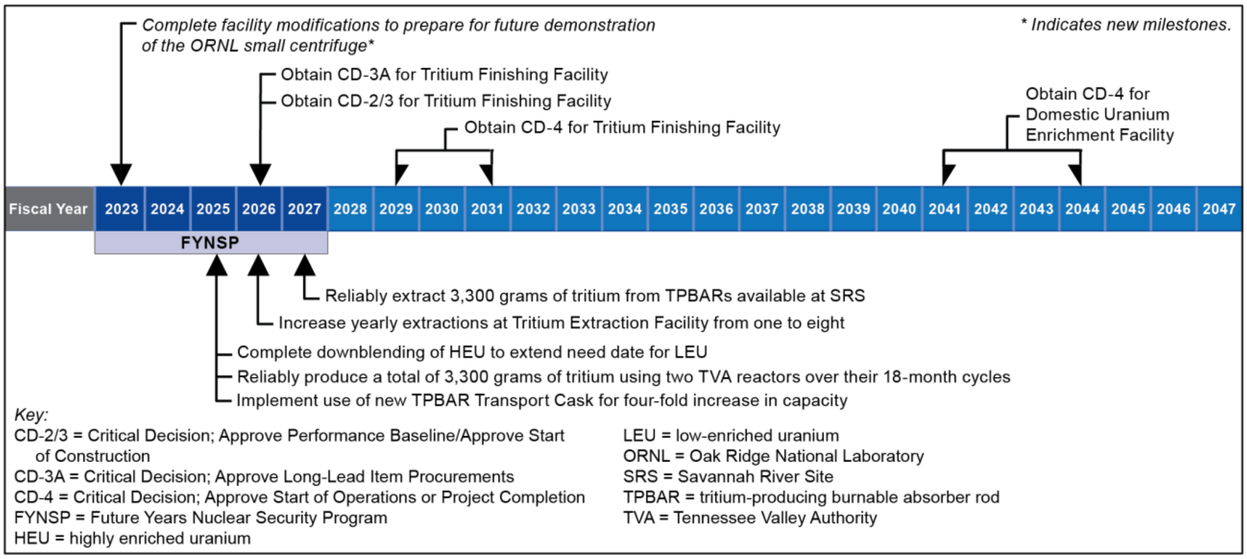


Figure 5–6. Key milestones for Tritium Modernization and Domestic Uranium Enrichment

5.5.3.4 Non-Nuclear Capability Modernization

Key milestones for Non-Nuclear Capability Modernization are in **Figure 5–7**. One milestone in last year's SSMP, *Complete NNCC Long Term Plan*, is no longer applicable and therefore not published in Figure 5–7. Major changes from last year's plan related to Non-Nuclear Capability Modernization are:

- The FY 2023 milestone, *Complete SNL Agile Facility final fitout and transition to operations*, is delayed to FY 2024 based on the construction contractor's draft schedule of completion in the first quarter of 2024 vice the fourth quarter of 2023 due to delays in obtaining materials and potential difficulties with hiring laborers.
- The FY 2023 milestone, *Finalize design and obtain CD-2/3 for Power Sources Capabilities*, is delayed to FY 2024 to accommodate a conceptual re-design after the original conceptual design was deemed unaffordable.
- The FY 2025 milestone, *Obtain KCNSC Short-Term Expansion Space*, has been delayed to FY 2027 to reflect the KCNSC Building 23 North completion timeline. KCNSC Short-Term Expansion Space is on schedule to complete buildout of the South end of Building 23 by FY 2026, and plans to additionally complete buildout of the North end of Building 23 by FY 2028.

- The FY 2026 milestone, *Obtain CD-4 Power Sources Capability*, is delayed to FY 2029 due to earlier design milestone delays and expected construction schedule challenges due to availability of craft in the greater Albuquerque area.
- The FY 2022 milestone, *Upgrade Annular Core Research Reactor Simulator*, is shifted to FY 2024 due to challenges with obtaining the necessary electronic components.

Four milestones from last year's SSMP were completed in FY 2022 or the first quarter of FY 2023:

- *Obtain CD-1 for Power Sources Capabilities*
- *Complete standup of Lawrence Livermore National Laboratory (LLNL) Polymer Enclave*
- *Complete Award of Construction for Agile Facility Build Out*

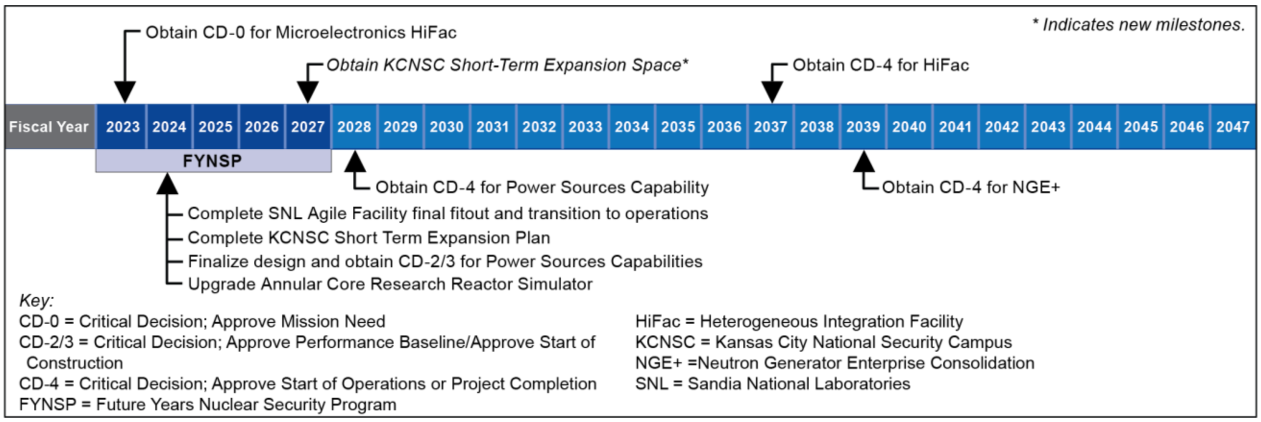


Figure 5–7. Key milestones for Non-Nuclear Capability Modernization

5.5.3.5 Capability Based Investments

CBI does not have its own milestones since its numerous, relatively low-cost, short duration projects, enable activities that support other programs' milestones.

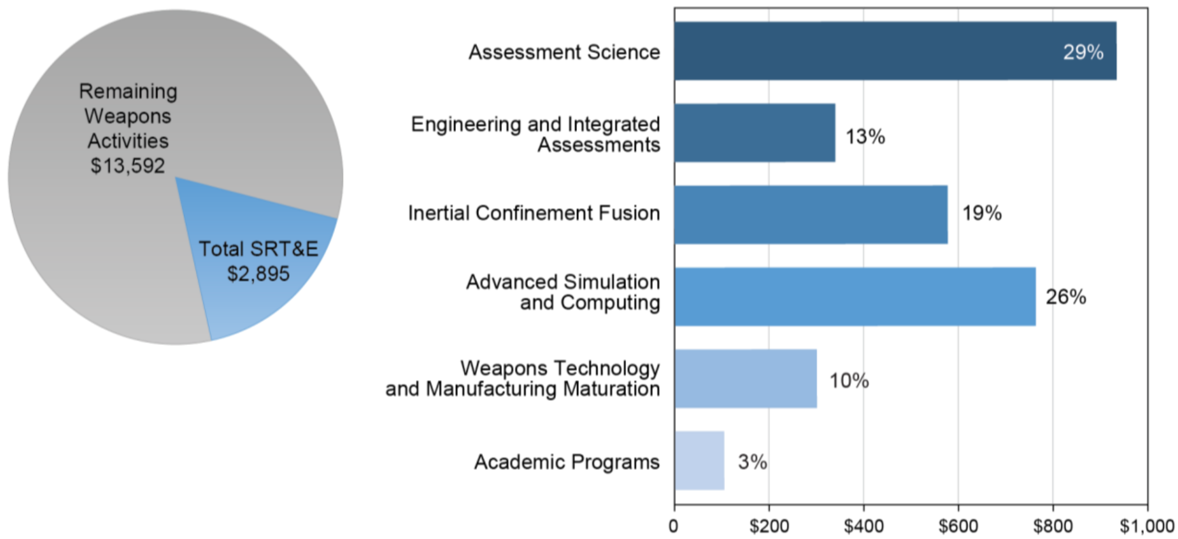
5.6 Stockpile Research, Technology, and Engineering

Stockpile Research, Technology, and Engineering (SRT&E) provides the knowledge and expertise needed to maintain confidence in the nuclear stockpile without additional nuclear explosive testing. SRT&E encompasses six major subprograms: (1) Assessment Science, (2) Engineering and Integrated Assessments, (3) Inertial Confinement Fusion (ICF), (4) Advanced Simulation and Computing (ASC), (5) Weapon Technology and Manufacturing Maturation, and (6) Academic Programs.

5.6.1 Budget

The budget request for SRT&E decreased 3.6 percent from the FY 2021 enacted budget (comparable structure) due to reductions in line-item construction project funding and is illustrated in **Figure 5–8**.

Stockpile Research, Technology, and Engineering Funding Request for FY 2023
(Dollars in Millions)



	2021 Enacted	2022 Enacted	Fiscal Year ($M) 2023	2024	2025	2026	2027
Assessment Science	930.0	904.4	854.8	948.5	744.1	679.8	689.6
Engineering and Integrated Assessments	337.4	342.1	366.5	366.9	434.4	481.4	539.4
Inertial Confinement Fusion	575.0	580.0	544.1	549.7	549.7	549.7	561.2
Advanced Simulation and Computing	761.2	747.0	742.6	753.8	753.8	753.8	769.4
Weapons Technology and Manufacturing Maturation	298.0	292.6	286.2	345.4	351.1	321.1	306.5
Academic Programs	101.9	111.9	100.5	102.5	104.6	106.7	108.8
Total SRT&E	3,003.5	2,978.0	2,894.7	3.066.8	2,937.7	2,892.5	2,975.0

Note: Numbers may not add due to rounding

Figure 5–8. FY 2023 President's Budget Request for Stockpile Research, Technology, and Engineering

5.6.2 FY 2023 Budget Request Compared to FY 2021 Enacted Budget

5.6.2.1 Assessment Science

Assessment Science provides the knowledge and expertise needed to maintain confidence in the nuclear stockpile in the absence of nuclear explosive testing. The program is comprised of six subprograms: (1) Primary Assessment Technologies, (2) Dynamic Materials Properties, (3) Advanced Diagnostics, (4) Secondary Assessment Technologies, (5) Enhanced Capabilities for Subcritical Experiments (ECSE), and (6) Hydrodynamic and Subcritical Experiment Execution Support. The U1a Complex (U1a) Enhancements Project line-item is also now captured within this program instead of Infrastructure and Operations.

The budget request for Assessment Science decreased, driven by reduced funding needs for U1a Enhancements that are partially offset by increases to support burn studies for boost science and analysis as well as ECSE procurements.

5.6.2.2 Engineering and Integrated Assessments

Engineering and Integrated Assessments is responsible for developing the foundational technologies and enterprise capabilities underpinning warhead survivability. These technologies and capabilities are matured and developed from a system agnostic perspective until a warhead's stockpile-to-target sequence is understood, ensuring a responsive nuclear deterrent through collaborative partnerships, proactive integration, and assessments. This program includes seven subprograms: (1) Archiving and Support, (2) Delivery Environments, (3) Weapons Survivability (previously Nuclear Survivability), (4) Studies and Assessments, (5) Aging and Lifetimes, (6) Stockpile Responsiveness, and (7) Advanced Certification and Qualification. The Combined Radiation Environments for Survivability Testing (CREST) line-item project now resides within this program instead of Infrastructure and Operations.

The budget request for Engineering and Integrated Assessments increased to support:

- Conceptual design costs for CREST—the increased funding for CREST is partially offset by shifting resources from all Engineering and Integrated Assessments' programs to support higher priority NNSA efforts.
- Studies and Assessments to support pre-*Phase X/6.X* studies, which focus on the conduct and management of refurbishment activities of existing weapons per the Phase 6.X guidelines, in addition to feasibility assessments of future nuclear weapon stockpile requirements.

5.6.2.3 Inertial Confinement Fusion

ICF provides high energy density (HED) science capabilities and expertise that support research and testing across the breadth of stockpile stewardship. Its two-fold mission is to meet immediate, and emerging, HED science needs to support the deterrent of today and to advance the R&D capabilities necessary to meet those needs for the deterrent of the future. The program includes three subprograms: (1) HED and Ignition Science for Stockpile Applications, (2) ICF Diagnostics and Instrumentation, and (3) Facility Operations.

The budget request for ICF decreased to use available carryover while prioritizing support for maturing experimental platforms to execute HED experiments critical to supporting stockpile needs.

5.6.2.4 Advanced Simulation and Computing

ASC provides high-end simulation capabilities (e.g., modeling codes, computing platforms, and supporting infrastructure) to meet stockpile stewardship requirements. ASC provides the weapon codes that provide the integrated assessment capability supporting annual assessment, future sustainment program qualification and certification of warheads on entry into the stockpile. The program includes six subprograms: (1) Integrated Codes, (2) Physics and Engineering Models, (3) Verification and Validation, (4) Advanced Technology Development and Mitigation, (5) Computational Systems and Software Environment, and (6) Facility Operations and User Support. The Exascale Computing Facility Modernization line-item project now falls within the ASC program instead of Infrastructure and Operations.

The overall decrease in the budget request for ASC is due to Exascale Computing Facility Modernization project completion, while funding for the rest of ASC increased slightly.

5.6.2.5 Weapon Technology and Manufacturing Maturation

Weapons Technology and Manufacturing Maturation is responsible for developing agile, affordable, assured, and responsive technologies and capabilities for nuclear stockpile sustainment and modernization to enable the future success of the nuclear security enterprise. It is comprised of three subprograms: (1) Surety Technologies, (2) Weapon Technology Development, and (3) Advanced Manufacturing Development.

The budget request for Weapons Technology and Manufacturing Maturation decreased due to:

- The transfer of quality assurance scope and funding from Weapon Technology Development to the Stockpile Management/Production Operations
- The transfer of direct cast scope and funding from Advanced Manufacturing Development to the Secondary Capability Modernization program within the Office of Production Modernization
- The shift of resources from the three Weapon Technology and Manufacturing Maturation programs to support higher priority DOE/NNSA efforts

5.6.2.6 Academic Programs

Academic Programs support investments in science and engineering disciplines critically important to the nuclear security enterprise. Funding provided for the program's grants, research centers of excellence, fellowships, and other activities offers individuals an introduction to the mission and people of the national laboratories and helps establish a workforce pipeline to strengthen the future enterprise. Academic Programs includes five subprograms: (1) Stewardship Science Academic Alliance, (2) Minority Serving Institution Partnership Program, (3) Joint Program in High Energy Density Laboratory Plasmas, (4) Computational Science Graduate Fellowships, and (5) Predictive Science Academic Alliance Program.

The slight decrease in the budget request for Academic Programs reflects reprioritization of Stewardship Science Academic Alliance, while supporting existing awards until completion.

5.6.3 Key Milestones

The Stewardship Capability Delivery Schedule is used to align SRT&E programs with mission objectives, coordinate efforts across Defense Programs, and communicate with internal and external stakeholders. Other high-level planning activities, such as the National Plutonium Aging Science Plan, serve as vehicles for coordinating work in specific areas of mission need. Key milestones for SRT&E are illustrated in **Figure 5–9**. Major changes from last year's plan are:

- The FY 2022 milestone, *Accept ATS-3/Crossroads Phase 1 computing platform, is shifted to FY 2023 due to supply chain challenges, as well as application and software issues.*
- The FY 2023 milestone, *Accept ATS-4/El Capitan exascale computing platform,* is now correctly shown in FY 2024 and was previously published in error.
- The FY 2023 milestone, *Complete Advanced Sources and Detectors (ASD) accelerator injector testing at the integrated test stand*, is delayed to FY 2026 due to COVID-19 and supply chain issues associated with delivery of materials. ASD was in the design phase during COVID-19, which caused delays as designers could not come to laboratories to work using CAD machines, and many parts ordered for prototyping were delayed due to vendor staffing.
- The FY 2025 milestone, *Obtain CD-4 for ASD-Scorpius*, is delayed to FY 2027 due to COVID-19 and supply chain issues associated with delivery of materials.
- The FY 2024 milestone, *Execute Excalibur Experiment (ECSE reactivity)*, is delayed to FY 2025 due to an updated subcritical experiments (SCE) schedule.
- The FY 2025 milestone, *Complete Red Sage & Nimble subcritical experiment campaigns*, is delayed to FY 2026 due to an updated SCE schedule.
- The FY 2026 milestone, *Execute Sherman Experiment (ECSE plutonium radiograph)*, is delayed to FY 2028 due to an updated SCE schedule.

Three milestones from last year's SSMP were completed in FY 2022:

- *Complete construction of Exascale Computing Facility Modernization*
- *Obtain CD-2/3 for ASD-Scorpius*
- *Qualify and deploy a new scintillator for Confined Large Optical Scintillator Screen and Imaging System (CoLOSSIS) I and II*

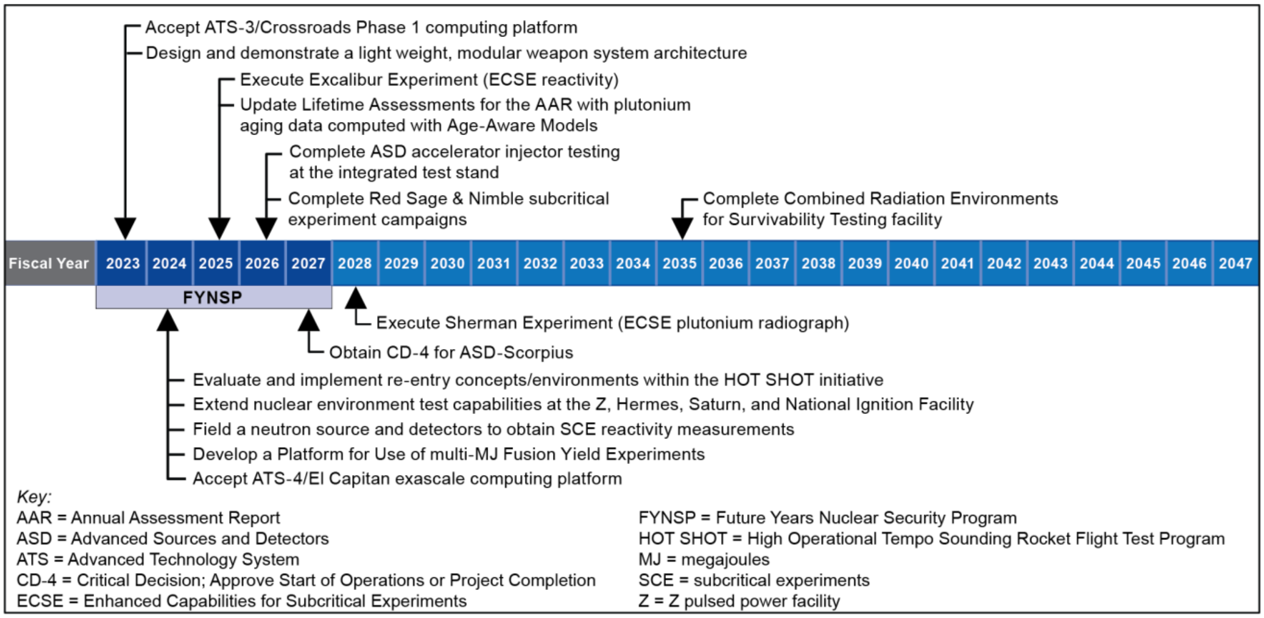


Figure 5–9. Key milestones for Stockpile Research, Technology, and Engineering

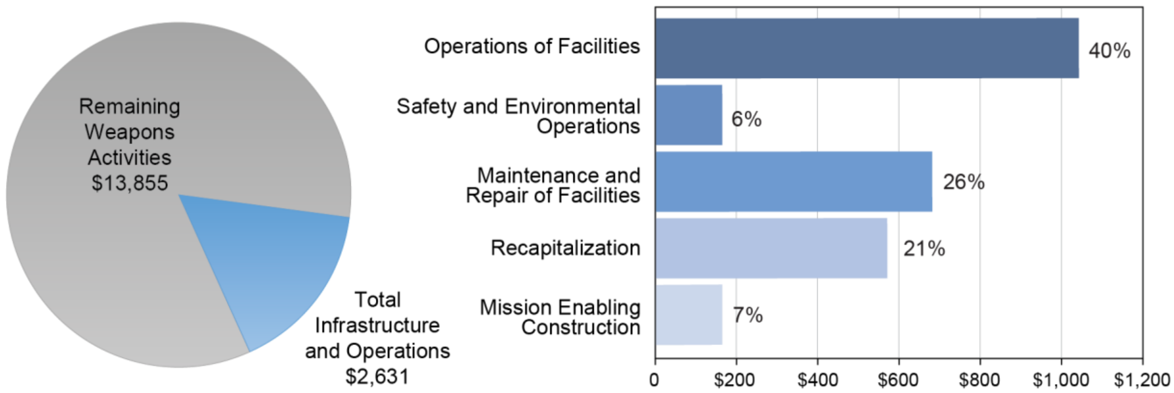
5.7 Infrastructure and Operations

Infrastructure and Operations maintains, operates, and modernizes DOE/NNSA's infrastructure in a safe, secure, and cost-effective manner to support all DOE/NNSA programs. Infrastructure and Operations takes a comprehensive approach to modernizing DOE/NNSA's infrastructure while maximizing return on investment, enabling program results, and reducing enterprise risk. The program also plans, prioritizes, and constructs mission-enabling facilities and infrastructure. Infrastructure and Operations includes (1) Operations of Facilities, (2) Safety and Environmental Operations, (3) Maintenance and Repair of Facilities, (4) Recapitalization, and (5) Line-Item Construction. Capabilities Based Investments, previously under Recapitalization, now resides under Production Modernization, and programmatic construction projects have shifted to their relevant programs. Additional information about Infrastructure and Operations can be found in Chapter 4, "Infrastructure and Operations."

5.7.1 Budget

The budget request for Infrastructure and Operations increased 3.5 percent from the FY 2021 enacted budget (comparable structure) and is illustrated in **Figure 5–10**.

Infrastructure and Operations Funding Request for FY 2023
(Dollars in Millions)



	Fiscal Year ($M)						
	2021 Enacted	2022 Enacted	2023	2024	2025	2026	2027
Operations of Facilities	1,014.0	1,014.0	1,038.0	1,144.0	1,182.0	1,222.0	1,250.0
Safety and Environmental Operations	165.4	165.4	162.0	161.0	167.0	167.0	171.0
Maintenance and Repair of Facilities	667.0	700.0	680.0	711.0	727.0	743.0	751.0
Recapitalization	573.7	600.0	561.7	580.5	582.2	604.2	666.4
Mission Enabling Construction	122.0	8.0	189.3	178.5	184.5	157.7	133.7
Total Infrastructure and Operations	2,542.1	2,487.4	2,631.0	2,775.0	2,842.7	2,893.9	2,972.1

Note: Numbers may not add due to rounding

Figure 5–10. FY 2023 President's Budget Request for Infrastructure and Operations

5.7.2 FY 2023 Budget Request Compared to FY 2021 Enacted Budget

5.7.2.1 Operations of Facilities

Operations of Facilities provides the funding required to operate DOE/NNSA facilities in a safe and secure manner and is fundamental to achieving DOE/NNSA's plutonium, uranium, tritium, lithium, HE, and other mission objectives. This program includes essential support, such as water and electrical utilities, safety systems, lease agreements, and activities associated with Federal, state, and local environmental, worker safety, and health regulations.

The budget request for Operations of Facilities increased to support:

- The Plutonium Modernization mission, including the production of at least 30 ppy at Los Alamos National Laboratory (LANL)
- Operations support personnel to complete 100 percent of SRS mission deliverables, including LEP requirements and gas transfer system surveillance requirements per schedule
- Increased safety basis needs at the Pantex Plant (Pantex)

Note: The increase is partially offset by a transfer of scope for programmatic equipment maintenance at SNL to the Production Operations program.

5.7.2.2 Safety and Environmental Operations

Safety and Environmental Operations provides DOE's Nuclear Criticality Safety Program, Nuclear Safety Research and Development, Packaging subprogram, Long Term Stewardship subprogram, and Nuclear Materials Integration subprogram. These activities support safe, efficient operation of the nuclear security enterprise by providing safety data, nuclear material packaging, environmental monitoring, and nuclear material tracking.

The decrease to the budget request for Safety and Environmental Operations reflects a small adjustment to reduce uncosted balances. This is offset by an increase for additional support for the Material Managers at the sites under the Nuclear Materials Integration Program.

5.7.2.3 Maintenance and Repair of Facilities

Maintenance and Repair of Facilities provides direct-funded maintenance activities across the nuclear security enterprise for the recurring daily work required to sustain and preserve DOE/NNSA facilities and facility-related equipment in a condition suitable for their designated purpose. These efforts include predictive, preventive, and corrective maintenance activities to maintain facilities, property, assets, systems, roads, and vital safety systems.

The budget request for Maintenance and Repair of Facilities increased to support:

- The Plutonium Modernization mission, including the production of at least 30 ppy at LANL
- Increased maintenance needs at SNL to support the Microsystems Engineering, Science, and Applications Extended Life Program
- Transfer of the Waste Solidification Building at SRS from the Material Management and Minimization's Material Disposition subprogram within Defense Nuclear Nonproliferation

Note: The increase is partially offset by a transfer of scope for programmatic equipment maintenance at KCNSC to the Production Operations program.

5.7.2.4 Recapitalization

Recapitalization modernizes DOE/NNSA's infrastructure by prioritizing investments to improve the condition and extend the life of structures, capabilities, and systems, thereby improving the safety and quality of the workplace. Funding is used to address numerous obsolete support and safety systems, revitalize facilities that are beyond the end of their design life, address climate adaptability and resilience, and improve the reliability, efficiency, and capability of infrastructure to meet mission requirements. Recapitalization investments help achieve operational efficiencies and reduce safety, security, environmental, and program risk. The Recapitalization program includes minor construction projects, real property purchases, planning, other project costs for Infrastructure and Operations-funded mission enabling infrastructure, and deactivation and disposal of excess infrastructure.

The decrease of the budget request for Recapitalization reflects a realignment to Mission Enabling Construction to address modernizing larger projects.

5.7.2.5 Line-Item Construction

Construction is critical in revitalizing the nuclear security enterprise. These projects will replace obsolete, unreliable facilities and infrastructure to reduce safety and program risk while improving responsiveness, capacity, and capabilities. NNSA uses a prioritization methodology for mission enabling line-item construction that evaluates investments on closing mission gaps, reducing infrastructure risk and safety risk, improving sustainability, and reducing deferred maintenance. Programmatic construction no longer falls under this subprogram, and instead was shifted to the respective programs.

The budget request for Mission Enabling Construction includes funding in FY 2023 for:

- Design for the Electrical Power Capacity Upgrade at LANL
- Plutonium Modernization Operations and Waste Management Office Building at LANL
- Construction for the Special Materials Facility at the Y-12 National Security Campus (Y-12)
- The transition to construction for the Digital Infrastructure Capability Expansion project at LLNL

Additional information on planned line-item investments can be found in Chapter 4, "Infrastructure and Operations."

5.7.3 Key Milestones

Key milestones for Programmatic Construction are shown in the relevant program sections within this chapter, as program mission execution often depends on completion of line-item projects. Schedules for the highest priority Programmatic and Mission Enabling project proposals are displayed in Chapter 4, Figures 4–5 through 4–12. Projects proposed within the FYNSP have higher-fidelity estimates, and some planned projects in the out-years may decide to use alternative strategies other than a line-item project once each respective Analysis of Alternatives (AoA) is completed.

Per the *National Defense Authorization Act for Fiscal Year 2018*, DOE/NNSA established the Infrastructure Modernization Initiative (IMI) program. Per the *National Defense Authorization Act for Fiscal Year 2022*, Congress amended the IMI to require reducing deferred maintenance (DM) per replacement plant value (RPV) by not less than 45 percent by 2030. The IMI will be carried out by infrastructure recapitalization, maintenance and repair of facilities, and construction programs. The initial plan was transmitted to Congress in September 2018 and an updated plan was delivered in October 2022.

5.7.4 Infrastructure Maintenance and Recapitalization Investments

As part of the IMI, DOE/NNSA is using BUILDER, a system developed by the Army Corps of Engineers and recognized by the National Academy of Sciences as a best-in-class practice for infrastructure management. The BUILDER system uses comprehensive inventory, life cycle, cost, and assessment data and risk-informed standards and policies to recommend repairs, and replacements, at the most opportune time, thus improving DOE/NNSA's ability to pinpoint and prioritize investments. Historical approaches greatly underestimated the RPV of DOE/NNSA's facilities. As shown in **Table 5–2**, DOE/NNSA's new calculated RPV is $124.9 billion based on end-of-year data. The DM backlog is tied to RPV as it costs more to repair a more expensive facility, therefore, as expected, DM increased with the deployment of DOE/NNSA's new, more accurate, data-driven approach from $5.8 billion as of FY 2020 to $6.1 billion as of FY 2021. The overall physical condition of DOE/NNSA's infrastructure did not decline.

Table 5–2. DOE/NNSA deferred maintenance as a percentage of Replacement Plant Value

Metric	*FY 2019*	*FY 2020*	*FY 2021*
RN	$8.9B	$9.4B	$9.8B
DM	$4.8B	$5.8B	$6.1B
RPV	$124.3B	$116.3B	$124.9B
RN/RPV Ratio	7.16%	8.08%	7.88%
DM/RPV Ratio	3.85%	4.99%	4.90%

RN = repair needs
DM = deferred maintenance
RPV = replacement plant value

In response to GAO recommendations, this information is provided to improve transparency in the budget. **Table 5–3** compares investments in Maintenance and Recapitalization to benchmarks (based on the percentage of beginning of the year RPV) derived from the DOE Real Property Asset Management Plan and associated guidance. DOE/NNSA has decreased recapitalization investments by $25 million from FY 2022 to FY 2023 to support additional construction of larger facilities. Recapitalization continues to include deactivation and demolition of excess, and underused, facilities to reduce DOE/NNSA's footprint. Maintenance investments reflect a decreased funding level from FY 2022 to FY 2023 due to the unanticipated increase above the request level in FY 2022. Overall funding for maintenance has grown significantly, but appropriately, over the last several years. This sustained funding level will support current maintenance staffing levels to maintain and preserve facilities in a condition suitable to meet an increasing mission demand. DOE/NNSA also continues to use targeted asset management programs that use supply chain management practices to increase purchasing power for common building components across the nuclear security enterprise (e.g., roofs and heating, ventilating, and air conditioning).

Table 5–3. Projected FY 2023 DOE/NNSA infrastructure maintenance and recapitalization investments[5]

		FY 2021	*FY 2022*	*FY 2023*
Replacement Plant Value (RPV) ($B)		116.3	124.9	125.9
Maintenance Benchmark 2–4% RPV	Infrastructure and Safety Maintenance Investments ($K)	667,000	700,000	680,000
	Other NNSA Maintenance Investments (direct and indirect funded) ($K)	286,397	284,090	284,434
	Total NNSA Maintenance Investments ($K)	953.397	984,090	964,434
	Maintenance as % RPV	0.76%	0.78%	0.76%
Recapitalization Benchmark 1%	Infrastructure and Safety Recapitalization Investments ($K)	573,717	600,000	561,663
	Other NNSA Recapitalization Investments ($K)	331,979	393,716	407,393
	Total NNSA Recapitalization Investments ($K)	905,696	993,716	969.056
	Recapitalization as % RPV	0.73%	0.79%	0.76%

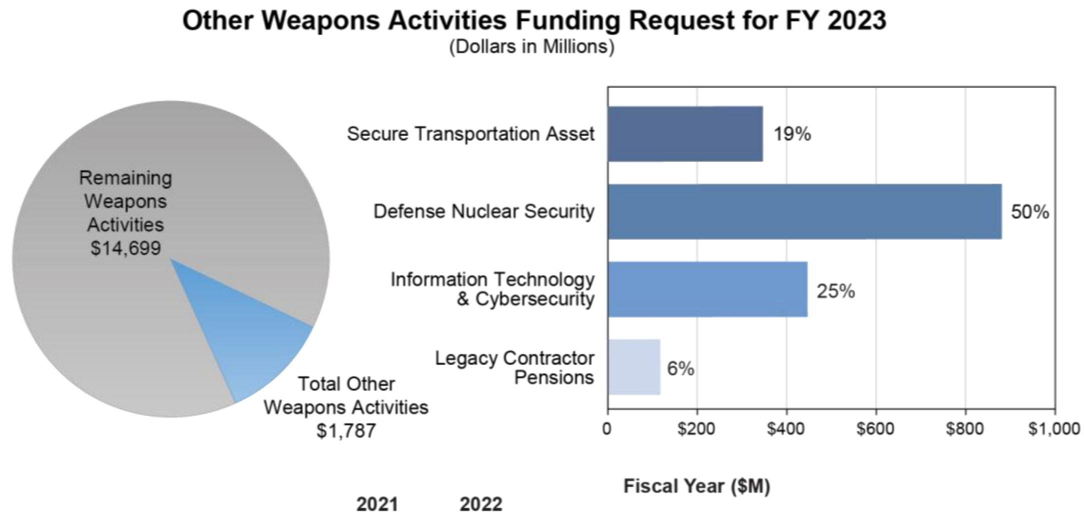
$B = billion dollars
$K = thousand dollars

5.8 Other Weapons Activities

5.8.1 Budget

The funding schedule for Other Weapons Activities is illustrated in **Figure 5–11**.

[5] These values do not include Naval Reactors investments.



	2021 Enacted	2022 Enacted	2023	2024	2025	2026	2027
Secure Transportation Asset	348.7	330.8	344.4	354.7	381.0	389.0	442.1
Defense Nuclear Security	789.1	844.1	882.3	927.6	955.3	991.5	1,049.2
Information Technology & Cybersecurity	366.2	406.5	445.7	494.1	513.9	534.4	587.2
Legacy Contractor Pensions	101.7	78.7	114.6	73.5	77.6	79.2	80.9
Total Other Weapons Activities	1,605.7	1,660.0	1,787.0	1,849.8	1,927.8	1,994.2	2,159.4

Note: Numbers may not add due to rounding

Figure 5–11. FY 2023 President's Budget Request for Other Weapons Activities

5.8.2 Secure Transportation Asset

Secure Transportation Asset (STA) provides safe, secure transport of the Nation's nuclear weapons, weapon components, and special nuclear material throughout the nuclear security enterprise. STA includes two subprograms: (1) Operations and Equipment and (2) Program Direction. Operations and Equipment provides the transportation service infrastructure required for STA to meet DOE/NNSA's nuclear security activities. Program Direction provides salaries, travel, and other related expenses for Federal Agents and the secure transportation workforce.

5.8.2.1 FY 2023 Budget Request Compared to FY 2021 Enacted Budget

The budget request for Secure Transportation Asset decreased 1.2 percent from FY 2021.

The overall budget request for Operations and Equipment decreased due to the completion of aircraft procurement in FY 2021, however, an increase is requested for the Mobile Guardian Transporter (MGT) subprogram to support its schedule deliverables including:

- Continued development of Engineering Releases
- Continued Pre-Production Unit stage builds
- Validation of the Pre-Production Unit manufacturing process
- Test Article 2 Crash Test

The budget request for Program Direction increased to support the transfer of support service contract costs from Operations and Equipment to Program Direction.

5.8.2.2 Key Milestones

Aging transportation assets must be replaced to meet, and maintain, convoy safety and security requirements. The STA milestones in **Figure 5–12** will enable DOE/NNSA to support evolving transportation requirements for the current and future stockpile.

Changes from last year's plan are:

- The FY 2037 milestone, *Complete MGT production*, is delayed to FY 2038 due to supply chain disruptions stemming from the COVID-19 pandemic; disruptions to materials and piece parts, and a loss of critical skills in the vendor bases are impacting deliverables. Custom electronic (printed wiring boards/printed wiring assembly) fabrication needed to support MGT has been especially impacted. This is a persistent issue, however, the MGT team is working to minimize future delays by looking at advanced purchases of materials needed for production to account for the extended delivery timeline.

One milestone from last year's SSMP, *Design and begin production of the next generation armored tractor and escort vehicle,* was anticipated to be completed in FY 2022 but was not completed. This milestone is now split into two separate milestones, *Design and begin production of the next generation armored tractor* and *Design and begin production of the next generation escort vehicle.*

- *Design and begin production of the next generation armored tractor* is delayed to 2025 due to inadequate vendor response. The program is evaluating the contracting vehicle and will continue pursuing this project.
- *Design and begin production of the next generation escort vehicle* is delayed to FY 2023. Prototypes are currently being evaluated, and final design review and production are anticipated to commence by the end of FY 2023.

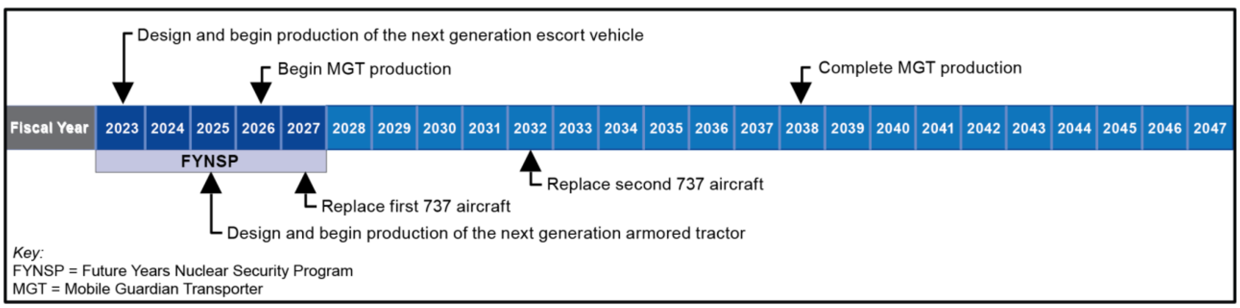


Figure 5–12. Key milestones for Secure Transportation Asset

5.8.3 Defense Nuclear Security

DOE/NNSA missions must be carried out in a secure environment protected by safeguards and security personnel, layers of physical security systems and technology, and sophisticated cybersecurity systems. Defense Nuclear Security (DNS) provides protection across the nuclear security enterprise for DOE/NNSA personnel, facilities, nuclear weapons, and materials from a full spectrum of threats, ranging from minor security incidents to acts of terrorism. The West End Protected Area Reduction (WEPAR) line-item project is also included within DNS.

5.8.3.1 FY 2023 Budget Request Compared to FY 2021 Enacted Budget

The budget request for DNS increased 11.8 percent from FY 2021 to FY 2023.

The budget request for DNS increased to support:

- Refined security requirements associated with growth across the nuclear security enterprise, including plutonium pit production and the Uranium Processing Facility
- Increased security requirements related to design-basis threat implementation and sustaining core security requirements

- Caerus, the highest priority Security Infrastructure Revitalization Program (SIRP) projects, and the highest priority initiatives for the Physical Security Center of Excellence and the Center for Security Technology, Analysis, Response, and Testing (CSTART)

Funding for the WEPAR line-item project decreased as construction moves toward completion.

5.8.3.2 Key Milestones

The SIRP refreshes aging security infrastructure across the enterprise based on a long-range plan that is modified periodically based on DOE/NNSA's budget, mission, and needs.

The DNS milestones in **Figure 5–13** are directly linked to modernization of the national security infrastructure and will assure that DOE/NNSA mission requirements for the current and future stockpile are carried out in a safe and secure environment. Changes from last year's plan are:

- The FY 2024 milestone, *Complete Y-12 WEPAR, PIDAS modernization, and entry control facility upgrade*, is shifted to FY 2025 to correct a mistake in the FY 2022 SSMP and align with the CD-4 date, as outlined in the approved CD-2/3 package.
- The FY 2026 milestone, *Complete Caerus cutover*, is delayed to FY 2027 due to the initial rollout delay, caused by supply chain issues.
- The FY 2029 milestone, *Complete Pantex Perimeter Intrusion Detection and Assessment System (PIDAS) physical security system components and infrastructure refresh for Zone 4*, is delayed to FY 2030 due to a reprioritization of SIRP projects.
- The FY 2030 milestone, *Complete SRS SRPPF PIDAS*, is shifted to FY 2029 to reflect the CD-4 date for the SRS SRPPF PIDAS project. The training and certification of all forces and systems for the SRS SRPPF PIDAS will be complete in FY 2031. This milestone previously read *Complete SRS PIDAS* and has been updated for clarity. [6]

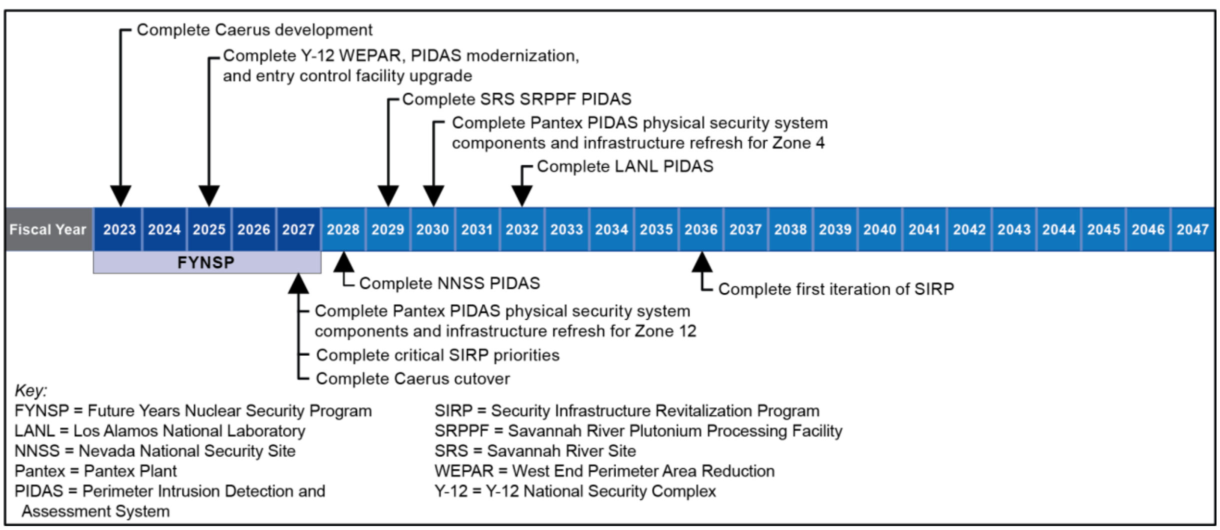


Figure 5–13. Key milestones for Defense Nuclear Security

[6] The SRS SRPPF PIDAS is funded through the SRPPF Safeguards and Security Subproject, which has a CD-2/3 date of FY 2024 and a CD-4 date of FY 2029. Since the PIDAS is a major milestone within that subproject, it is called out separately in this graphic.

5.8.4 Information Technology and Cybersecurity

The DOE/NNSA Office of the Associate Administrator for Information Management and Chief Information Officer (OCIO) supports IT and cybersecurity services and solutions, which include continuous monitoring, cloud-based technologies, and enterprise security technologies to help meet security challenges. The DOE/NNSA OCIO must provide a set of capabilities that enable the mission to increase organizational efficiency, protect information assets, enhance communication with internal and external partners, ensure continuous monitoring, and support effective incident response. DOE/NNSA OCIO executes a strong cybersecurity program that funds ongoing operations and invests in improvements across the nuclear security enterprise to meet the President's Executive Order 14028 to improve the nation's cybersecurity.

5.8.4.1 FY 2023 Budget Request Compared to FY 2021 Enacted Budget

The budget request for Information Technology and Cybersecurity increased 21.7 percent from FY 2021.

The FY 2023 budget request includes funding for the operation and modernization of the Emergency Communications Network previously funded under Emergency Operations within Defense Nuclear Nonproliferation.

The budget request for IT and Cybersecurity increased to support:

- Investments in cybersecurity tools and services provided to the enterprise
- Technology modernization investments for critical classified and unclassified systems

5.8.4.2 Key Milestones

The milestones in **Figure 5–14** are necessary steps toward achieving a modernized IT infrastructure and cybersecurity posture for the nuclear security enterprise. Several milestones with ongoing activities from last year's SSMP anticipated for completion in FY 2022 have been reworked and are not published again in Figure 5–14:

- *Implement Phase II of DOE/NNSA's IT Modernization Plan*
- *Begin architecture development of the classified wireless network for non-pit production facilities*
- *Deploy KCNSC hybrid cloud platform in support of Joint Technology Demonstrator project*
- *Perform cybersecurity program budget re-baseline site assessments*
- *Develop phase II system architecture for modernizing the Enterprise Secure Computing environment*
- *Implement special network access*
- *Implement the DOE/NNSA Application Modernization Strategy*
- *Implement a Telecommunications Security Program within DOE/NNSA*
- *Complete the modernization of the Information Assurance Response Center cybersecurity infrastructure*
- An additional milestone that was not published in last year's SSMP was completed in FY 2022:
- *Complete the external Institute for Defense Analyses cybersecurity assessment*

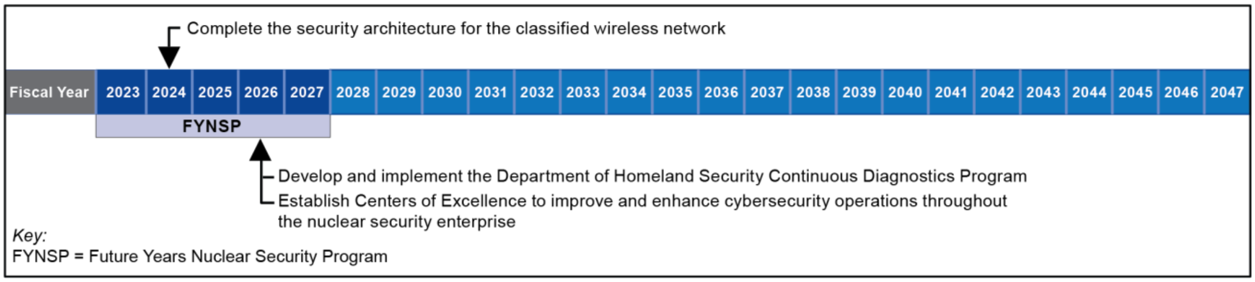


Figure 5–14. Key milestones for Information Technology and Cybersecurity

5.8.5 Legacy Contractor Pensions and Settlement Payments

Starting in FY 2022, Legacy Contractor Pensions and Settlement Payments includes funding to reimburse the University of California for a portion of a settlement reached in 2019 with former University of California employees of LLNL related to health care plans, as well as funding for DOE/NNSA's share of the unfunded liability of the Savannah River Nuclear Solutions pension plan. This budget line also continues to include the Weapons Activities share of the DOE's annual reimbursement made to the University of California Retirement Plan for former University of California employees and annuitants who worked at the LLNL and LANL.

5.9 Budget Projections Beyond FY 2027

This section explains the cost estimation methodology that DOE/NNSA uses to create long-term budget projections. These projections are used to evaluate, over a longer timeframe than considered in the FYNSP and during programming activities, the total required resources to accomplish the program of record, how those resources are allocated, and the overall affordability of the program (see Section 5.10).

5.9.1 Basis for Budget Projections

For most of Weapons Activities, the FY 2023–FY 2027 budget request was generated as part of the DOE/NNSA planning and programming process and reflects a roll-up of individual estimates developed interactively by Federal Program Managers and DOE/NNSA's M&O partners using historical cost data, current plans for programs and projects, and expert judgment. The budget requests for Stockpile Major Modernization programs are informed by the processes described in Section 5.9.2. The budget estimates for FY 2028 and beyond reflect the costs of continuing the FYNSP program described in this SSMP, while sustaining, and enhancing, the Weapons Activities capabilities that are essential to executing the stockpile mission.

The budget projections beyond the FYNSP are based on requirements and will vary, depending on the individual program or subprogram. Some portions of the Weapons Activities portfolio are assumed to continue beyond the FYNSP at the same level of effort as during the FYNSP.[7] For these cost projections, such as for Stockpile Sustainment, an escalation factor of 2.1 percent was applied.

Some portions of the program, primarily Stockpile Major Modernization programs and major programmatic construction projects, will not proceed at the same level of effort from FY 2028 through FY 2047. The estimates and the basis for each of these elements of the Weapons Activities portfolio are described in Sections 5.9.2–5.10.

[7] Projection of budget estimates for these efforts in this way assumes the continued manageability of whatever risks are present during the FYNSP at the same level of effort over the FYNSP period, as is typically represented by the funding level of the last year of the FYNSP.

5.9.2 Stockpile Major Modernization

Stockpile Major Modernization programs have the goal of extending the lifetime of the nation's nuclear stockpile while addressing required updates and improving their safety and security as possible. Figure 2–2 in Chapter 2, "Stockpile Management," provides a summary of planned Stockpile Major Modernization activities.

The next sections summarize cost estimates for Stockpile Major Modernization programs within the current 25-year period. The basis for the cost estimates varies from those using top-down cost models (such as analogy comparisons to past work completed, parametric relationships, and subject matter expert judgment) to those using bottom-up models (deterministic, unit cost, and activity-based). The decision to use the top-down cost model versus the bottom-up model is made depending on where the warhead program is in the *Phase X/6.X Process*, reflecting the maturity of the process.

Reflecting decisions made during the 2022 *Nuclear Posture Review*, no funding is requested for the W80-4 Alteration Sea-launched Cruise Missile-Nuclear (SLCM-N) program in the FY 2023 budget request. The program, following direction in the *Nuclear Posture Review*, has been removed from this section.

5.9.2.1 Cost Estimates across the *Phase X/6.X Process*

Figure 5–15 shows the governing cost estimate type for each phase of the *Phase 6.X Process* and the *Phase X Process*. DOE/NNSA works in conjunction with DoD and M&O partners to develop, refine, and update the estimates throughout these processes.

Phase 1/6.1	Phase 2/6.2	Phase 2A/6.2A	Phase 3/6.3[1]	Phase 4/6.4[1]	Phase 5/6.5[1]	Phase 6/6.6	Phase 7
Concept Assessment	Feasibility Study & Design Options	Design Definition and Cost Study	Development Engineering	Production Engineering	First Production	Full-Scale Production/ Sustainment	Retirement, Dismantlement and Disposal
Planning Estimate		Weapons Design and Cost Report	Baseline Cost Report reported as part of the Selected Acquisition Report				

[1]The Office of Cost Estimating and Program Evaluation conducts the DOE/NNSA independent cost review prior to Phase 2/6.2 and independent cost estimates prior to entry in Phases 3/6.3, 4/6.4 and 5/6.5.

Figure 5–15. Cost estimates across the *Phase 6.X Process*

The DOE/NNSA Office of Management and Budget, Office of Programming, Analysis and Evaluation develops and publishes major modernization planning cost estimates for the SSMP. These cost estimates are initiated at very early program maturity, often well before Phase 6.1, *Concept Assessment*, and are planning estimates for alternatives analysis, early programming, and budget deliberations. These planning estimates for Stockpile Major Modernization are:

- Based on a defined scope and cost uncertainty at the time and updated annually for the SSMP[8]

[8] Planning estimates assume scopes that are in line with current policy objectives (such as a commitment to surety upgrades) for the modernization effort. The Nuclear Weapons Council approves the specific scope for the weapon modernization program based on the alternatives developed during Phase 6.2/2. The cost estimate range used in a planning estimate reflects the uncertainty in implementing a single assumed point solution, rather than the range of every possible design solution.

- Inclusive of warhead modernization program (development and production) and non-warhead modernization program line-item costs that are critical to program success (namely Other Program Money and DoD costs)[9]
- Unconstrained by future budget availability, which may differ from future budget requests

These cost estimates are used to reflect the anticipated cost of each modernization program in the SSMP until the Weapon Design and Cost Report (WDCR) is approved for the effort. The estimate methodology is described in more detail in Section 5.9.2.2.

The WDCR is developed by the program teams responsible for the warhead modernization programs and provides cost estimates for design, qualification, production, and life cycle activities. The WDCR includes detailed multi-site input and, although primarily performed using a bottom-up approach, may contain other methodologies (e.g., parametric, analogous, and subject matter expertise). The WDCR developed during Phase 6.2A, *Design Definition and Cost Study,* is a key input into the Phase 6.2A study report to the Nuclear Weapons Council and is required prior to entry to Phase 6.3. Once approved by the Nuclear Weapons Council, the WDCR becomes the basis for the Selected Acquisition Report (SAR) to Congress required upon entry into Phase 6.3.

The Baseline Cost Report (BCR), which is also developed by the program team, formally updates the WDCR based on late development and pre-production activities. The BCR is updated based on refined scopes and schedule definitions (reflecting the increased maturity of the program) and represents a more definitive cost estimate than either the planning estimate or WDCR. The NNSA Administrator approves a program baseline, including the BCR, prior to Phase 6.3. The BCR supersedes previous cost estimates and becomes the program of record, which is transmitted annually to Congress as part of the SAR.

The DOE/NNSA Office of Cost Estimating and Program Evaluation conducts an independent cost review prior to Phase 6.2A, and independent cost estimates prior to entry into Phase 6.3, Phase 6.4, and 6.5, *First Production*.

5.9.2.2 DOE/NNSA Office of Management and Budget Cost Estimating Methodology

The DOE/NNSA's Office of Programming, Analysis and Evaluation planning estimates for Stockpile Major Modernization programs are developed in the following manner:

- Performed using a "top-down" analogy method that is consistent with early-stage planning[10]
- Informed by ongoing and past program costs (such as the development of the W76-1, B61-12, W88 Alt 370, W80-4, and production of the W76-1, B61-12 and W88 Alt 370) and the evaluation of the relative complexities of future systems[11]

[9] In estimating the cost of a warhead modernization program, the weapon programs depend on an adequately funded base of other DOE/NNSA capabilities, as well as activities that are incremental to that base, and reflect both each program's budgeted line-item and increments to other critical activities (such as early-stage technology maturation [called Other Program Money]). As the overall program integrator, the Federal Program Manager identifies the funding streams needed for the program to be successful and coordinated with other programs to ensure funding is available to support the modernization program

[10] Additional detail on the cost estimating methodology of DOE/NNSA's Office of Management and Budget planning estimates can be found in the technical paper, "Planning for the Future: Methodologies for Estimating U.S. Nuclear Stockpile Cost" (Lewis et al. 2016; Cost Engineering, 58 [5], pp. 6-12).

[11] These program and subject matter experts evaluate the relative scope complexity between the complete W76-1 and near-complete B61-12 LEP and W88 Alt 370 Program compared to each planned future warhead modernization program, which aids in providing a cost estimate range based on underlying technical and cost uncertainties.

- Based on time-phased development costs using a standard profile,[12] as well as production costs using a nonlinear cost growth profile similar to that of the W76-1
- Based on technical and programmatic inputs from Federal Program Managers, Federal site offices, and subject matter experts across the national security laboratories and nuclear weapons production facilities

Cost ranges reflect the underlying technical and modeling uncertainties of the programmatic scope at the time. During the early stages of warhead acquisitions (Phases 1/6.1 and 2/6.2), designs may experience scope changes due to ongoing down-select decisions regarding threshold and objective requirements, which may result in cost changes compared to those reported in previous SSMPs. These ranges will typically be greatest for earlier-stage programs and narrow over time. The cost estimates for future systems with little design definition were based on the W87-1 and W93 estimates, with an expanded range due to uncertainty in scope and quantities and in the escalation rate so far in the future.

5.9.2.3 Current Estimates

Figures 5–16 through 5–20 and Tables 5–4 through 5–12 provide cost estimates for each Stockpile Major Modernization program for the 25-year SSMP timeframe. **Table 5–4** delineates the type of cost estimate for each of the warhead modernization programs included in the 25-year plan. Additional details on the basis for each estimate are provided for each individual program in Sections 5.9.2.4 through 5.9.2.10.

Table 5–4. DOE/NNSA cost estimates for Stockpile Major Modernization Programs[13]

Stockpile Major Modernization Program	*Type of Cost Estimate*	*Total Estimated Cost (FY 2022 dollars in billions)*	*Total Estimated Cost (then-year dollars in billions)*
B61-12 LEP	BCR/SAR	9.6	8.3
W88 Alteration Program	BCR/SAR	3.0	2.8
W80-4 LEP	WDCR/SAR	10.4	11
W87-1 Modification Program[14]	Planning Estimate	10.4	12.5
W93 Program	Planning Estimate	14.1	19.8
Future Strategic Land-Based Warhead	Planning Estimate	13.3	20.2
Future Strategic Sea-Based Warhead	Planning Estimate	17.8	27.9
Future Air-Delivered Weapon	Planning Estimate	11.2	20.3

BCR= Baseline Cost Report
LEP = life extension program
SAR = Selected Acquisition Report
WDCR = Weapon Design and Cost Report

[12] See Lee, David. The Cost Analyst's Companion, 3rd ed., McLean, VA: Logistics Management Institute, McLean, VA.
[13] SAR and WDCR values are provided when available. For programs that only have a planning estimate, the proposed budget is provided; for programs pre-phase 1/6.1 the p90 value of a representative design and quantity is provided. Tables 8–5 through 8–13 provide values for a high and low estimate range, in addition to the SAR, WDCR, or planning estimate totals. Due to the differing types of cost estimates, the accuracy of these total program cost estimates varies.
[14] The total estimated costs for the W87-1 Modification program represent the midpoint between the p50 and p85 values.

Each Stockpile Major Modernization program section contains a summary table with high, low, and nominal (proposed budget or BCR/SAR value) estimates for DOE/NNSA and DoD, in constant FY 2022 and then-year dollars. Where appropriate, the tables also include pre-SAR values for pre-Phase 6.2 costs.[15] The low estimates presented in the tables and graphs as the green line represent the mid-point (p50) of the cost estimate. The high estimates continue to represent the 85th percent (p85) for the B61-12, W88 Alt 370, W80-4, W87-1, and W93; the estimate increased to the 90th percent (p90) for the future systems to reflect the greater uncertainty.

For early-stage programs using planning estimates (such as the W87-1 Modification Program), the figures and tables reflect the proposed FY 2023 FYNSP budget and, for years beyond FY 2023, the midpoint between the high and low estimates.

Items to consider when comparing estimates to one another:

- The constant-year cost totals in the tables are the most comparable because inflation effects become significant over warhead modernization activity timeframes. Consideration should also be given to the varying quantities of warheads being refurbished for each system. The FY 2023 SSMP's classified Annex provides additional information on production quantities.
- The then-year planning estimates in the tables and figures are derived from constant-year estimates using an escalation rate of 3.0 percent. This 3.0 percent rate represents an average of the individual site escalation rates as documented in current WDCR/BCR estimates. The WDCR and BCR program office estimates are developed at the site and component level, and therefore use the escalation rates specific to each site and function rather than an average.
- Published estimate ranges are meant to reflect the underlying technical and cost uncertainty of the assumed scope. Early-stage programs, particularly those before Phase 6.3, may experience significant scope changes because the Nuclear Weapons Council may update and/or down-select design options that significantly impact the work scope and cost estimate.
- Only the planning estimates include pre-Phase 6.2 costs. The WDCR and BCR/SAR estimates do not include these costs.

5.9.2.4 B61-12 Life Extension Program Cost Estimate

The B61-12 LEP received authorization to enter Phase 6.5 in FY 2021 and achieved first production unit in November 2021. In 2022, the Nuclear Weapons Council formally accepted the B61-12 into the stockpile and authorized Phase 6.6, *Full-Scale Production*. Additionally, all commercial off-the-shelf Base Metal Electrode capacitor components that experienced an issue in late 2019 have completed first production unit and are at or are ramping to full-rate production. The values for development and production costs in **Figure 5–16** and **Table 5–5** reflect DOE/NNSA's FY 2020 BCR update issued in November 2020, with an overall cost estimate of $8.3 billion (then-year dollars) and are unchanged from last year's SSMP. The B61-12 LEP completed its use of Other Program Money for multi-system production process improvements in FY 2022. The costs of these related programs are estimated to be $648 million.

[15] DoD amounts reflect the costs for weapon components for which DoD is responsible, such as arming and fuzing. While not budgeted or executed by DOE/NNSA, these costs reflect the program's best approximation and are published for transparency to better reflect anticipated all-in costs. The total estimated cost is provided because warhead modernization program profiles often have later portions that extend beyond the published 25-year SSMP timeframe.

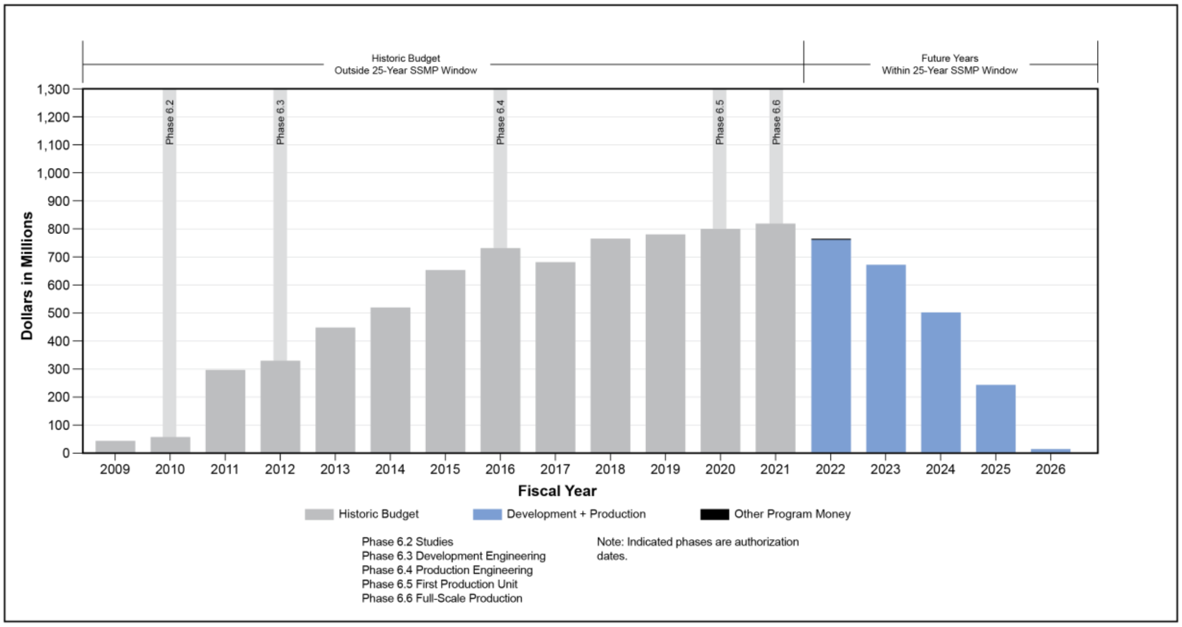


Figure 5–16. B61-12 Life Extension Program cost from FY 2009 to completion[16]

Table 5–5. Total estimated cost for B61-12 Life Extension Program

FY 2012–FY 2027 Dollars in Billions	DOE/NNSA		DoD[17]	
	FY 2022 Dollars	Then-Year Dollars	FY 2022 Dollars	Then-Year Dollars
Pre-SAR Cost	0.5	0.4	N/A	N/A
SAR Total	8.9	8.3	N/A	N/A
SAR OPM Total	0.8	0.6	N/A	N/A
Planning Estimate (High)[a]	10.0	9.4	0.2	0.2
Planning Estimate (Low)[a]	9.4	8.8	0.2	0.2

OPM = Other Program Money
SAR = Selected Acquisition Report
[a] Including OPM

5.9.2.5 W88 Alt 370 Cost Estimate

The W88 Alt 370 Program received authorization to enter Phase 6.5 in FY 2021 and completed the July 2021 first production unit per the baseline schedule. The Nuclear Weapons Council formally accepted the W88 Alt 370 into the stockpile in December 2021 and authorized Phase 6.6 entry in 2022. The current estimate is unchanged from the updated BCR issued by DOE/NNSA in September 2020, with an estimate of $2.8 billion (then-year dollars). The revised BCR was reconciled with the independent cost estimate performed by DOE/NNSA's Office of Cost Estimating and Program Evaluation. The W88 Alt 370 Program is continuing to use other DOE/NNSA programs for multi-system production process improvements. The estimated costs of these related programs (Other Program Money) remain unchanged at $171 million. The numbers in **Figure 5–17** and **Table 5–6** reflect the BCR update.

[16] The value for FY 2012 has been updated from previous SSMPs to represent the appropriate SAR value for that year. The SAR value represents money spent after Phase 6.3 approval in July 2012.
[17] The DoD costs in this table represent funds provided by DoD for work by DOE/NNSA on specific components, per cost sharing agreements between DoD and DOE/NNSA, and does not include work done exclusively by DoD, such as the B61-12 tail kits.

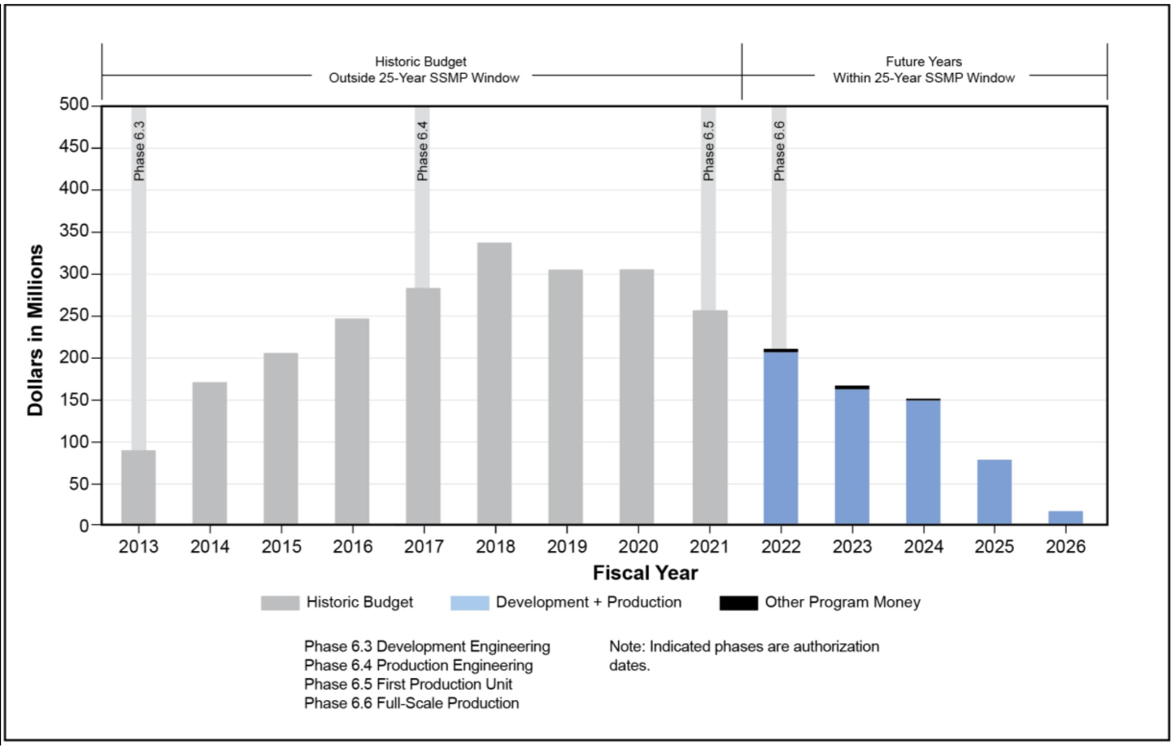


Figure 5–17. W88 Alteration 370 Program (with conventional high explosive refresh) from FY 2013 to completion

Table 5–6. Total estimated cost for W88 Alteration 370 Program (with conventional high explosive refresh)

FY 2013–FY 2027 Dollars in Billions	*DOE/NNSA*		*DoD*	
	FY 2022 Dollars	*Then-Year Dollars*	*FY 2022 Dollars*	*Then-Year Dollars*
Pre-SAR Cost	0.1	0.1	N/A	N/A
SAR Total	3.0	2.8	N/A	N/A
SAR OPM Total	0.2	0.2	N/A	N/A
Planning Estimate (High)[a]	3.2	3.1	1.0	1.0
Planning Estimate (Low)[a]	3.1	2.9	1.0	0.9

OPM = Other Program Money
SAR = Selected Acquisition Report
[a] Including OPM

5.9.2.6 W80-4 Life Extension Program Cost Estimate

In FY 2019, the W80-4 LEP completed its WDCR and entered Phase 6.3 in which the design will continue to be refined. Prior to entry into Phase 6.4 in FY 2023, the W80-4 program will publish its BCR, an update to the WDCR. The W80-4 LEP is on track to support fielding the Air Force's scheduled Long Range Standoff cruise missile initial and final operational capability dates. The current cost estimate is displayed in **Figure 5–18** and **Table 5–7**.

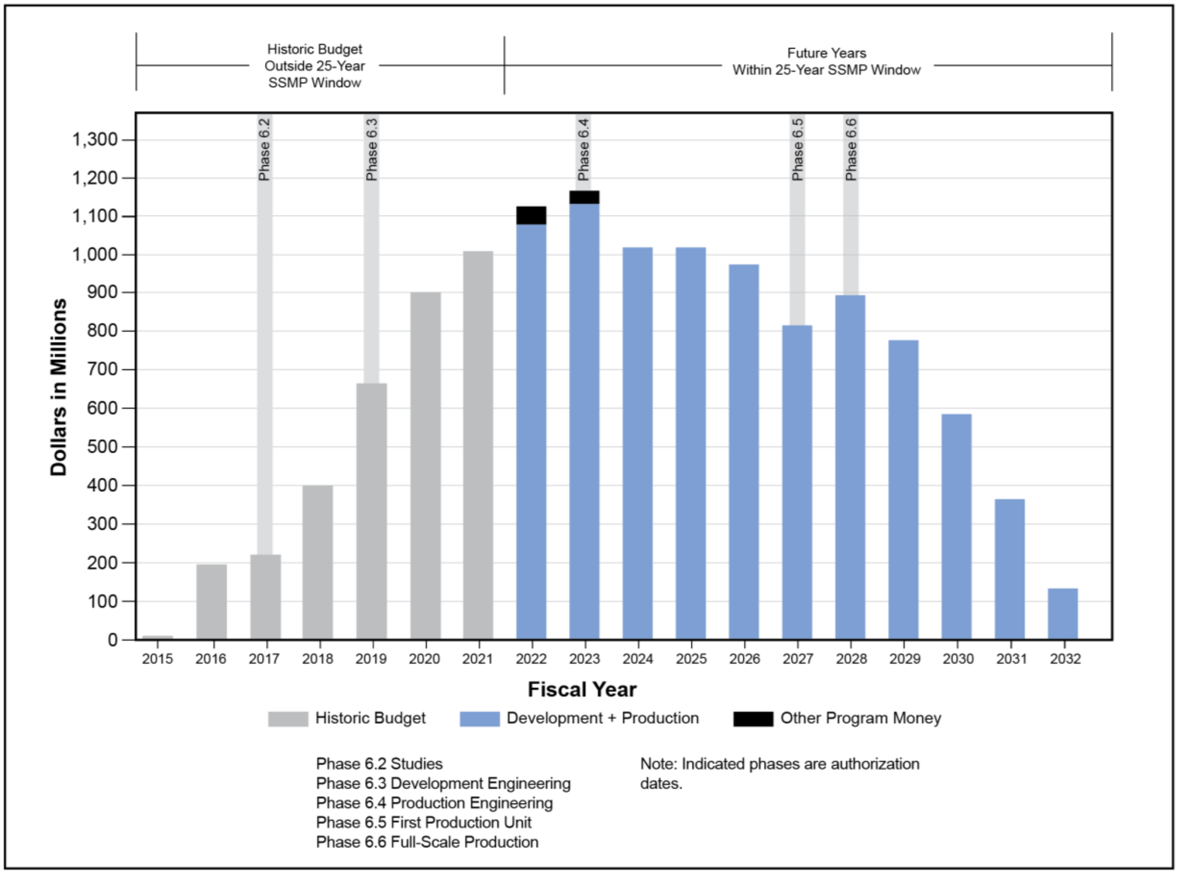


Figure 5–18. W80-4 Life Extension Program cost from FY 2015 to completion

Table 5–7. Total estimated cost for W80-4 Life Extension Program

FY 2015–FY 2032 Dollars in Billions	DOE/NNSA		DoD	
	FY 2022 Dollars	Then-Year Dollars	FY 2022 Dollars	Then-Year Dollars
SAR Total	10.4	11.0	N/A	N/A
SAR OPM Total	0.2	0.2	N/A	N/A
Planning Estimate (High)[a]	11.8	12.8	0.2	0.2
Planning Estimate (Low)[a]	10.3	11.1	0.1	0.1

OPM = Other Program Money

SAR = Selected Acquisition Report

[a] Including OPM

5.9.2.7 W87-1 Modification Program Cost Estimate

In February 2019, the Nuclear Weapons Council authorized a restart of Phase 6.2 activities for the W87-1 Modification Program, and the program is slated to deploy on the LGM-35A Sentinel, previously referred to by the generic name of Ground Based Strategic Deterrent, in the early 2030s. In 2019, the Nuclear Weapons Council reviewed a series of surety architecture design options, to include detailed risk/benefit and cost analyses, before selecting a single surety option for W87-1 Modification Program. DOE/NNSA continues to evaluate other component design options and trades. In FY 2021, the W87-1 Modification Program completed Phase 6.2 and entered Phase 6.2A. The cost estimate in **Figure 5–19** represents the latest projected program cost reflecting downselect and trade studies completed in Phase 6.2, and the FYNSP is informed by the ongoing WDCR. The estimates in Figure 5–19 and **Table 5–8** do not include costs associated with the production of plutonium pits for the W87-1 Modification Program. Those costs are contained in Plutonium Modernization.

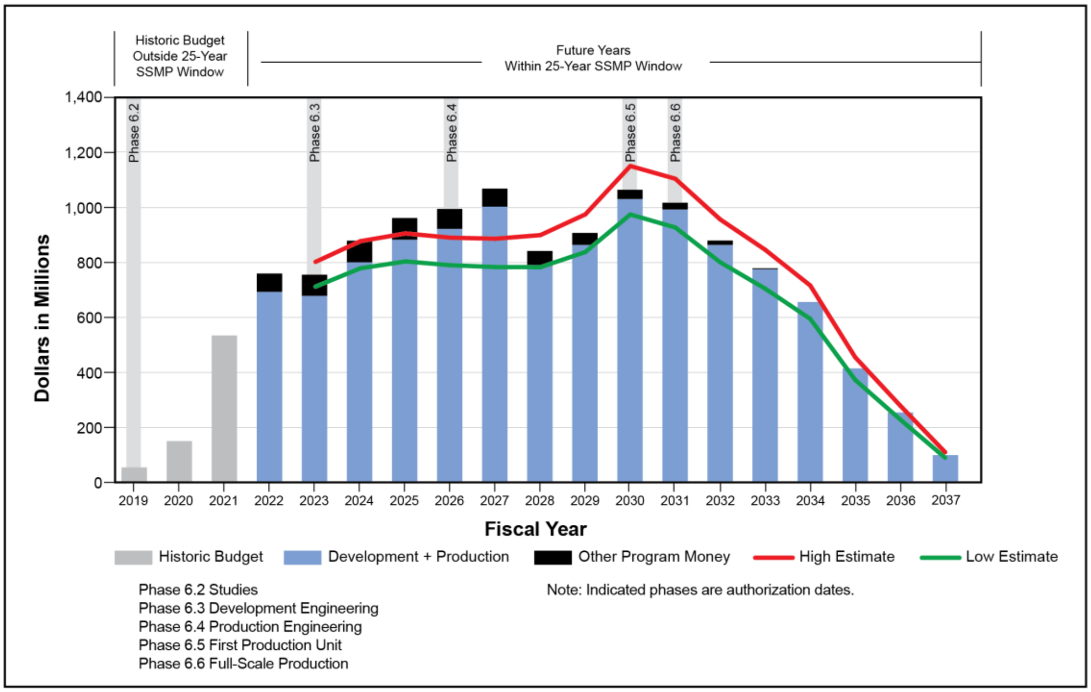


Figure 5–19. W87-1 Modification Program cost from FY 2019 to completion[18]

Table 5–8. Total estimated cost for W87-1 Modification Program

FY 2019–FY 2037 Dollars in Billions	DOE/NNSA		DoD	
	FY 2022 Dollars	Then-Year Dollars	FY 2022 Dollars	Then-Year Dollars
Planning Estimate (High)[a]	10.6	12.6	0.4	0.5
Planning Estimate (Low)[a]	9.3	11.1	0.3	0.4
Proposed Budget	10.4	12.5	N/A	N/A

[a] Including Other Program Money

5.9.2.8 W93 Program Cost Estimate

The W93 Program will mitigate future risk to the sea leg of the nuclear triad and address the changing strategic environment. DOE/NNSA is coordinating with DoD on specific requirements and design options for the W93 Program, which entered Phase 2 in FY 2022. The W93 Program cost estimate (see **Table 5–9**) is based on preliminary assumptions for one of the W93 designs, Option 2A, and provides a planning estimate only. The midpoint of the estimates (average of p50 and p85) for the entire list of options analyzed in the Phase 1 study ranged from \$17.1 billion to \$26.1 billion in then-year dollars, including Other Program Money. These estimates will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

[18] Since the W87-1 Modification Program is using a planning estimate, the red and green lines represent the high and low estimates based on funding models from historical data. The blue bars in this figure show the program's proposed FY 2023 FYNSP budget and, for years beyond FY 2023, the midpoint between the high and low estimates from the funding models.

Table 5–9. Total estimated cost for W93 Program (Option 2A)

Dollars in Billions	DOE/NNSA		DoD	
	FY 2022 Dollars	Then-Year Dollars	FY 2022 Dollars	Then-Year Dollars
Planning Estimate (High) [a]	15.1	21.2	1.3	1.8
Planning Estimate (Low) [a]	13.1	18.5	1.0	1.4
Proposed Budget	14.1	19.8	N/A	N/A

[a] Including Other Program Money

5.9.2.9 Future Strategic Missile Warhead Cost Estimates

DOE/NNSA is coordinating with DoD to define the appropriate ballistic missile warheads to support anticipated future threats. These warheads currently include the Future Strategic Land-Based Warhead, the Future Strategic Sea-Based Warhead, the Future Air-Delivered Warhead, and a Submarine-Launched Warhead (to replace the W76-1/2) that will be needed in the 2040s. The military capabilities required from the Future Strategic Land-Based Warhead and the Future Strategic Sea-Based Warhead, formerly referred to as Interoperable Warheads or Future Ballistic Missile Warheads, are being analyzed, and appropriate requirements are being developed to address emerging threats, and aging concerns, in candidate stockpile warheads.

The Future Strategic Missile Warhead cost estimates (see **Table 5–10, Table 5–11,** and **Table 5–12**) provide a planning estimate for notional systems based on an existing stockpile weapon scope with increased uncertainty in design scope and quantities, adjusted for out-year escalation. These estimates will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

Table 5–10. Total estimated cost for Future Strategic Missile – Land-Based Warhead (FSLW)

Dollars in Billions	DOE/NNSA		DoD	
	FY 2022 Dollars	Then-Year Dollars	FY 2022 Dollars	Then-Year Dollars
Planning Estimate (High) [a]	14.5	22.6	0.4	0.6
Planning Estimate (Low) [a]	11.9	18.6	0.3	0.5
Proposed Budget	13.3	20.6	N/A	N/A

[a] Including Other Program Money

Table 5–11. Total estimated cost for Future Strategic Missile – Sea-Based Warhead

Dollars in Billions	DOE/NNSA		DoD	
	FY 2022 Dollars	Then-Year Dollars	FY 2022 Dollars	Then-Year Dollars
Planning Estimate (High) [a]	19.6	31.5	1.3	2.0
Planning Estimate (Low) [a]	15.8	25.2	1.0	1.6
Proposed Budget	17.7	28.4	N/A	N/A

[a] Including Other Program Money

Table 5–12. Total estimated cost for Future Air-Delivered Weapon

Dollars in Billions	DOE/NNSA		DoD	
	FY 2022 Dollars	Then-Year Dollars	FY 2022 Dollars	Then-Year Dollars
Planning Estimate (High) [a]	12.0	21.9	0.2	0.4
Planning Estimate (Low) [a]	10.3	18.8	0.1	0.3
Proposed Budget	11.2	20.3	N/A	N/A

[a] Including Other Program Money

5.9.2.10 Summary of Cost Estimates

Figure 5–20 represents a summary of cost estimate ranges for all presently known warhead modernization programs from FY 2022 through FY 2047 based on schedule assumptions that are subject to change. The differences in the values from the FY 2022 SSMP reflect increases in new estimates for the W93, and in turn the estimates for other future systems that are based off the W93, as well as a later start for the development of the future systems which shifted the cost profile to the right. This chart also includes a wedge for a warhead modernization program starting in the early 2040s.

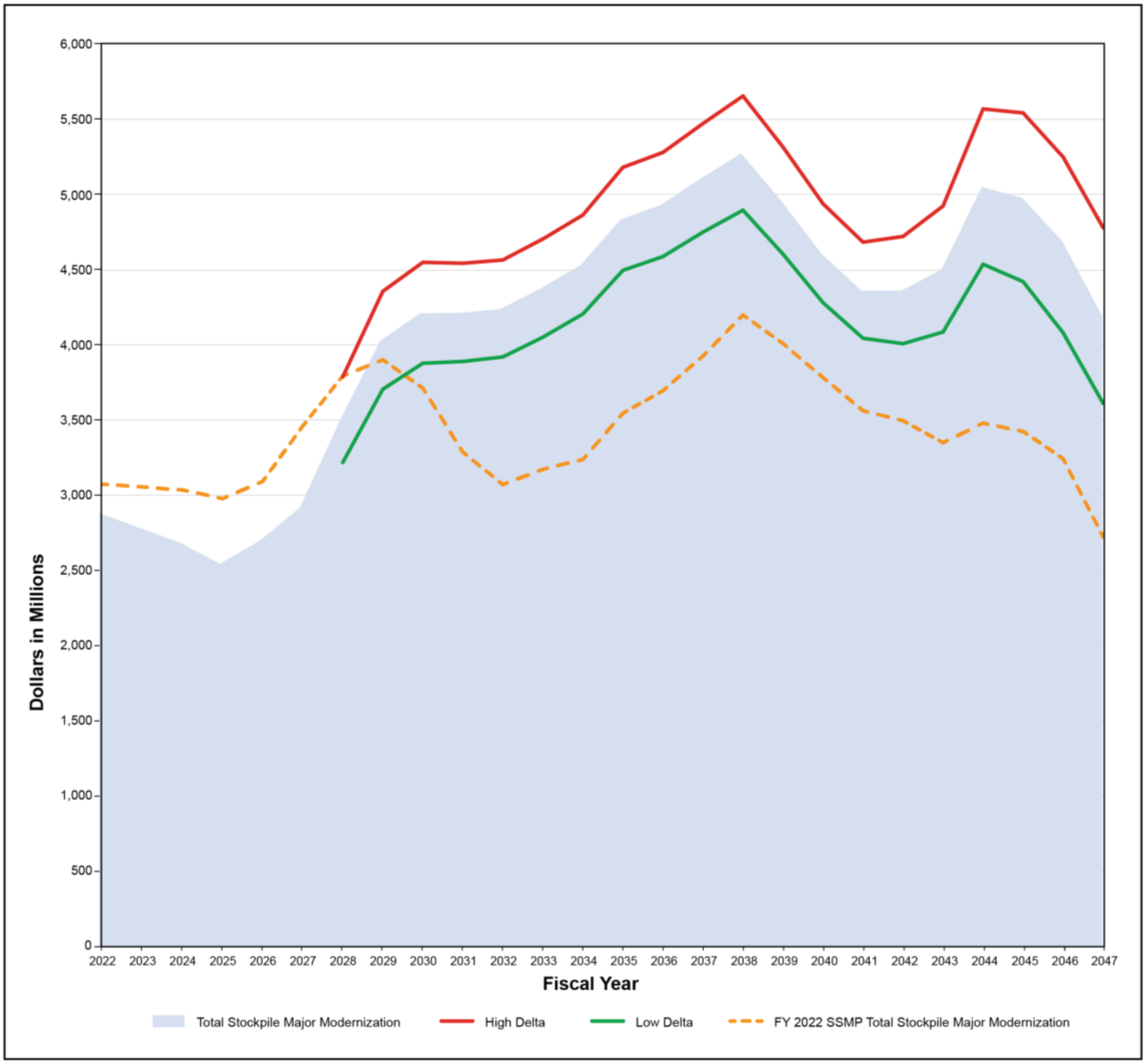


Figure 5–20. Total projected Stockpile Major Modernization costs for FY 2022–FY 2047 with high and low estimates (then-year dollars)

5.9.3 Construction

5.9.3.1 Cost Estimation for Capital Acquisitions

In FY 2020, DOE/NNSA began publishing cost estimates for early-stage capital acquisitions. These early planning estimates, published as much as a decade or more before a project's initial mission approval, primarily inform long-term cost projections for programmatic construction and are supplemental to DOE acquisition requirements outlined in DOE Order 413.3B.

Notably, these cost estimates are:

- Performed by an organization separate from the Federal program office[19]
- Performed using a top-down parametric method consistent with early-stage planning
- Based on historic DOE/NNSA project schedules, costs, and project phasing
- Based on current anticipated project scopes
- Based on affordability analysis
- Updated annually for the SSMP

Once a project begins the acquisition process, the approved cost estimate ranges at the CD-0 milestone, *Approve Mission Need*, supersede previous estimates and becomes the basis for resource planning. The project then progresses as described in DOE Order 413.3B (i.e., alternative selection and cost range at CD-1, performance baseline at CD-2, etc.). Per DOE Order 413.3B and DOE/NNSA policy, the project cost estimates are reconciled with independent cost estimates or independent cost reviews performed by either the Office of Cost Estimating and Program Evaluation (pre-CD-0 and -1) or DOE's Office of Project Management (pre-CD-2).

The early-stage planning estimates use technical input based on an assumed scope. However, these assumptions do not predetermine the project's actual acquisition strategy or the outcome of subsequent AoAs. The assumed scope should be considered estimated until the design matures and the project reaches CD-2, *Performance Baseline*.

The cost estimation professional society, American Association of Cost Engineering International, has published a cost estimate classification system[20] based on the scope definition of the project. DOE/NNSA has mapped the American Association of Cost Engineering International cost estimate classes to the most common uses for capital acquisitions.[21] **Table 5–13** summarizes the cost estimation classification system, including the level of project definition, the expected uncertainty range, and the corresponding DOE/NNSA capital acquisition milestones. Note that the estimate ranges and typical applications represent rough expectations and cannot simply be applied to an estimate to determine uncertainty.

[19] The DOE/NNSA Office of Management and Budget, Office of Programing, Analysis and Evaluation, performs the cost estimates on behalf of Defense Programs.
[20] American Association of Cost Engineering International Recommended Practice 18R-97, Cost Estimation Classification System as Applied in Engineering, Procurement and Construction for the Process Industries.
[21] DOE Guide 413.3-21A, Cost Estimating Guide.

Table 5–13. Capital Acquisition Cost Estimate Classification System

Estimate Class	*Primary Characteristic*	*Secondary Characteristic*			
	Maturity Level of Project Definition (percent)	*DOE Capital Acquisition Milestone*	*Typical Types of Estimate*	*Methodology*	*Expected Accuracy Range (percent)*
Class 5	0 to 2	Mission Need (CD-0)	Planning Estimate, Rough Order of Magnitude	Capacity factored, parametric models, judgment, or analogy	Low: -20 to -50 High: +30 to +100
Class 4	1 to 15	Alternative Selection (CD-1)	Analysis of Alternatives, Conceptual Design	Equipment factored or parametric models	Low: -15 to -30 High: +20 to +50
Class 3	10 to 40	Performance Baseline (CD-2) (low-risk projects)	Preliminary Design	Semi-detailed unit costs with assembly level line-items	Low: -10 to -20 High: +10 to +30
Class 2	30 to 75	Start of Construction (CD-3)/ Performance Baseline (CD-2) (high-risk projects)	Final Design	Detailed unit cost with forced detailed take-off	Low: -5 to -15 High: +5 to +20
Class 1	65 to 100			Detailed unit cost with detailed take-off	Low: -3 to -10 High: +3 to +15

5.9.3.2 FY 2023 through FY 2047 Estimates

The budget request for capital acquisitions in FY 2023 reflects the latest estimates for existing construction projects. DOE/NNSA continues to execute the schedules of multiple ongoing major capital acquisition projects, such as the Uranium Processing Facility and U1a Complex Enhancements projects. A list of major capital acquisition project proposals has been developed through the efforts of a series of working groups and deep dives with representatives from DOE/NNSA sites and responsible Federal offices. The schedule for the highest-priority project proposals is shown by major capital acquisition projects and project proposals listed in Chapter 4, “Infrastructure and Operations.” This planning schedule will be updated annually. Changes will be made based on available funding and programmatic priorities.

The current program of record and the vetted programmatic construction project proposals included in Figures 4–5 through 4–11 are the basis for the aggregated cost estimates shown in **Table 5–14**.[22] Table 5–14 lists low and high estimates in then-year dollars for planned and proposed programmatic capital acquisition projects from FY 2023 through FY 2047.

Table 5–14. Weapons Activities capital acquisition estimated costs, FY 2023–FY 2047

Then-Year Dollars, in Billions	*Low* [a]	*High* [b]
Weapons Activities capital acquisition estimated costs	70.2	82.2

[a] The “Low” estimate reflects the base capital acquisition estimate captured in Figure 5–22. The low value is programmatically informed and represents the 70th percentile for the planned and proposed major construction projects listed in Section 4.3.1.

[b] The “High” estimate represents the 85th percentile for the planned and proposed major construction projects listed in Section 4.3.1.

[22] At this time, only programmatic construction cost estimates are included in the values shown in Table 5–14. It does not include mission enabling construction projects.

The difference in the estimates as compared to the FY 2022 SSMP are a result of further analysis and higher fidelity estimates on major construction projects, including Domestic Uranium Enrichment and Depleted Uranium Manufacturing Capabilities.

5.10 Affordability

As described throughout this document, DOE/NNSA is undertaking a risk-informed, complex, and time-constrained modernization and recapitalization effort in coordination with DoD. DOE/NNSA must make concerted investments now to make available the necessary capabilities and infrastructure to execute modernization programs to meet DoD timelines. If adjustments need to be made in future years, DOE/NNSA will work with DoD to consider and adjust schedule and/or scope to major activities, including potential effects to warhead modernization programs and infrastructure projects.

DOE/NNSA needs are subject to a high level of uncertainty due to the unique requirements inherent in the work that must be completed to meet objectives. Limited numbers of completed projects with similar complexity and scope, low quantities, stringent specifications, and multi-year development schedules add to the high level of uncertainty in early estimates. For these reasons, the projected costs beyond FY 2023 incorporate some amount of uncertainty in the out-year weapons modernization and construction resource needs. These later plans and estimates are compared to external straight-line budget projections that have not been adjusted to be more predictive based on actual scope and schedule. Variances are managed as the out-years estimates move into the FYNSP window and as scope and schedule are further refined.

Budget projections for the out-years incorporate the Stockpile Major Modernization program cost estimates described in Section 5.9.2 and the cost estimates for the planned major programmatic construction projects described in Chapter 4, Section 4.2.1. Significant out-year projects include:

- Reestablishing a plutonium pit production capability
- Reestablishing a Domestic Uranium Enrichment capability
- Revitalizing depleted uranium manufacturing capability
- Modernizing DOE/NNSA's SRT&E capabilities for certifying warheads upon entry into the stockpile

Chapter 6
Conclusion

This Department of Energy's National Nuclear Security Administration's (DOE/NNSA) *Fiscal Year 2023 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP), together with its classified annex, is a key planning document for the nuclear security enterprise. This SSMP is the culmination of planning and programming efforts across numerous DOE/NNSA programs and organizations and documents the 25-year plan for ensuring the safety, security, and effectiveness of the U.S. nuclear stockpile. The fiscal year (FY) 2023 SSMP also details efforts to maintain the scientific and engineering tools, capabilities, and infrastructure that underpin the current and future nuclear deterrent. The SSMP was prepared by the DOE/NNSA Federal workforce in collaboration with DOE/NNSA's management and operating partners and coordinated with the Department of Defense through the Nuclear Weapons Council.

In large part due to the current global security environment, DOE/NNSA executed its largest program in its 21-year history, advancing the Nation's nuclear security mission through innovative science and technology solutions. These efforts are critical to ensuring the U.S. strategic deterrent remains safe, secure, and effective, and that the deterrence commitments extended to U.S. allies remains strong and credible.

Appendix A
Requirements Mapping

A.1 National Nuclear Security Administration Response to Statutory Reporting Requirements and Related Requests

The *Fiscal Year 2023 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (FY 2023 SSMP) consolidates a number of statutory reporting requirements and related congressional requests. This appendix maps the statutory and congressional requirements to the respective chapter and section in the fiscal year (FY) 2023 SSMP.

A.2 50 U.S. Code § 2523

50 U.S. Code § 2523	*FY 2022 Response*	*FY 2023 Response*
§ 2523. Nuclear weapons stockpile stewardship, management, and responsiveness plan		
(a) Plan requirement The Administrator, in consultation with the Secretary of Defense and other appropriate officials of the departments and agencies of the Federal Government, shall develop and annually update a plan for sustaining the nuclear weapons stockpile. The plan shall cover, at a minimum, stockpile stewardship, stockpile management, stockpile responsiveness, stockpile surveillance, program direction, infrastructure modernization, human capital, and nuclear test readiness. The plan shall be consistent with the programmatic and technical requirements of the most recent annual Nuclear Weapons Stockpile Memorandum.	*Unclassified* All Chapters	
(b) Submissions to Congress		
(1) In accordance with subsection (c), not later than March 15 of each even-numbered year, the Administrator shall submit to the congressional defense committees a summary of the plan developed under subsection (a).	*N/A*	*Unclassified* All Chapters
(2) In accordance with subsection (d), not later than March 15 of each odd-numbered year, the Administrator shall submit to the congressional defense committees a detailed report on the plan developed under subsection (a).	*Unclassified* All Chapters	*N/A*
(3) The summaries and reports required by this subsection shall be submitted in unclassified form, but may include a classified annex.		
(c) Elements of biennial plan summary Each summary of the plan submitted under subsection (b)(1) shall include, at a minimum, the following:		
(1) A summary of the status of the nuclear weapons stockpile, including the number and age of warheads (including both active and inactive) for each warhead type.	*N/A*	*Unclassified* Chapter 1, Section 1.3, Figure 1-1
(2) A summary of the status, plans, budgets, and schedules for warhead life extension programs and any other programs to modify, update, or replace warhead types.	*N/A*	*Unclassified* Chapter 1, Section 1.4; Chapter 2, Section 2.2, Figure 2-2

50 U.S. Code § 2523	*FY 2022 Response*	*FY 2023 Response*
(3) A summary of the methods and information used to determine that the nuclear weapons stockpile is safe and reliable, as well as the relationship of science-based tools to the collection and interpretation of such information.	*N/A*	*Unclassified* Chapter 2, Sections 2.1, 2.2
(4) A summary of the status of the nuclear security enterprise, including programs and plans for infrastructure modernization and retention of human capital, as well as associated budgets and schedules.	*N/A*	*Unclassified* Chapter 4, Sections 4.2, 4.3; Appendix C, Section C-1
(5) A summary of the status, plans, and budgets for carrying out the stockpile responsiveness program under section 2538b of this title.	*N/A*	*Unclassified* Chapter 2, Section 2.1; Chapter 5, Section 5.4
(6) A summary of the plan regarding the research and development, deployment, and lifecycle sustainment of technologies described in subsection (d) (7).	*N/A*	*Unclassified* Chapter 1, Sections 1.4, 1.5, Figure 1-3
(7) A summary of the assessment under subsection (d)(8) regarding the execution of programs with current and projected budgets and any associated risks.	*N/A*	*Unclassified* Chapter 5, Sections 5.1, 5.5, 5.6, 5.9
(8) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*N/A*	*Unclassified* Chapter 5, Section 5.4
(9) Such other information as the Administrator considers appropriate.	*N/A*	
(d) Elements of biennial detailed report Each detailed report on the plan submitted under subsection (b)(2) shall include, at a minimum, the following:		
(1) With respect to stockpile stewardship, stockpile management, and stockpile responsiveness—		
(A) the status of the nuclear weapons stockpile, including the number and age of warheads (including both active and inactive) for each warhead type;	*Unclassified* Chapter 1, Section 1.4; Chapter 2, Sections 2.1, 2.2	*N/A*
(B) for each five-year period occurring during the period beginning on the date of the report and ending on the date that is 20 years after the date of the report— (i) the planned number of nuclear warheads (including active and inactive) for each warhead type in the nuclear weapons stockpile; and (ii) the past and projected future total lifecycle cost of each type of nuclear weapon;	*Unclassified* Chapter 8, Section 8.4, 8.9	*N/A*
(C) the status, plans, budgets, and schedules for warhead life extension programs and any other programs to modify, update, or replace warhead types;	*Unclassified* Chapter 2, Sections 2.2, 2.4; Chapter 8, Section 8.4	*N/A*
(D) a description of the process by which the Administrator assesses the lifetimes, and requirements for life extension or replacement, of the nuclear and non-nuclear components of the warheads (including active and inactive warheads) in the nuclear weapons stockpile;	*Unclassified* Chapter 2, Section 2.1; Chapter 3, Section 3.5; Chapter 4, Section 4.3	*N/A*

50 U.S. Code § 2523	*FY 2022 Response*	*FY 2023 Response*
(E) a description of the process used in recertifying the safety, security, and reliability of each warhead type in the nuclear weapons stockpile;	*Unclassified* Chapter 2, Section 2.1; Chapter 4, Sections 4.2.2, 4.3	*N/A*
(F) any concerns of the Administrator that would affect the ability of the Administrator to recertify the safety, security, or reliability of warheads in the nuclear weapons stockpile (including active and inactive warheads);	*Unclassified* Chapter 2, Section 2.1; Chapter 3, Sections 3.3.2, 3.4.2; Chapter 4, Sections 4.2, 4.3	*N/A*
(G) mechanisms to provide for the manufacture, maintenance, and modernization of each warhead type in the nuclear weapons stockpile, as needed;	*Unclassified* Chapter 2, Sections 2.1, 2.2, 2.4; Chapter 3, Sections 3.2-3.5; Chapter 4, Section 4.3	*N/A*
(H) mechanisms to expedite the collection of information necessary for carrying out the stockpile management program required by section 2524 of this title, including information relating to the aging of materials and components, new manufacturing techniques, and the replacement or substitution of materials;	*Unclassified* Chapter 2, Sections 2.1.1, 2.4; Chapter 3, Section 3.5; Chapter 4, Section 4.3	*N/A*
(I) mechanisms to ensure the appropriate assignment of roles and missions for each national security laboratory and nuclear weapons production facility, including mechanisms for allocation of workload, mechanisms to ensure the carrying out of appropriate modernization activities, and mechanisms to ensure the retention of skilled personnel;	*Unclassified* Chapter 1, Section 1.3; Chapter 4, Section 4.2.2; Chapter 7 ; Appendix E	*N/A*
(J) mechanisms to ensure that each national security laboratory has full and complete access to all weapons data to enable a rigorous peer-review process to support the annual assessment of the condition of the nuclear weapons stockpile required under section 2525 of this title;	*Unclassified* Chapter 2, Section 2.1.2	*N/A*
(K) mechanisms for allocating funds for activities under the stockpile management program required by section 2524 of this title, including allocations of funds by weapon type and facility; and	*Unclassified* Chapter 8, Sections 8.3-8.6, 8.9	*N/A*
(L) for each of the five fiscal years following the fiscal year in which the report is submitted, an identification of the funds needed to carry out the program required under section 2524 of this title;	*Unclassified* Chapter 8, Section 8.3	*N/A*
(M) the status, plans, activities, budgets, and schedules for carrying out the stockpile responsiveness program under section 2538b of this title;	*Unclassified* Chapter 4, Section 4.3; Chapter 8, Section 8.4–8.6; Appendix D	*N/A*
(N) for each of the five fiscal years following the fiscal year in which the report is submitted, an identification of the funds needed to carry out the program required under section 2538b of this title; and	*Unclassified* Chapter 8, Section 8.4–8.6; Appendix D	*N/A*

50 U.S. Code § 2523	*FY 2022 Response*	*FY 2023 Response*
(O) as required, when assessing and developing prototype nuclear weapons of foreign countries, a report from the directors of the national security laboratories on the need and plan for such assessment and development that includes separate comments on the plan from the Secretary of Energy and the Director of National Intelligence.	*N/A*	*N/A*
(2) With respect to science-based tools—		
(A) a description of the information needed to determine that the nuclear weapons stockpile is safe and reliable;	*Unclassified* Chapter 2, Section 2.1; Chapter 4, Sections 4.2.2, 4.3;	*N/A*
(B) for each science-based tool used to collect information described in subparagraph (A), the relationship between such tool and such information and the effectiveness of such tool in providing such information based on the criteria developed pursuant to section 2522(a) of this title; and	*Unclassified* Chapter 4, Section 4.3	*N/A*
(C) the criteria developed under section 2522(a) of this title (including any updates to such criteria).	*N/A*	*N/A*
(3) An assessment of the stockpile stewardship program under section 2521 (a) of this title by the Administrator, in consultation with the directors of the national security laboratories, which shall set forth—		
(A) an identification and description of— (i) any key technical challenges to the stockpile stewardship program; and (ii) the strategies to address such challenges without the use of nuclear testing;	*Unclassified* Chapter 4, Sections 4.2, 4.3	*N/A*
(B) a strategy for using the science-based tools (including advanced simulation and computing capabilities) of each national security laboratory to ensure that the nuclear weapons stockpile is safe, secure, and reliable without the use of nuclear testing;	*Unclassified* Chapter 2, Section 2.1.2; Chapter 4, Section 4.3; Appendix E	*N/A*
(C) an assessment of the science-based tools (including advanced simulation and computing capabilities) of each national security laboratory that exist at the time of the assessment compared with the science-based tools expected to exist during the period covered by the future-years nuclear security program; and	*Unclassified* Chapter 2, Section 2.1.2; Chapter 4, Section 4.2; Appendix E	*N/A*
(D) an assessment of the core scientific and technical competencies required to achieve the objectives of the stockpile stewardship program and other weapons activities and weapons-related activities of the Administration, including—	*Unclassified* Chapter 7, Sections 7.1, 7.3; Appendix E	*N/A*
(i) the number of scientists, engineers, and technicians, by discipline, required to maintain such competencies; and	*Unclassified* Chapter 7, Sections 7.2, 7.3; Appendix E	*N/A*
(ii) a description of any shortage of such individuals that exists at the time of the assessment compared with any shortage expected to exist during the period covered by the future-years nuclear security program.	*Unclassified* Chapter 7, Section 7.4; Appendix E	*N/A*
(4) With respect to the nuclear security infrastructure—		
(A) a description of the modernization and refurbishment measures the Administrator determines necessary to meet the requirements prescribed in—	*Unclassified* Chapter 6, Sections 6.3, 6.4	*N/A*

50 U.S. Code § 2523	*FY 2022 Response*	*FY 2023 Response*
(i) the national security strategy of the United States as set forth in the most recent national security strategy report of the President under section 3043 of this title if such strategy has been submitted as of the date of the plan;	*Unclassified* Chapter 6, Sections 6.3, 6.4	*N/A*
(ii) the most recent quadrennial defense review if such strategy has not been submitted as of the date of the plan; and	*Unclassified* Chapter 6, Sections 6.3, 6.4	*N/A*
(iii) the most recent Nuclear Posture Review as of the date of the plan;	*Unclassified* Chapter 6, Sections 6.3, 6.4	*N/A*
(B) a schedule for implementing the measures described under subparagraph (A) during the 10-year period following the date of the plan;	*Unclassified* Chapter 6, Sections 6.3.1, 6.3.2	*N/A*
(C) the estimated levels of annual funds the Administrator determines necessary to carry out the measures described under subparagraph (A), including a discussion of the criteria, evidence, and strategies on which such estimated levels of annual funds are based; and	*Unclassified* Chapter 8, Sections 8.7.1, 8.9.3	*N/A*
(D) a description of— (I) the metrics (based on industry best practices) used by the Administrator to determine the infrastructure deferred maintenance and repair needs of the nuclear security enterprise; and (II) the percentage of replacement plant value being spent on maintenance and repair needs of the nuclear security enterprise; and (III) an explanation of whether the annual spending on such needs complies with the recommendation of the National Research Council of the National Academies of Sciences, Engineering, and Medicine that such spending be in an amount equal to four percent of the replacement plant value, and, if not, the reasons for such noncompliance and a plan for how the Administrator will ensure facilities of the nuclear security enterprise are being properly sustained.	*Unclassified* Chapter 8, Section 8.7.4	*N/A*
(5) With respect to the nuclear test readiness of the United States—		
(A) an estimate of the period of time that would be necessary for the Administrator to conduct an underground test of a nuclear weapon once directed by the President to conduct such a test;	*Unclassified* Chapter 4, Section 4.4	*N/A*
(B) a description of the level of test readiness that the Administrator, in consultation with the Secretary of Defense, determines to be appropriate;	*Unclassified* Chapter 4, Section 4.4	*N/A*
(C) a list and description of the workforce skills and capabilities that are essential to carrying out an underground nuclear test at the Nevada National Security Site;	*Unclassified* Chapter 4, Section 4.4	*N/A*
(D) a list and description of the infrastructure and physical plants that are essential to carrying out an underground nuclear test at the Nevada National Security Site; and	*Unclassified* Chapter 4, Section 4.4	*N/A*
(E) an assessment of the readiness status of the skills and capabilities described in subparagraph (C) and the infrastructure and physical plants described in subparagraph (D).	*Unclassified* Chapter 4, Section 4.4	*N/A*

50 U.S. Code § 2523	*FY 2022 Response*	*FY 2023 Response*
(6) A strategy for the integrated management of plutonium for stockpile and stockpile stewardship needs over a 20-year period that includes the following:		
(A) An assessment of the baseline science issues necessary to understand plutonium aging under static and dynamic conditions under manufactured and nonmanufactured plutonium geometries.	*Unclassified* Chapter 4, Sections 4.3.1, 4.3.2	*N/A*
(B) An assessment of scientific and testing instrumentation for plutonium at elemental and bulk conditions.	*Unclassified* Chapter 4, Sections 4.3.1, 4.3.2	*N/A*
(C) An assessment of manufacturing and handling technology for plutonium and plutonium components.	*Unclassified* Chapter 3, Section 3.2.1; Appendix E, Sections E.2.2, E.3.3	*N/A*
(D) An assessment of computational models of plutonium performance under static and dynamic loading, including manufactured and nonmanufactured conditions.	*Unclassified* Chapter 4, Sections 4.2.2, 4.3.1 - 4.3.4	*N/A*
(E) An identification of any capability gaps with respect to the assessments described in subparagraphs (A) through (D).	*Unclassified* Chapter 4, Sections 4.3.1 - 4.3.4	*N/A*
(F) An estimate of costs relating to the issues, instrumentation, technology, and models described in subparagraphs (A) through (D) over the period covered by the future-years nuclear security program under section 2453 of this title.	*Unclassified* Chapter 8, Section 8.5.1, 8.6.1	*N/A*
(G) An estimate of the cost of eliminating the capability gaps identified under subparagraph (E) over the period covered by the future-years nuclear security program.	*Unclassified* Chapter 8, Section 8.5.1, 8.6.1	*N/A*
(H) Such other items as the Administrator considers important for the integrated management of plutonium for stockpile and stockpile stewardship needs.	*Unclassified* Chapter 3, Section 3.2.1	*N/A*
7) A plan for the research and development, deployment, and lifecycle sustainment of the technologies employed within the nuclear security enterprise to address physical and cyber security threats during the five fiscal years following the date of the report, together with—	*Unclassified* Chapter 5	*N/A*
(A) for each site in the nuclear security enterprise, a description of the technologies deployed to address the physical and cybersecurity threats posed to that site;	*Unclassified* Chapter 5	*N/A*
(B) for each site and for the nuclear security enterprise, the methods used by the Administration to establish priorities among investments in physical and cybersecurity technologies; and	*Unclassified* Chapter 5, Sections 5.3, 5.4	*N/A*
(C) a detailed description of how the funds identified for each program element specified pursuant to paragraph (1) in the budget for the Administration for each fiscal year during that five-fiscal-year period will help carry out that plan.	*Unclassified* Chapter 8, Sections 8.8.3, 8.8.4	*N/A*
(8) An assessment of whether the programs described by the report can be executed with current and projected budgets and any associated risks.	*Unclassified* Chapter 8, Sections 8.9, 8.10	*N/A*
(9) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*Unclassified* Chapter 8	*N/A*

50 U.S. Code § 2523	*FY 2022 Response*	*FY 2023 Response*
(e) Nuclear Weapons Council assessment (1) For each detailed report on the plan submitted under subsection (b)(2), the Nuclear Weapons Council shall conduct an assessment that includes the following: (A) An analysis of the plan, including— (i) whether the plan supports the requirements of the national security strategy of the United States or the most recent quadrennial defense review, as applicable under subsection (d)(4)(A), and the Nuclear Posture Review; (ii) whether the modernization and refurbishment measures described under subparagraph (A) of subsection (d)(4) and the schedule described under subparagraph (B) of such subsection are adequate to support such requirements; and (iii) whether the plan supports the stockpile responsiveness program under section 2538b of this title in a manner that meets the objectives of such program and an identification of any improvements that may be made to the plan to better carry out such program. (B) An analysis of whether the plan adequately addresses the requirements for infrastructure recapitalization of the facilities of the nuclear security enterprise. (C) If the Nuclear Weapons Council determines that the plan does not adequately support modernization and refurbishment requirements under subparagraph (A) or the nuclear security enterprise facilities infrastructure recapitalization requirements under subparagraph (B), a risk assessment with respect to— (i) supporting the annual certification of the nuclear weapons stockpile; and (ii) maintaining the long-term safety, security, and reliability of the nuclear weapons stockpile. (2) Not later than 180 days after the date on which the Administrator submits the plan under subsection (b)(2), the Nuclear Weapons Council shall submit to the congressional defense committees a report detailing the assessment required under paragraph (1).	*N/A*	*N/A*
(f) Definitions – In this section: (1) The term "budget", with respect to a fiscal year, means the budget for that fiscal year that is submitted to Congress by the President under section 1105(a) of title 31. (2) The term "future-years nuclear security program" means the program required by section 2453 of this title. (3) The term "nuclear security budget materials", with respect to a fiscal year, means the materials submitted to Congress by the Administrator in support of the budget for that fiscal year. (4) The term "quadrennial defense review" means the review of the defense programs and policies of the United States that is carried out every four years under section 118 of title 10. (5) The term "weapons activities" means each activity within the budget category of weapons activities in the budget of the Administration. (6) The term "weapons-related activities" means each activity under the Department of Energy that involves nuclear weapons, nuclear weapons technology, or fissile or radioactive materials, including activities related to— (A) nuclear nonproliferation; (B) nuclear forensics; (C) nuclear intelligence; (D) nuclear safety; and (E) nuclear incident response.		*Unclassified* Appendix G, Glossary

A.3 50 U.S. Code § 2538a

50 U.S. Code § 2538a	*FY 2022 Response*	*FY 2023 Response*
§2538a. Plutonium pit production capacity (a) Requirement Consistent with the requirements of the Secretary of Defense, the Secretary of Energy shall ensure that the nuclear security enterprise- (1) during 2021, begins production of qualification plutonium pits; (2) during 2024, produces not less than 10 war reserve plutonium pits; (3) during 2025, produces not less than 20 war reserve plutonium pits; (4) during 2026, produces not less than 30 war reserve plutonium pits; and (5) during 2030, produces not less than 80 war reserve plutonium pits.	*Unclassified* Executive Summary; Chapter 3, Section 3.2; Chapter 6, Section 6.3.1.1; Chapter 8, Section 8.5.3.1; Appendix E, Sections E.2.2, E.3.3	*Unclassified* Chapter 0, Executive Summary; Chapter 3, Section 3.4.1; Chapter 4, Section 4.2.1; Chapter 5, Section 5.5.3
(b) Annual certification Not later than March 1, 2015, and each year thereafter through 2030, the Secretary of Energy shall certify to the congressional defense committees and the Secretary of Defense that the programs and budget of the Secretary of Energy will enable the nuclear security enterprise to meet the requirements under subsection (a).	*Unclassified* Chapter 3, Section 3.2; Chapter 8, Section 8.5.3.1	*Unclassified* Chapter 3, Section 3.4.1; Chapter 5, Sections 5.5.3, 5.9.2
(c) Plan If the Secretary of Energy does not make a certification under subsection (b) by March 1 of any year in which a certification is required under that subsection, by not later than May 1 of such year, the Chairman of the Nuclear Weapons Council shall submit to the congressional defense committees a plan to enable the nuclear security enterprise to meet the requirements under subsection (a). Such plan shall include identification of the resources of the Department of Energy that the Chairman determines should be redirected to support the plan to meet such requirements.	*N/A*	*N/A*

A.4 H.R. 116-449

H.R. 116-449 – *ENERGY AND WATER DEVELOPMENT AND RELATED AGENCIES APPROPRIATIONS BILL, 2021, July 15, 2020, pp 141-142*	*FY 2022 Response*	*FY 2023 Response*[1]
Stockpile Responsiveness Program The NNSA shall submit to the Committee an annual report with the budget request that includes a detailed accounting and status of each program, project, and activity within the program. The Committee expects to receive timely updates on the status of any new and existing taskings, studies, and assessments.	*Unclassified* Appendix D	*Unclassified* Appendix E and standalone report

[1] H. Rept. 117-98 accompanying the *Energy and Water Development and Related Agencies Appropriations Bill, 2022* restated this annual Stockpile Responsiveness Program (SRP) reporting requirement and noted that as the Stockpile Stewardship and Management Plan (SSMP) does not typically accompany the annual budget request, including the report within the SSMP "therefore does not offer a useful and timely companion to the budget." This direction was reiterated again through Joint Explanatory Statement accompanying the *Energy and Water Development and Related Agencies Appropriations Act, 2022*. In accordance with this direction, the Department of Energy's National Nuclear Security Administration (DOE/NNSA) submitted the report as a standalone document in September 2022 to provide as timely updates as possible. This report has been resubmitted within the SSMP, as the SSMP is also required to provide information on SRP under 50 USC 2523 and 2523(c)(5), as noted.

A.5 H.R. 244

H.R.244 – Consolidated Appropriations Act, 2017, P.L. 115-31	*FY 2022 Response*	*FY 2023 Response*
SEC. 4. EXPLANATORY STATEMENT. The explanatory statement regarding this Act, printed in the House section of the Congressional Record on or about May 2, 2017, and submitted by the Chairman of the Committee on Appropriations of the House, shall have the same effect with respect to the allocation of funds and implementation of divisions A through L of this Act as if it were a joint explanatory statement of a committee of conference.		
Congressional Record – House, Vol 163, No 76—Book II, page H3753, May 3, 2017 (Explanatory Statement to Accompany the FY 17 Omnibus Appropriations [P.L. 115-31]]		
Life Extension Reporting. – The NNSA is directed to provide to the Committees on Appropriations of both Houses of Congress a classified summary of each ongoing life extension and major refurbishment program that includes explanatory information on the progress and planning for each program beginning with the award of the phase 6.3 milestone and annually thereafter until completion of the program.	*Classified Annex*	*Classified Annex*

A.6 Related Legislation: 50 U.S. Code § 2521

50 U.S. Code § 2521
§ 2521. Stockpile stewardship program (a) Establishment The Secretary of Energy, acting through the Administrator for Nuclear Security, shall establish a stewardship program to ensure – (1) the preservation of the core intellectual and technical competencies of the United States in nuclear weapons, including weapons design, system integration, manufacturing, security, use control, reliability assessment, and certification; and (2) that the nuclear weapons stockpile is safe, secure, and reliable without the use of underground nuclear weapons testing.
(b) Program elements The program shall include the following:
1) An increased level of effort for advanced computational capabilities to enhance the simulation and modeling capabilities of the United States with respect to the performance over time of nuclear weapons.
(2) An increased level of effort for above-ground experimental programs, such as hydrotesting, high-energy lasers, inertial confinement fusion, plasma physics, and materials research.
(3) Support for new facilities construction projects that contribute to the experimental capabilities of the United States, such as an advanced hydrodynamics facility, the National Ignition Facility, and other facilities for above-ground experiments to assess nuclear weapons effects.
(4) Support for the use of, and experiments facilitated by, the advanced experimental facilities of the United States, including - (A) the National Ignition Facility at Lawrence Livermore National Laboratory; (B) the Dual Axis Radiographic Hydrodynamic Testing facility at Los Alamos National Laboratory; (C) the Z Machine at Sandia National Laboratories; and (D) the experimental facilities at the Nevada National Security Site.
(5) Support for the sustainment and modernization of facilities with production and manufacturing capabilities that are necessary to ensure the safety, security, and reliability of the nuclear weapons stockpile, including - (A) the nuclear weapons production facilities; and (B) production and manufacturing capabilities resident in the national security laboratories.
(1) With respect to exascale computing—
(a) PLAN REQUIRED.—The Administrator for Nuclear Security shall develop and carry out a plan to develop exascale computing and incorporate such computing into the stockpile stewardship program under section 4201 of the Atomic

50 U.S. Code § 2521
Energy Defense Act (50 U.S.C. 2521) during the 10-year period beginning on the date of the enactment of this Act [Dec. 26, 2013]
(b) MILESTONES.—The plan required by subsection (a) shall include major programmatic milestones in— (1) the development of a prototype exascale computer for the stockpile stewardship program; and (2) mitigating disruptions resulting from the transition to exascale computing.
(c) COORDINATION WITH OTHER AGENCIES.—In developing the plan required by subsection (a), the Administrator shall coordinate, as appropriate, with the Under Secretary of Energy for Science, the Secretary of Defense, and elements of the intelligence community (as defined in section 3(4) of the National Security Act of 1947 (50 U.S.C. 3003[4]).
(d) INCLUSION OF COSTS IN FUTURE-YEARS NUCLEAR SECURITY PROGRAM.—The Administrator shall— (1) address, in the estimated expenditures and proposed appropriations reflected in each future-years nuclear security program submitted under section 3253 of the National Nuclear Security Administration Act (50 U.S.C. 2453) during the 10-year period beginning on the date of the enactment of this Act, the costs of— (A) developing exascale computing and incorporating such computing into the stockpile stewardship program; and (B) mitigating potential disruptions resulting from the transition to exascale computing; and (2) include in each such future-years nuclear security program a description of the costs of efforts to develop exascale computing borne by the National Nuclear Security Administration, the Office of Science of the Department of Energy, other Federal agencies, and private industry.
(e) SUBMISSION TO CONGRESS.—The Administrator shall submit the plan required by subsection (a) to the congressional defense committees [Committees on Armed Services and Appropriations of Senate and the House of Representative] with each summary of the plan required by subsection (a) of section 4203 of the Atomic Energy Defense Act (50 U.S.C. 2523) submitted under subsection (b)(1) of that section during the 10-year period beginning on the date of the enactment of this Act.
(f) EXASCALE COMPUTING DEFINED.—In this section, the term ‘‘exascale computing’’ means computing through the use of a computing machine that performs near or above 10 to the 18^{th} power floating point operations per second.

A.7 Related Legislation: 50 U.S. Code § 2522

50 U.S. Code § 2522
§ 2522. Stockpile stewardship criteria
(a) Requirement for criteria The Secretary of Energy shall develop clear and specific criteria for judging whether the science-based tools being used by the Department of Energy for determining the safety and reliability of the nuclear weapons stockpile are performing in a manner that will provide an adequate degree of certainty that the stockpile is safe and reliable.
(b) Coordination with Secretary of Defense The Secretary of Energy, in developing the criteria required by subsection (a), shall coordinate with the Secretary of Defense.

A.8 Related Legislation: 50 U.S. Code § 2524

50 U.S. Code § 2524
§ 2524. Stockpile management program
(a) Program required The Secretary of Energy, acting through the Administrator for Nuclear Security and in consultation with the Secretary of Defense, shall carry out a program, in support of the stockpile stewardship program, to provide for the effective management of the weapons in the nuclear weapons stockpile, including the extension of the effective life of such weapons. The program shall have the following objectives:
(1) To increase the reliability, safety, and security of the nuclear weapons stockpile of the United States.
(2) To further reduce the likelihood of the resumption of underground nuclear weapons testing.
(3) To achieve reductions in the future size of the nuclear weapons stockpile.

50 U.S. Code § 2524
(4) To reduce the risk of an accidental detonation of an element of the stockpile.
(5) To reduce the risk of an element of the stockpile being used by a person or entity hostile to the United States, its vital interests, or its allies.
(b) Program limitations In carrying out the stockpile management program under subsection (a), the Secretary of Energy shall ensure that—
(1) any changes made to the stockpile shall be made to achieve the objectives identified in subsection (a); and
(2) any such changes made to the stockpile shall— (A) remain consistent with basic design parameters by including, to the maximum extent feasible, components that are well understood or are certifiable without the need to resume underground nuclear weapons testing; and (B) use the design, certification, and production expertise resident in the nuclear security enterprise to fulfill current mission requirements of the existing stockpile.
(c) Program budget In accordance with the requirements under section 2529 of this title, for each budget submitted by the President to Congress under section 1105 of title 31, the amounts requested for the program under this section shall be clearly identified in the budget justification materials submitted to Congress in support of that budget.

A.9 Related Legislation: 50 U.S. Code § 2538b

50 U.S. Code § 2538b
§ 2538b. Stockpile responsiveness program (a) Statement of policy It is the policy of the United States to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive.
(b) Program required The Secretary of Energy, acting through the Administrator and in consultation with the Secretary of Defense, shall carry out a stockpile responsiveness program, along with the stockpile stewardship program under section 2521 of this title and the stockpile management program under section 2524 of this title, to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons.
(c) Objectives The program under subsection (b) shall have the following objectives: (1) Identify, sustain, enhance, integrate, and continually exercise all of the capabilities, infrastructure, tools, and technologies across the science, engineering, design, certification, and manufacturing cycle required to carry out all phases of the joint nuclear weapons life cycle process, with respect to both the nuclear security enterprise and relevant elements of the Department of Defense. (2) Identify, enhance, and transfer knowledge, skills, and direct experience with respect to all phases of the joint nuclear weapons life cycle process from one generation of nuclear weapon designers and engineers to the following generation. (3) Periodically demonstrate stockpile responsiveness throughout the range of capabilities required, including prototypes, flight testing, and development of plans for certification without the need for nuclear explosive testing. (4) Shorten design, certification, and manufacturing cycles and timelines to minimize the amount of time and costs leading to an engineering prototype and production. (5) Continually exercise processes for the integration and coordination of all relevant elements and processes of the Administration and the Department of Defense required to ensure stockpile responsiveness. (6) The retention of the ability, in consultation with the Director of National Intelligence, to assess and develop prototype nuclear weapons of foreign countries and, if necessary, to conduct no-yield testing of those prototypes.
(d) Joint nuclear weapons life cycle process defined In this section, the term "joint nuclear weapons life cycle process" means the process developed and maintained by the Secretary of Defense and the Secretary of Energy for the development, production, maintenance, and retirement of nuclear weapons.

A.10 Related Legislation: S. 4049 NDAA for FY 2021

S. 4049 NDAA for FY 2021
§ 3153. MONITORING OF INDUSTRIAL BASE FOR NUCLEAR WEAPONS COMPONENTS, SUBSYSTEMS, AND MATERIALS. (a) DESIGNATION OF OFFICIAL.—Not later than March 1, 2021, the Administrator for Nuclear Security shall designate a senior official within the National Nuclear Security Administration to be responsible for monitoring the industrial base that supports the nuclear weapons components, subsystems, and materials of the Administration, including— (1) the consistent monitoring of the current status of the industrial base; (2) tracking of industrial base issues over time; and (3) proactively identifying gaps or risks in specific areas relating to the industrial base.
(b) PROVISION OF RESOURCES.—The Administrator shall ensure that the official designated under subsection (a) is provided with resources sufficient to conduct the monitoring required by that subsection.
(c) CONSULTATIONS.—The Administrator, acting through the official designated under subsection (a), shall, to the extent practicable and beneficial, in conducting the monitoring required by that subsection, consult with— (1) officials of the Department of Defense who are members of the Nuclear Weapons Council established under section 179 of title 10, United States Code; (2) officials of the Department of Defense responsible for the defense industrial base; and (3) other components of the Department of Energy that rely on similar components, subsystems, or materials.
(d) BRIEFINGS.— (1) INITIAL BRIEFING.—Not later than April 1, 2021, the Administrator shall provide to the Committees on Armed Services of the Senate and the House of Representatives a briefing on the designation of the official required by subsection (a), including on— (A) the responsibilities assigned to that official; and (B) the plan for providing that official with resources sufficient to conduct the monitoring required by subsection (a). (2) SUBSEQUENT BRIEFINGS.—Not later than April 1, 2022, and annually thereafter through 2024, the Administrator shall provide to the Committees on Armed Services of the Senate and the House of Representatives a briefing on activities carried out under this section that includes an assessment of the progress made by the official designated under subsection (a) in conducting the monitoring required by that subsection. The committee notes that the NNSA industrial base shares many of the same challenges faced by that of the Department of Defense (DOD): parts and materials are procured in small quantities, at irregular intervals, and with exacting performance specifications. Unlike the DOD, however, the NNSA does not comprehensively monitor the health of its industrial base and instead has left this responsibility to individual programs or contractors. As a result, efforts are fragmented and duplicative, as identified by the Department of Energy Inspector General in a July 2018 report titled ''Supplier Quality Management at National Nuclear Security Administration Sites'' (DOE–IG–18–41). The committee believes that this provision would help the NNSA reduce cost, schedule, and performance risk in future programs.

A.11 Related Legislation: S. 1605A NDAA for FY 2022

S. 1605A for FY 2022 NDAA
§ 3135. Reports on risks to and gaps in industrial base for nuclear weapons components, subsystems, and materials Section 3113 of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (Public Law 116– 283; 50 U.S.C. 2512 note) is amended by adding at the end the following new subsection: ''(e) REPORTS.—The Administrator, acting through the official designated under subsection (a), shall submit to the Committees on Armed Services of the Senate and the House of Representatives, contemporaneously with each briefing required by subsection (d)(2), a report— ''(1) identifying actual or potential risks to or specific gaps in any element of the industrial base that supports the nuclear weapons components, subsystems, or materials of the National Nuclear Security Administration; ''(2) describing the actions the Administration is taking to further assess, characterize, and prioritize such risks and gaps; ''(3) describing mitigating actions, if any, the Administration has underway or planned to mitigate any such risks or gaps; ''(4) setting forth the anticipated timelines and resources needed for such mitigating actions; and ''(5) describing the nature of any coordination with or burden sharing by other departments or agencies of the Federal.

Appendix B
Weapons Activities Capabilities

This appendix describes the breadth of capabilities maintained by Weapons Activities programs in the Department of Energy's National Nuclear Security Administration (DOE/NNSA) nuclear security enterprise to execute the stockpile mission. These capabilities should not be viewed in isolation or as mutually exclusive, as many overlap and are complementary. They represent the underlying disciplines, activities, and specialized skills required to meet DOE/NNSA missions. In this document, the capabilities are presented as facets of seven interdependent areas, each containing a suite of capabilities that together address a particular aspect of Weapons Activities. In part, this appendix supports the legislative requirements listed in Appendix A.

As part of its portfolio management approach for Weapons Activities, DOE/NNSA continuously evaluates the health of the Weapons Activities capabilities, which are comprised of four elements:

- Human capital (experience, skill, people)
- Physical assets (facilities, infrastructure, equipment)
- Resources (resources, materials)
- Enabling processes (knowledge, technology, processes)

All four elements must be sustained and modernized to meet current and future missions. If any of these elements are missing, the capabilities cannot function as a system. Chapters 3 and 4 detail the evaluation of the four elements of each capability.

B.1 Weapon Science and Engineering

The Weapon Science and Engineering area includes the suite of physical sciences and engineering disciplines that comprise the theoretical and experimental capabilities necessary to assess the current nuclear stockpile and certify future stockpile weapons.

Capability	***Definition***
Atomic Physics, Nuclear Physics, Nuclear Engineering, and Radiochemistry	Atomic physics is the study of atomic systems, such as a collection of atoms and electrons, and their interaction with X-rays. The extremely high temperatures of functioning nuclear weapons generate X-rays. Nuclear physics is the study of atomic nuclei and their constituents, and nuclear engineering is the translation of nuclear physics principles to the practical application of nuclear interactions, especially fission and fusion. The need to understand the design and function of the nuclear explosive package drives the requirement to improve understanding of both fission and fusion, which requires new experimental data from the Los Alamos Neutron Science Center (LANSCE). Radiochemistry is the study of radioactive materials and their interactions. It is critical to evaluating data from legacy underground testing, as well as modeling problems in nuclear forensics and attribution. Thermonuclear fusion experiments at the National Ignition Facility (NIF), Omega Laser Facility (Omega), and Z pulsed power facility (Z) can use radiochemical tracers in their diagnostic suites.

Capability	*Definition*
Materials Science, High Explosives and Energetics Science and Engineering, Chemistry, and Actinide Science	Materials science, in this context of stockpile stewardship, is the study of how materials in a nuclear weapon are produced, age, and are replaced. Chemistry studies the elemental composition, structure, bonding, and properties of matter. The stability of material properties and the nature of reactions and interactions are critical components of system aging studies. How materials and properties change with time must be understood to ensure reliability and safety of the stockpile. Strength, aging, compatibility, viability, and damage mechanics are among the materials characteristics to be evaluated. Materials science and chemistry play a key role in resolving stockpile and production issues, validating computational models, and developing new materials (e.g., materials produced through additive manufacturing). Actinide science is the study of physics and chemistry of elements from actinium to lawrencium. This is useful to understand production, purification, compatibility, targets, and behavior of actinide materials relevant to the stockpile. This section also includes high explosives and energetics science and engineering, which are the study of detonation and deflagration physics, shock wave propagation, and reaction initiation. It includes the design, synthesis, manufacture, inspection, testing and evaluation of high explosives and other energetic materials and components for specific applications. Knowledge of these materials is necessary for understanding nuclear weapon performance. Data required to advance and underpin this knowledge is obtained from LANSCE and national light source facilities.
High Energy Density Science and Plasma Physics	High energy density science is the study of matter and radiation under extreme conditions such as those in a functioning nuclear weapon and reproduced in high-temperature experiments. Plasma physics is the study of systems containing separate ions and electrons that exhibit a collective behavior. The extremely high temperatures of functioning nuclear weapons generate plasma. Facilities such as NIF, Omega, and Z generate high energy density states, producing data exploring the physical processes that occur in plasma states to validate computational models.
Technologies for Creating Extreme Conditions (lasers, accelerators, pulsed power)	This capability area includes laser, pulsed power, and accelerator technologies that are focused on creating extreme conditions under which to study weapons-relevant matter and radiation behavior. Lasers are coherent light sources delivering intense beams of energy to localized regions to generate and probe high energy density conditions similar to those produced during nuclear weapon operation. A laser's rapid energy delivery enables studies of fundamental properties of matter, radiation transport, hydrodynamics and turbulence, thermonuclear ignition and burn, as well as outputs and effects. Pulsed power devices accumulate energy over long periods of time and release it rapidly to generate extreme pressures, temperatures, and radiation conditions. Accelerators use electromagnetic fields to accelerate charged particles to the velocities needed to generate high-energy X-rays, protons, or neutrons. The resulting emissions are sources for advanced imaging, investigating nuclear physics phenomena, or simulating weapons outputs and hostile environments. Advancements in these areas produce data critical to understanding physical phenomena, qualifying nuclear weapon components, and improving performance assessments. Facilities include NIF, Omega, LANSCE, and Z.

Capability	Definition
Advanced Experimental Diagnostics and Sensors	Advanced diagnostics and sensors provide detailed measurements of materials, objects, and dynamic processes that are critical to weapon operation and other national security operations. Standard diagnostics provide lower-resolution data suitable for basic inquiries, but not for detailed part, process, or physics qualification; continued diagnostic and sensor development is important to addressing these limitations. An example of an advanced diagnostic is static or multi-frame dynamic radiography at high resolution. Radiography is an imaging technique that uses X-rays or subatomic particles (e.g., protons, neutrons) to view the internal structure of an object that is opaque to visible light. Static radiography of a stationary object is used during the post-fabrication inspection process to ensure that components are defect-free and meet exacting quality requirements. Dynamic radiography takes multiple images of a dynamic process to examine physical behavior in progress.
Hydrodynamic and Subcritical Experiments	Hydrodynamic experiments explore implosion physics and provide data on the behavior of full-scale dynamic systems. Subcritical experiments are driven by high explosives and contain special nuclear material (SNM) that never achieves a critical configuration and does not create nuclear yield. Both types of experiments provide data that are essential to validating models within multi-physics design codes and predicting nuclear weapon performance.

B.2 Weapon Simulation and Computing

The Weapon Simulation and Computing area includes high-performance computers, weapons codes, models, and data analytics used to assess the behavior of nuclear weapons and components. It must support calculations of sufficient resolution and complexity to simulate and assess the behavior of weapon systems, components, and fundamental science processes that are critical to nuclear weapon performance.

Capability	Definition
High Performance Computing	High performance computing (HPC) encompasses software, hardware, and facilities of sufficient power to achieve the dimensionality, resolution, and complexity in simulation codes to accurately model the performance of weapon systems and components and the fundamental physical processes that are critical to nuclear operation. This capability includes research and development (R&D) in computer, information, and mathematical sciences to support developing and operating HPC.
Simulation Capabilities for Weapon Science, Engineering, and Physics	Advanced computer codes, models, and data analytics are used to simulate and assess the behavior of nuclear weapons and their components. Codes range in application from design of systems to fundamental science processes. DOE/NNSA codes operate on computers ranging from desktop machines to the world's largest high-performance supercomputers.

B.3 Weapon Design and Integration

The Weapon Design and Integration area encompasses the capabilities needed to design, test, analyze, qualify, and integrate components and subsystems into weapon systems that will meet all military requirements and endure all predicted environments to validate and verify that they will always work as expected and never work when not intended.

Capability	Definition
Weapons Physics Design and Analysis	Design and analysis of the nuclear explosive package is required to maintain existing U.S. nuclear weapons; modernize the stockpile; evaluate possible proliferant nuclear weapons; and respond to emerging threats, unanticipated events, and technological innovation. Elements of design capability include concept exploration, conceptual design, requirements satisfaction, detailed design and development, production, process development, certification, and qualification. Weapons physics analysis includes evaluation of weapons effects.
Weapons Engineering Design, Analysis, and Integration	Elements of weapons engineering include the following life cycle phases: concept exploration, requirements satisfaction, conceptual design, detailed design and development, production, certification, and qualification. This capability also encompasses systems integration, which includes understanding and developing the interfaces among the non-nuclear subsystems, between the non-nuclear components and the nuclear explosives package, and between DOE/NNSA and Department of Defense (DoD) systems.
Environmental Effects Analysis, Testing, and Engineering Sciences	Environmental effects analysis, testing, and engineering sciences use an array of test equipment, tools, and techniques to create stockpile-to-target sequence conditions and measure the ensuing response of materials, components, and systems. Examples of environmental testing (normal, hostile, and abnormal) include shock, vibration, radiation, acceleration, temperature, electrostatics, and pressure conditions. The engineering sciences that support this analysis include thermal and fluid sciences, structural mechanics, dynamics, aerodynamics, and electromagnetics.
Weapons Surety Design, Testing, Analysis, and Manufacturing	Weapons surety design, analysis, integration, and manufacturing employ a variety of safety and use control systems to prevent accidental nuclear detonation and unauthorized use of nuclear weapons to ensure a safe and secure stockpile. This knowledge, infrastructure, and equipment requires strict classification control and secure facilities.
Radiation-Hardened Microelectronics Design and Manufacturing	Research, design, production, and testing of radiation-hardened microelectronics is required for nuclear weapons to function properly in hostile environments. This capability requires a secure, trusted supply chain, including quality control of the materials used in the process and products.

B.4 Weapon Material Processing and Manufacturing

The Weapon Material Processing and Manufacturing area covers the packaging, processing, handling, and/or manufacture of plutonium, uranium, tritium, energetic and hazardous materials, lithium, and other metal and organic materials needed for nuclear weapons.

Capability	Definition
Plutonium Management	Components that contain plutonium require special conduct of operations, physical security protection, facilities, and equipment to handle, package, process, manufacture, and inspect these components.
Uranium Management	Components that contain enriched and depleted uranium require special conduct of operations, physical security protection, facilities, and equipment to handle, package, process, manufacture, and inspect these components.

Capability	Definition
Tritium Management	Tritium has a 12-year half-life and must be periodically replenished in gas transfer systems. Tritium is produced by irradiating tritium-producing burnable absorber rods (TPBARs) in Tennessee Valley Authority's Watts Bar nuclear reactors. Handling and processing of tritium includes transporting TPBARs to the Savannah River Site and extracting tritium from the TPBARS, as well as purifying, storing, and loading the tritium into gas transfer system reservoirs and inspecting reservoirs. Tritium is also recovered from returned gas transfer systems.
High Explosives and Energetics Management	Development and production of energetics, including the associated manufacturing processes and infrastructure modernization to meet legacy and modernization stockpile applications. Energetics are materials that provide instantaneous energy through an exothermic chemical reaction. Energetics include specific end products, such as high explosives (conventional and insensitive) low explosives (pyrotechnics and propellants), their respective energetic ingredients, and various inert ingredients required for manufacturing (e.g., polymers, reactants, catalysts, plasticizers, oxidizers, fuels, ballistic modifiers, stabilizers, surfactants, and bonding agents).
Lithium Management	Handling, packaging, processing, manufacturing, and inspecting components that contain lithium materials require special conduct of operations, physical security protection, facilities, and equipment.
Additional Material Needs	Specialized components and materials that are not commercially available must be produced within the nuclear security enterprise. This production may require synthesis of organic materials and processing, manufacturing, and inspection of metallic and organic products, based on knowledge of material behavior, compatibility, and aging. This includes, but is not limited to, polymer material and part manufacturing.

B.5 Weapon Component Production

The Weapon Component Production area includes the core capabilities for producing the components and systems required to arm, fuze, fire, and deliver nuclear weapons to their targets. The Weapon Component Production area includes the capabilities for producing the non-nuclear components and systems for weaponization of the nuclear explosive package. These functions enable the weapons to arm, fuze, and fire for the designed function when needed. This capability includes both internal and external manufacturing and a broad supply base, as well as identification and verification of trusted suppliers to provide materials and parts within the weapon product realization process.

Capability	Definition
Non-Nuclear Component Modernization and Production	Non-nuclear weapon components and assembly processes require special manufacturing, assembly, and inspection protocols. The components include, but are not limited to, cable assemblies; electronic assemblies; microelectronics packaging; gas transfer systems; arming, fuzing, and firing assemblies; lightning arrestor connectors; environmental sensing devices; radars; neutron generators; and power sources.
Weapon Component and Material Process Development	Process development of weapon components involves small-lot production, precise controls, and a deep understanding of the hazards of working with SNM and other exotic materials. Component process development is needed whenever process changes are made to reduce cost or production time.

Capability	*Definition*
Weapon Component and System Prototyping	Development, qualification, and manufacture of high-fidelity, full-scale prototype weapon components and systems reduce the cost and life cycle time to develop and qualify new designs and technologies. This capability includes the ability to design, manufacture, and employ mockups with sensors to support laboratory and flight tests that provide evidence that components can function with DoD delivery systems in realistic environments.
Advanced Manufacturing	Advanced manufacturing uses innovative techniques from industry, academia, or internal R&D to reduce costs, reduce component development and production time, improve safety and performance, and control waste streams. Examples include additive manufacturing, use of microreactors, microwave casting, and electrorefining.

B.6 Weapon Assembly, Storage, Testing, and Disposition

After weapon components are produced, each requires assembly into complete warheads and temporary storage before delivery to DoD. Some of these warheads are removed from the stockpile on an annual basis for surveillance to provide data to evaluate the health of the stockpile. These surveillance activities (such as inspections, laboratory and flight tests, nondestructive tests, and component and material evaluations) provide data over time to predict, detect, assess, and resolve aging trends and any observed anomalies. This process requires disassembly and sometimes reassembly. At their end of life or for other reasons, nuclear weapons undergo disposition. The Weapon Assembly, Storage, Testing, and Disposition area covers all of these capabilities.

Capability	*Definition*
Weapon Assembly, Storage, and Disposition	This capability includes assembly and disassembly of all warheads, including components and subsystems contained within a device. This encompasses the breadth of national security enterprise capabilities requiring special conduct of operations, equipment, facilities, and quality control. Disassembly, inspection, and disposition of the warhead, components, and subsystems requires similar special conduct of operations, equipment, and facilities. Storage of weapons and subsystems requires special safety and security processes and protocols.
Testing Equipment Design and Fabrication	Design and fabrication of special test equipment to simulate environmental and functional conditions ensure that products meet specifications. Data from test equipment provide evidence for qualification, certification, reliability, surety, and surveillance.
Weapon Component and System Surveillance and Assessment	Surveillance enhances integration across test regimes to demonstrate performance requirements for stockpile systems by inspections, laboratory and flight tests, nondestructive tests, and component and material evaluations. Comparing data over time provides the ability to predict, detect, assess, and resolve aging trends and anomalous changes in the stockpile and address or mitigate issues or concerns. Assessment is the analysis, largely through modeling and simulation, of data gathered during surveillance to evaluate the safety, performance, and reliability of weapon systems and the effect of aging on performance, uncertainties, and margins.

B.7 Transportation and Security

The Transportation and Security area includes DOE/NNSA's capabilities for protecting the people, places, information, and other items and processes critical to the function of the nuclear security enterprise.

Capability	*Definition*
Secure Transportation	Protection and movement of nuclear weapons, weapon components, and SNM between facilities includes design and fabrication or modification of vehicles, design and fabrication of special communication systems, and training of Federal agents.
Physical Security	Physical security protects the Nation's nuclear materials, infrastructure assets, and workforce at DOE/NNSA sites involved in Weapons Activities. It protects assets from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile or noncompliant acts that may adversely affect national security, program continuity, and employee security.
Information Technology and Cybersecurity	Information technology and cybersecurity provides infrastructure and protection for both classified and unclassified computing networks, secure communications, applications, systems, and logical environments. It ensures electronic information and information assets are operating nominally and are protected from unauthorized access and malicious acts that would adversely affect national and economic security.

Appendix C
Workforce Retention

The greatest asset of the Department of Energy's National Nuclear Security Administration (DOE/NNSA) is the highly qualified and skilled world-class scientific and engineering workforce, without which DOE/NNSA could not meet its vital national security missions. The workforce simultaneously performs surveillance, warhead maintenance, technology exploration and maturation, research and development, supply chain management, and acquisition, among its modernization programs and other responsibilities. Given this workload, attracting and retaining the right talent is critical. This appendix provides the summary of human capital retention required in 50 U.S. Code § 2523c(4) and includes an updated demographic snapshot (as of September 30, 2021) of the workforce across the nuclear security enterprise. A detailed discussion of the DOE/NNSA workforce is contained in Chapter 7 and Appendix D of the *Fiscal Year 2022 Stockpile Stewardship and Management Plan* (FY 2022 SSMP).

The nuclear security enterprise continues to grow its Federal and management and operating (M&O) partner workforce to meet mission requirements. Like any large organization, DOE/NNSA faces challenges regarding its sizeable and diverse workforce. Some of these challenges, notably related to retention, are discussed below.

C.1 Challenges and Approaches

DOE/NNSA has made significant progress in hiring, despite several retention challenges:

- Roughly a quarter of the current enterprise workforce is eligible to retire, and there will likely remain a significant retirement-eligible population for the near future. See **Table C–1** for details.
- There is a shortage of U.S. citizens with science, technology, engineering, and math (STEM) skill sets, posing a significant challenge to recruiting STEM personnel. DOE/NNSA sites compete with the private sector to recruit and retain personnel with highly valued STEM skills (e.g., computer science, electrical engineering, and other engineering and science fields). Given demand for these skills, qualified applicants can command significant salaries that may exceed the enterprise's ability to match. Nuclear security positions require extensive security screening and U.S. citizenship, further limiting the pool of potential applicants.
- DOE/NNSA has had continued mission success, despite impacts of the ongoing Coronavirus Disease 2019 (COVID-19) pandemic. It remains to be seen how the pandemic may continue to impact the enterprise.

Table C–1. Federal and site percent retirement-eligible population as of September 30, 2021

Site	% Retirement Eligible[1]
Federal (across all sites)	15
Los Alamos National Laboratory	38.8
Lawrence Livermore National Laboratory	28.4
Sandia National Laboratories	19.2
Nevada National Security Site	28
Savannah River Site	16.8
Y-12 National Security Complex	27.4
Kansas City National Security Campus	14.2
Pantex Plant	22.2

On an enterprise level, DOE/NNSA's workforce strategy team, with membership that spans NNSA Headquarters, laboratories, plants, and sites, collaborates to find the best solutions to recruit and retain the current and future workforce. Partnership and collaboration will be essential to solving workforce challenges and maintaining the scientific and technical competencies that underpin DOE/NNSA's national security missions.

NNSA Headquarters, site offices, and M&O partners support retention through a variety of programs:

- Critical skill retention programs to offer pay incentives for hard-to-fill critical positions and "reengagement" to attract and rehire recently separated critical talent
- Aggressive knowledge transfer programs to provide expertise to newer employees (e.g., the Weapons Intern Program transfers detailed weapons and enterprise knowledge to future enterprise professionals)
- Employee leadership development programs, educational opportunities and assistance, and apprentice skill program involvement to encourage career growth
- DOE/NNSA Site Directed Research and Development, Plant Directed Research and Development, and Laboratory Directed Research and Development funding to encourage new ideas
- Emphasis on employee engagement through career conversations, career development tools, workshops, and mentoring
- Rotational and promotional assignments to diversify experience (e.g., detail assignments to other M&O partners or Federal sites)
- Improved University relations, partnerships, and scholarship programs
- Transition of many programs to a virtual environment when necessary and feasible to support teleworking and the greater impacts of COVID-19
- Flexible work schedules to support family-friendly work/life options (networking groups, fitness classes, meetups, etc.)

NNSA Headquarters, site offices, and M&O partners are committed to attracting and retaining top talent.

[1] The definition of "retirement-eligible" varies by location based on bargaining agreements, pension plans, and other factors. The differences in definition account for some of the variation between sites.

C.2 Demographics (Snapshot as of September 30, 2021)

As of September 30, 2021, the enterprise reported a headcount more than 51,000[2] employees (Federal and M&O partner combined), with a net increase of 2,306 employees from the number reported in the FY 2022 SSMP. However, the enterprise must continue to hire aggressively to replace employee separations (i.e., retirement, voluntary, involuntary). As shown in **Figures C–1** and **C–2**, voluntary separations among early-career employees (age 35 and under), mid-career employees (ages 36–50), and those with 5 years of service or fewer remain a challenge. As shown in **Figures C–3** and **C–4**, two-thirds of the FY 2021 workforce are early- and mid-career, and nearly half of the total workforce have 5 years of service or fewer. If current trends continue, the nuclear security enterprise will face challenges training these new hires and retaining the talented individuals it recruits.

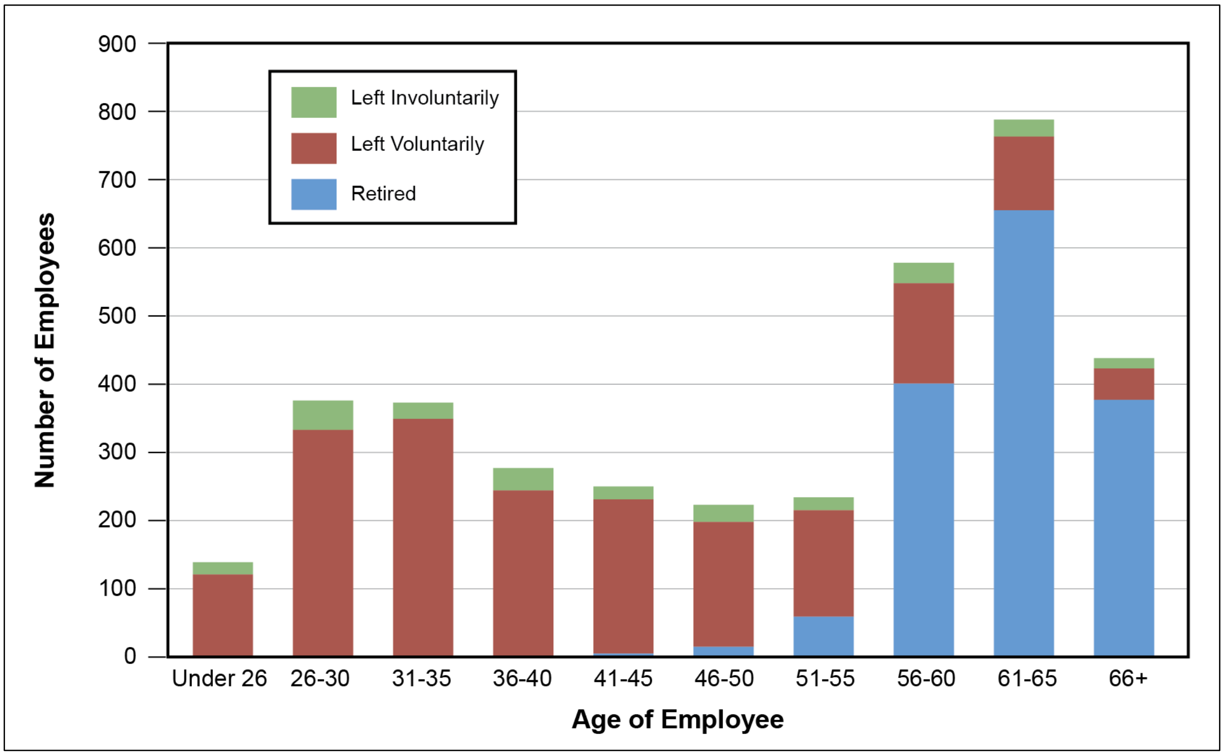


Figure C–1. Separation by age[3]

[2] This number omits Support Service Contractors and miscellaneous personnel not neatly incorporated into the Common Occupational Classification System categories.

[3] Workforce data is site-specific. For instance, if a person voluntarily leaves one M&O partner to work at another M&O partner, that movement appears as a separation and a hire. Similarly, if a Federal employee leaves DOE/NNSA to work at another Federal agency, that appears as a voluntary separation.

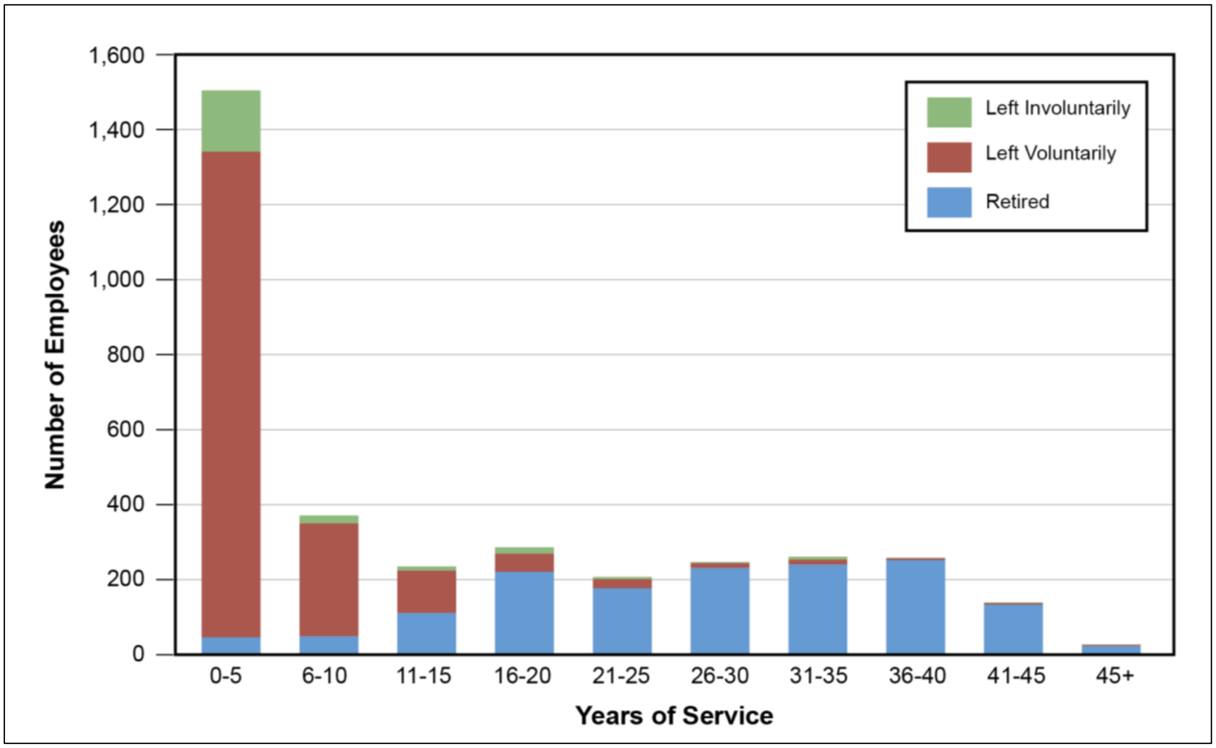


Figure C–2. Separation by years of service

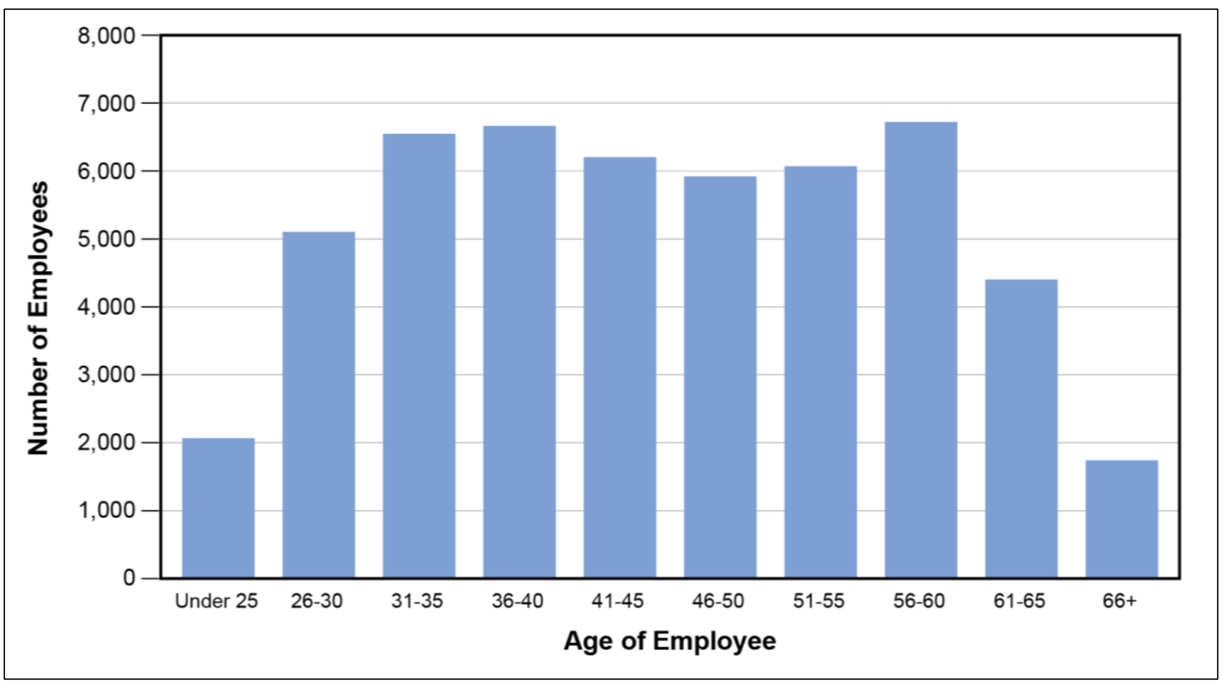


Figure C–3. Headcount by age

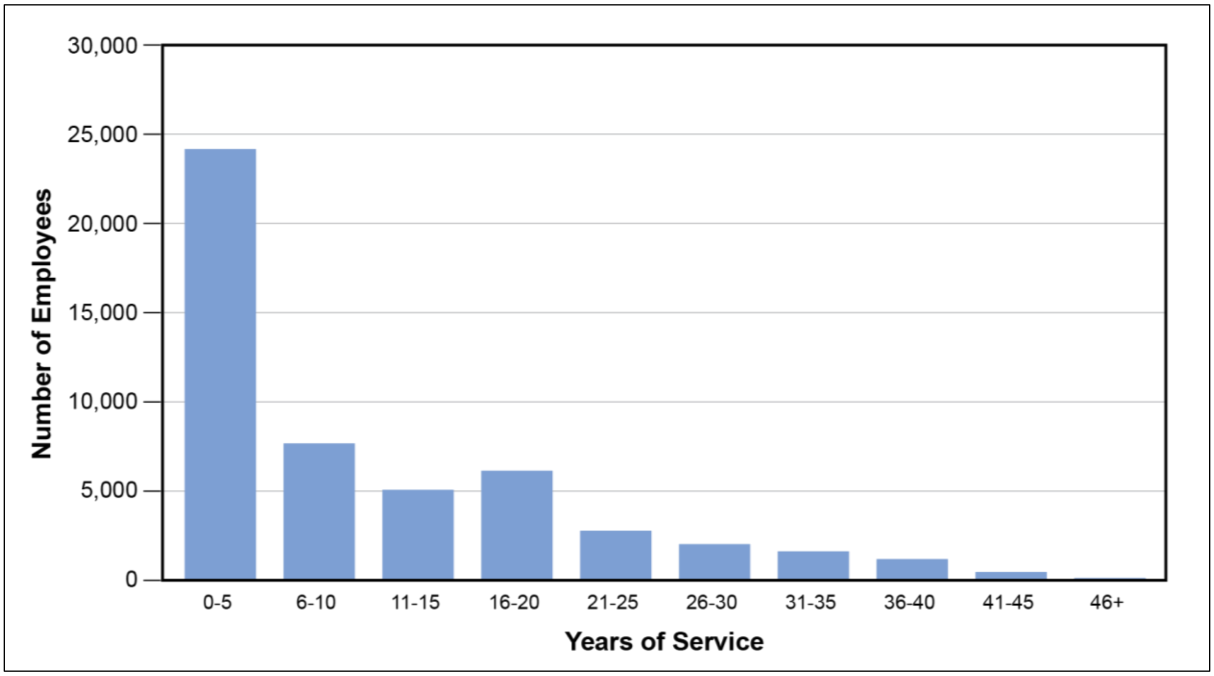


Figure C–4. Headcount by years of service

Appendix D
Exascale

The United States must retain state-of-the-art capabilities in high performance computing (HPC) to maintain competitive advantage and perform the annual assessment of the stockpile. HPC will support national security, economic prosperity, technological strength, and scientific and energy research leadership. Failure to apply HPC to national security, science, and growing big data needs will open the door for other nations with a demonstrated commitment to HPC investment to take the lead in several critical areas. Risk to U.S. leadership in high-end computing would increase, and could also eventually increase in science, national defense, energy innovation, and the commercial computing market.

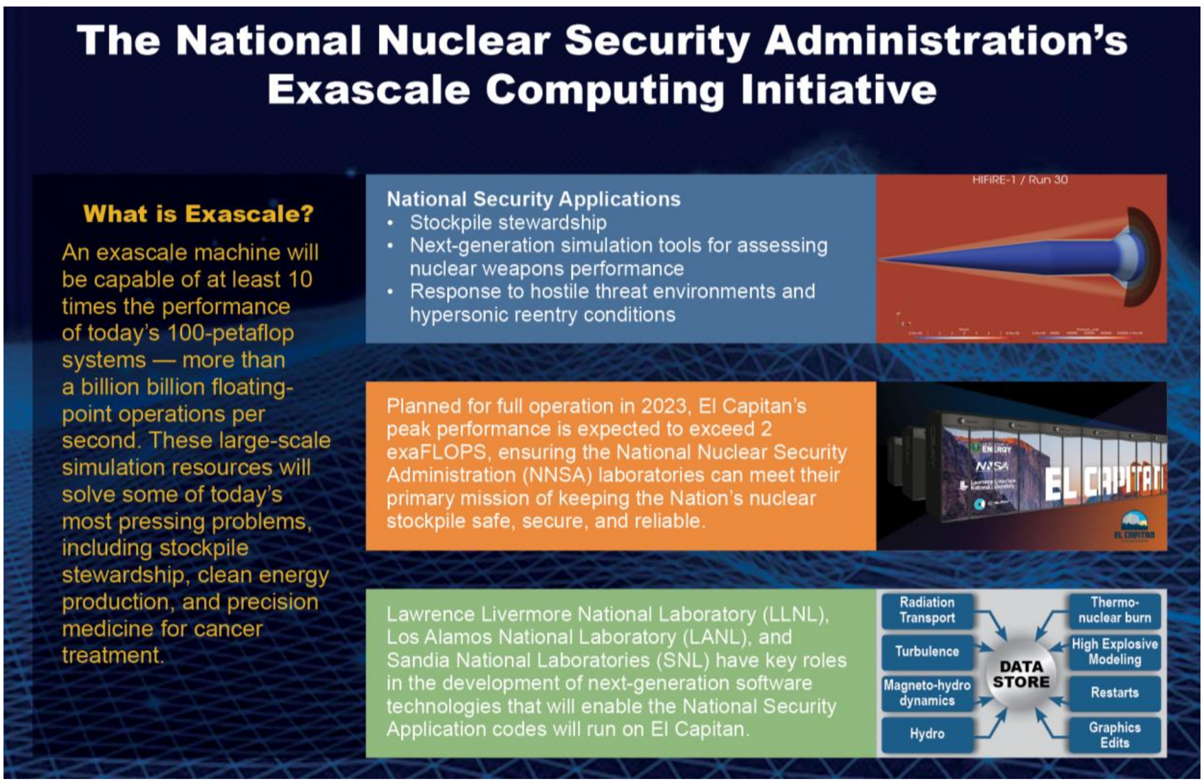


Figure D–1. Overview of the DOE/NNSA Exascale Computing Initiative

The National Strategic Computing Initiative was established as a Federal interagency campaign in 2015 to maximize the benefits of HPC for U.S. economic competitiveness, scientific discovery, and national security. Other agencies with major responsibilities for the Initiative include the National Science Foundation, the Intelligence Community, and the Departments of Commerce, Defense, Justice, and Homeland Security. The National Strategic Computing Initiative's major focus areas are the exploration and development of quantum computing, bio computing, and exascale computing. Within this initiative, the Department of Energy (DOE), represented by a partnership between the DOE Office of Science and DOE's National Nuclear Security Administration (DOE/NNSA), has the lead responsibility for focusing and implementing the joint Exascale Computing Initiative. This initiative focuses on advanced simulation that continues exploiting MOSFET[1] technology to emphasize sustained HPC to advance DOE/NNSA missions. The objectives and the associated scientific challenges define a mission need for a computing capability of 2 to 10 exaFLOPS[2] in the early to mid-2020s.

D.1 Challenges

To deliver the exascale computing capability for the nuclear security mission within the next decade while maintaining and modifying the integrated design codes (IDCs), DOE/NNSA will need to focus on six challenges:

- Developing HPC technologies and systems, in close partnership with computer vendors, that will provide at least an eight-fold increase in sustained application code performance over what is currently the largest NNSA supercomputer (a 125-petaFLOPS[3] system).
- Addressing code performance on the current advanced architecture and next-generation systems, which employ heterogeneous architectures that are very different from the homogeneous computing environment DOE/NNSA has experienced in the past two decades.
- Advancing the Advanced Simulation and Computing (ASC)-funded laboratory and open-source software stack to run efficiently on the new advanced architectures and to support emerging workflows.
- Developing prototype systems to assess the viability of alternate HPC architecture paths for the ASC.
- Improving remote computing infrastructure to facilitate access across the DOE/NNSA complex to exascale and other leading-edge platforms wherever each may be sited.
- Modernizing DOE/NNSA computing facilities to prepare them for siting future petascale and exascale platforms through increasing structural integrity, power, and cooling capabilities.

D.2 Approaches and Strategies

The U.S. Government has been interacting with industry in HPC technology development to achieve DOE/NNSA's exascale goals. Past partnerships between the U.S. Government and industry have led to development of innovative technologies that met Federal and private sector objectives. DOE/NNSA is continuing its partnership with the DOE Office of Science on the Exascale Computing Initiative, including investments in research and development (R&D) of hardware and systems technologies, software tools, and applications with computer vendors, the national laboratories, and universities. In addition, the two organizations collaborated on the joint April 2018 CORAL-2 procurement, which will deliver one exascale-class system to the DOE Office of Science in fiscal year (FY) 2021–2022 and another to DOE/NNSA in FY 2023. This joint procurement greatly supports the two organizations as they leverage each other's critical non-recurring engineering development costs and jointly manage the technical progress of the two exascale system projects.

The FY 2023 spend plan for Exascale Computing Initiative elements is delineated in **Table D–1**. In FY 2023, the DOE/NNSA portion of the Exascale Computing Initiative spans across all six ASC program elements:

---

[1] MOSFET stands for metal-oxide semiconductor, field-effect transistor. This technology, which has been the incumbent technology associated with Moore's law in microelectronics since the 1960s, theoretically begins failing significantly at speeds faster than exascale speeds.
[2] 1 exaFLOPS = 10^{18} floating-point operations per second.
[3] 1 petaFLOPS = 10^{15} floating-point operations per second.

Advanced Technology Development and Mitigation (ATDM); Integrated Codes; Physics and Engineering Models and Verification and Validation, which fund the next-generation simulation technologies for the weapons mission; Computational Systems and Software Environment subprogram that procures the El Capitan system; and Facility Operation and User Support that funds the site installation work for the power-up of El Capitan. Future exascale investments will include improvements to remote tri-lab computing infrastructure.

Table D–1. NNSA Exascale Computing Initiative funding schedule for FY 2023

Exascale Computing Initiative Elements	*FY 2023 Request (dollars in millions)*
Advanced Technology Development and Mitigation	12
Defense Applications and Modeling	18
Computational Systems and Software Environment	20
Facility Modifications	0
El Capitan Procurement	110
Total, NNSA Exascale Initiative	160

FY = fiscal year

Advanced Technology Development and Mitigation

For FY 2023, the ASC ATDM subprogram is designated as part of the DOE Exascale Computing Project (ECP), a jointly managed collaboration between DOE/NNSA and the DOE Office of Science in accordance with DOE Order 413.3B (tailored). This portion consists of the *ECP Software Technology,* in which ASC will make strategic investments in software technologies to directly support its IDC development requirements, where appropriate. Funding will support further development of compilers, math libraries, and programming models for the DOE/NNSA suite of weapons codes that are aligned with the algorithms and approaches used in those codes. This focused research is needed to optimize the performance of the algorithms within the overall simulations that are the most time-demanding or require the highest precision control in numerical approximations. Investments also will be made in various performance analysis tools and visualization techniques to aid code developers and users to navigate the new advanced architecture systems

Defense Application and Modeling – Next-Generation Application Development

In FY 2021, DOE/NNSA began transitioning the viable and validated ATDM next-generation code and associated capabilities into its Integrated Codes, Physics and Engineering Modeling, and Verification and Validation subprograms to support the annual assessment activities.

Computational Systems and Software Environment – Next-Generation Computing Technologies

In FY 2021, DOE/NNSA started the process of transitioning its previously ATDM-funded computing technology activities to Computational Systems and Software Environment. DOE/NNSA will continue evaluating its next-generation IDC performance portability on advanced architecture prototype systems. Funding will be used for development, maintenance, and user support for the DOE/NNSA tri-laboratory software stack that will be required for the next-generation codes to run efficiently on these advanced technology systems. In addition, DOE/NNSA will continue investing in the application of advanced machine learning techniques, which are well-suited to the imminent advanced architectures, to address stockpile stewardship challenges.

Computational Systems and Software Environment – El Capitan Procurement

DOE/NNSA is embarking on a multi-year collaboration with the selected system vendor and its subcontractors to work on non-recurring engineering and system integration to deliver El Capitan. The collaboration focuses on system engineering efforts and software technologies to assure the 2023 exascale system will be a capable and productive computing resource for the Stockpile Stewardship Program.

D.3 Collaborative Management

As the ECP spans across DOE/NNSA, its management equally involves both organizations' Federal and laboratory personnel. The ECP overall management structure includes the Integrated Project Team in **Figure D–2**. The Integrated Project Team provides planning, execution, coordination, and communication for the ECP to ensure the project's objectives are achieved on schedule and within budget and are consistent with quality, environment, safety, and health standards.

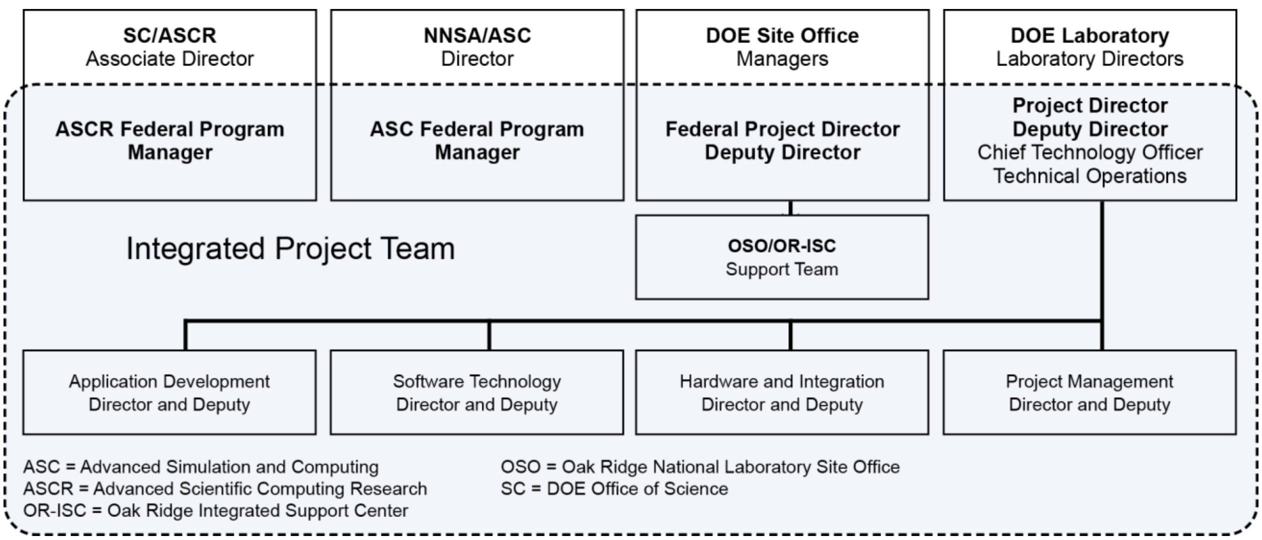


Figure D–2. Exascale Computing Project integrated project team

D.4 Milestones

DOE/NNSA has five milestones for FY 2023:

- Continue engagement with the El Capitan system vendor on system build activities
- Begin transition of DOE/NNSA ATDM application codes to the ASC Defense Applications and Modeling portfolio to support annual certification and assessment mission
- Begin transition of selected DOE/NNSA ATDM computing technologies to its Computational Systems and Software Environment portfolio
- Operate El Capitan early access system-3 nodes sited at Lawrence Livermore National Laboratory
- Port ATDM application codes to El Capitan early access system-3 nodes to analyze potential performance issues

D.5 Conclusion

DOE/NNSA, through the ASC exascale computing effort, is investing in products and approaches that will respond directly to anticipated disruptive changes in the HPC ecosystem. Activities include creating R&D partnerships with multiple HPC vendors, developing next-generation weapons codes with new simulation capabilities, advancing the tri-laboratory software stack, procuring an exascale system, deploying prototype systems to assess the viability of new computing technologies, and upgrading facilities to house future exascale and petascale systems. Collaboration projects with computer vendors has also led to significant advances in HPC software and hardware technologies. These activities have provided valuable lessons learned and delivered numerous software development tools and libraries that many ASC applications now rely on. More intensive research, development, and engineering effort is needed for DOE/NNSA to achieve the goal of deploying and fully utilizing an exascale capability in 2023.

Appendix E
Stockpile Responsiveness Program

This appendix is provided pursuant to 50 U.S. Code § 2523, which requires inclusion of plans for the Stockpile Responsiveness Program in the Stockpile Stewardship and Management Plan (SSMP). H. Rept. 117-98 accompanying the Energy and Water Development and Related Agencies Appropriations Bill, 2022, restated an annual Stockpile Responsiveness Program reporting requirement and noted that as the SSMP does not typically accompany the annual budget request, including the report within the SSMP "therefore does not offer a useful and timely companion to the budget." This direction was reiterated again through Joint Explanatory Statement accompanying the Energy and Water Development and Related Agencies Appropriations Act, 2022. Therefore, in accordance with this direction, the Department of Energy's National Nuclear Security Administration submitted the report as a standalone document in September 2022 to provide as timely updates as possible. This report is being resubmitted through this appendix, as the SSMP is also required to provide information on the Stockpile Responsiveness Program under 50 U.S. Code 2523 and 2523(c)(5), as noted above.

This page left blank intentionally

Status of and Plans for Projects and Activities within the Stockpile Responsiveness Program

2022 Annual Report

Report to Congress
August 2022

National Nuclear Security Administration
United States Department of Energy
Washington, DC 20585

Message from the Administrator

Meeting future deliverables for U.S. nuclear stockpile modernization requires a renewed focus on innovation to enable accelerated production and to permit the Nuclear Security Enterprise to respond more swiftly to evolving national security environments and Department of Defense (DoD) requirements for future systems.

As established by Congress, and in consultation with DoD, the Department of Energy's National Nuclear Security Administration (DOE/NNSA) Stockpile Responsiveness Program (SRP) provides nuclear weapons scientists and engineers with opportunities to exercise a range of skills across the entire weapon lifecycle, including manufacturing and production processes. Such activities fully exercise the capabilities of the Nuclear Security Enterprise and enable the workforce to identify efficiencies for current and future programs. SRP enhances DOE/NNSA's capabilities to improve the responsiveness of the United States to future threats, technology trends, and international developments not addressed by existing life extension programs.

Pursuant to legislative requirements, this report is being provided to:

- **The Honorable Patrick Leahy**
  Chairman, Senate Committee on Appropriations
- **The Honorable Richard Shelby**
  Vice Chairman, Senate Committee on Appropriations
- **The Honorable Dianne Feinstein**
  Chair, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations
- **The Honorable John Kennedy**
  Ranking Member, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations
- **The Honorable Rosa L. DeLauro**
  Chair, House Committee on Appropriations
- **The Honorable Kay Granger**
  Ranking Member, House Committee on Appropriations
- **The Honorable Marcy Kaptur**
  Chairwoman, Subcommittee on Energy and Water Development
  House Committee on Appropriations
- **The Honorable Mike Simpson**
  Ranking Member, Subcommittee on Energy and Water Development
  House Committee on Appropriations

If you have any questions or need additional information, please contact Dr. Benn Tannenbaum, Associate Administrator for Congressional and Intergovernmental Affairs, at (202) 586-7332.

Sincerely,

Jill Hruby
Under Secretary for Nuclear Security
Administrator, NNSA

Executive Summary

Meeting future deliverables for the Department of Defense (DoD) and modernizing the U.S. nuclear stockpile requires innovation to accelerate production and to enable responsive changes to developments in the geopolitical environment. The Stockpile Responsiveness Program (SRP) was created to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive. The Department of Energy's National Nuclear Security Administration (DOE/NNSA) collaborates closely with DoD on SRP execution, and the joint DoD-DOE/NNSA Nuclear Weapons Council (NWC) annually reviews and periodically updates guidance for the program.

SRP provides the Nuclear Security Enterprise with opportunities to exercise a range of capabilities to improve responsiveness throughout the entire nuclear weapons lifecycle, including design, production, and accelerated testing. Technology development teams also provide leadership opportunities for early-career staff members. SRP activities fully exercise the abilities of the workforce and allow the enterprise to identify efficiencies for current and future programs

DOE/NNSA has organized SRP according to major technical efforts aligned with the stated objectives of the program, and SRP heavily focuses on improving production responsiveness, a high priority for DOE/NNSA, Congress, and the NWC. DOE/NNSA and DoD also continue to explore joint activities with SRP and the Office of the Under Secretary of Defense for Research and Engineering. As requested by Congress, this report details these efforts, and provides information regarding the program's purpose, planned budget, governance, and priorities.

National Nuclear Security Administration

Status of and Plans for Projects and Activities within the Stockpile Responsiveness Program 2022 Annual Report

Table of Contents

I. Legislative Language

This report responds to legislative language set forth in House Report (H. Rept. 116-449) accompanying the *Energy and Water Development and Related Agencies Appropriations Bill, 2021*, wherein it is stated:

> *"Stockpile Responsiveness Program.—The NNSA shall submit to the Committee an annual report with the budget request that includes a detailed accounting and status of each program, project, and activity within the program. The committee expects to receive timely updates on the status of any new and existing taskings, studies, and assessments."*

House Report (H. Rept. 117-98) accompanying the *Energy and Water Development and Related Agencies Appropriations Bill, 2022*, restated the annual requirement, wherein it is noted:

> *"Stockpile Responsiveness Program.—The fiscal year 2021 Act directed the NNSA to submit to the Committee an annual report with the budget request that includes a detailed accounting and status of each program, project, and activity within the program. The NNSA has proposed meeting this reporting requirement by expanding the annual Stockpile Stewardship and Management Plan (SSMP) as necessary. The Committee notes that the SSMP does not typically accompany the annual budget request, and therefore does not offer a useful and timely companion to the budget. The Committee reiterates the fiscal year 2021 direction and expects to receive timely updates on the status of any new and existing taskings, studies, and assessments*."

The Joint Explanatory Statement accompanying the *Energy and Water Development and Related Agencies Appropriations Act, 2022*, also reiterated House direction regarding an annual report and periodic updates.

II. Introduction

The Department of Energy's National Nuclear Security Administration's (DOE/NNSA) Stockpile Responsiveness Program (SRP) was created to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive. SRP does not develop and deploy nuclear weapons for the stockpile. SRP is intended to exercise and enhance capabilities through the entire nuclear weapons lifecycle to improve the responsiveness of the United States to future threats, technology trends, and international developments not addressed by existing life extension programs.

As requested by Congress, this report details SRP's efforts, planned budget, governance, and priorities. The previous iteration of this annual report was included within the *Fiscal Year 2022 Stockpile Stewardship and Management Plan* (SSMP), as the SSMP is already required to provide information on SRP under 50 U.S.C. 2523 and 2523(c)(5). In accordance with direction provided in H. Rept. 117-98 and the Joint Explanatory Statement accompanying the *Energy and Water Development and Related Agencies Appropriations Act, 2022*, DOE/NNSA will also provide the report as a standalone document to provide as timely updates as possible.

III. Program Establishment, Purpose, Early Execution, and FY 2022 SRP Funding

SRP was created by Congress in Section 3112 of the *National Defense Authorization Act for Fiscal Year 2016* (NDAA), which states, "It is the policy of the United States to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive."

The Act directs that the program be carried out by the Secretary of Energy, in consultation with the Secretary of Defense. The five objectives for the program are:

1. Identify, sustain, enhance, integrate, and continually exercise all the capabilities, infrastructure, tools, and technologies required to carry out all phases of the joint nuclear weapons life cycle process.
2. Transfer knowledge to the next generation of scientists and engineers.
3. Demonstrate responsiveness including prototypes, flight testing, and development of plans for certification without the need for nuclear explosive testing.
4. Shorten design, certification, and manufacturing cycles and timelines to minimize the amount of time and costs leading to an engineering prototype and production.
5. Exercise relevant elements and processes with the Department of Defense (DoD) to ensure stockpile responsiveness.

Accompanying report language emphasized that the program was intended to respond to future threats to our nuclear deterrent through science and technology. Report language reiterated a key constraint that acquiring new or modified systems for the U.S. stockpile requires explicit congressional line-item appropriations.

Section 3118 of the *National Defense Authorization Act for Fiscal Year* (FY 2018 NDAA) provided additional guidance on design and prototyping activities and directed NNSA "to exercise the full set of design skills necessary for an effective nuclear deterrent, [by] develop[ing] and conduct[ing] the first in what the committee envisions to be a series of design competitions that integrate the full end-to-end process from novel design conception through engineering, building, and non-nuclear testing of a prototype." NNSA informed Congress it would meet the requirements of this section of legislation through SRP.

The SRP was funded at $34 million (M) in FY 2019. In FY 2020 and FY 2021, Congress increased the funding to $70M and NNSA broadened its scope to the establishment of national security laboratory/production plant collaborations focused on accelerating the production process.

The *Consolidated Appropriations Act, 2022* (P.L. 117-269), signed into law on March 15, 2022, included $50M for SRP. Table 1 provides the site allocations for SRP.

Table 1. Proposed Stockpile Responsiveness Program site allocations

Site	FY 2021 Enacted	FY 2022 Enacted	FY 2023 Request
Pantex Plant	3,975,000	2,255,276	3,975,000
Y-12 National Security Complex	3,625,000	750,000	3,625,000
Kansas City National Security Campus	5,397,670	2,758,670	5,397,000
Los Alamos National Laboratory	19,500,000	15.674,805	18,080,867
Lawrence Livermore National Laboratory	18,000,000	14,835,066	18,080,867
Sandia National Laboratories	18,000,000	12,630,687	18,080,867
Headquarters	1,502,400	1,095,496	1,502,400
Total	**$70,000,000**	**$50,000,000**	**$68,742,000**

IV. Governance and Priorities

From the outset, DOE/NNSA has collaborated closely with the Office of the Secretary of Defense, Deputy Assistant Secretary of Defense for Nuclear Matters on SRP execution. The Nuclear Weapons Council (NWC) receives annual briefings on program accomplishments and approves plans for the upcoming year, including authorization of joint DOE/NNSA- DoD activities. The NWC also annually reviews and periodically updates the "Stockpile Responsiveness Capabilities Development Guidance," (SRCDG) which establishes NWC guidance and priorities for SRP execution. DOE/NNSA and DoD hold a joint SRP conference each year to discuss accomplishments, issues, and opportunities.

The NWC's FY 2020 SRCDG, which remains effective for FY 2022, identified that DoD's overarching priority for SRP is to demonstrate methods to reduce the time and cost of producing and qualifying nuclear weapons components and systems. This priority is consistent with the views expressed on page 309 of the House Armed Services Committee Report 116–442, *William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021* (FY 2021 NDAA), which "encourages the Secretary of Defense and the Administrator of the National Nuclear Security Administration to focus some resources and effort toward reducing cost, risk, and difficulty of manufacturing and producing nuclear weapons."

NWC guidance directed SRP to pursue this overarching priority in the context of two key issues: hard and deeply buried targets (HDBT) and defended target defeat. Section 3118 of the 2018

NDAA also directed DOE/NNSA to execute a design competition to look at the challenge of holding defended targets at risk.

V. Approach to Responsiveness, Risk Management, Safety, and Security

The evolving modernization strategy for the Nuclear Security Enterprise requires a renewed focus on innovation. DOE/NNSA must be able to accelerate design and production of new or modified systems designed to be responsive to changes in the national security environment. Iteration of the design-build-test cycle must be accelerated from the current timetable of years to months. To surmount the technical risk inherent in adopting new technologies on expedited timetables, the enterprise must accept the inevitability of technical surprises along the development path from design to production and qualification.

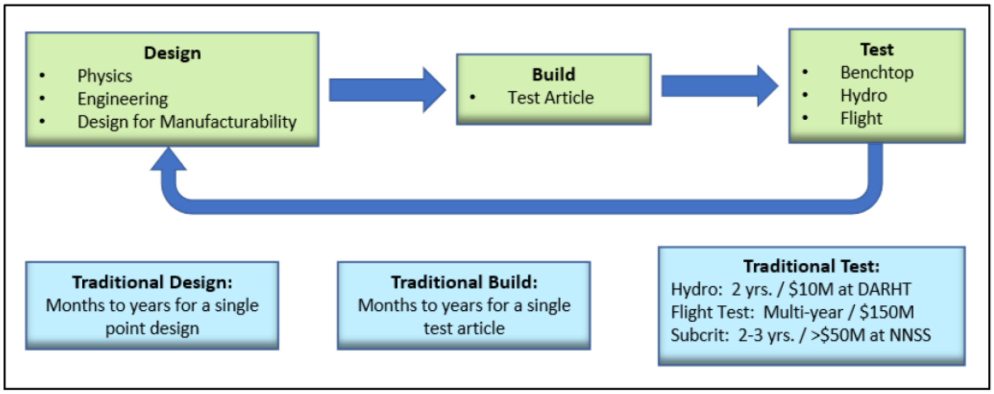


Figure 1. The traditional design-build-test cycle for weapon system development

Key to the necessary acceleration will be training and exercising the skills of the next generation of designers, engineers, technologists, scientists, and production staff. The Nuclear Security Enterprise must also develop prototype and test capabilities for warhead design and production.

A key accomplishment of SRP has been shifting the focus of some of DOE/NNSA's inter-site and interdisciplinary teams. These teams have been the backbone of past DOE/NNSA successes by improving collaboration between design and production agencies. Such collaboration emphasizes joint approaches to developing capabilities for design for production, modernized production technologies, and streamlining qualification processes.

SRP Challenge Problems are focused on integrated system designs to address future threats and are vital to setting the context for training staff to exercise and accelerate the design-build-test cycle. Challenge Problems provide the opportunity to take fresh approaches using modern technical capabilities independent of the constraints of current or proposed life extension programs (LEPs). SRP activities—because they do not interfere with current programs of record—can accept the risk of anomalous or surprising results in the quest to develop responsive and innovative solutions. Knowledge gained in SRP activities can be used to reduce risks for future warhead modernization programs by demonstrating success or ruling out specific processes or technologies, in advance of need.

The intended product of SRP is *responsiveness*, not to develop a new system but to accelerate the process by which new systems or improved production capabilities, when authorized, will be designed and built. SRP focuses on what can be done through accelerated technical activities by developing and demonstrating ways to sharply reduce timelines and costs.

SRP will not compromise personnel, facility, or nuclear safety or security requirements. SRP will in many cases develop unclassified surrogates or use material surrogates that eliminate safety and security issues. This will allow SRP to maximize the data derived from activities as well as testing and training experiences for the next generation of scientists and engineers.

VI. Execution of the Technical Program and Major Technical Efforts

DOE/NNSA has organized the program according to four major technical efforts (MTEs) aligned with the five SRP objectives. All technical efforts rely on seasoned mentors to transfer knowledge to less experienced technical staff members, from threat assessments to system design to testing activities to individual technologies development. Technology development teams provide leadership opportunities for early-career staff members. DoD connections are exercised throughout SRP execution from coordination with the NWC to technical exchanges with relevant U.S. Air Force and U.S. Navy organizations.

Exercising design capabilities critical to developing stockpile responsiveness is one part of the overall technical program to develop a responsive posture. The preponderance of the technical effort within SRP is focused on the acceleration of other aspects of responsiveness, such as testing and production.

Table 2. Distribution of the Stockpile Responsiveness Program Budget across Major Technical Efforts[a]

MTE	*Subject*	*Budget Fraction*	*Estimated Totals under FY 2023 Request*
1	Future threats, technology trends, and opportunities	10%	$6,874,200
2	Challenge Problems – integrated system designs to address future threats	20%	$13,748,400
3	Prototyping, testing, and flight testing	30%	$20,622,600
4	Technologies for production responsiveness	40%	$27,496,800

MTE = major technical effort.

[a] Each MTE's budget fractions and FY 2023 request totals are estimated targets and may not be exact. Some projects are crosscutting with overlap between MTEs and may also be mutually beneficial across select laboratories, plants, and sites. Please refer to each MTE section for additional detail on specific efforts.

Major Technical Effort 1: Future Threats, Technology Trends, and Opportunities

Under this MTE, national security laboratory technical capabilities are applied to understanding and anticipating future challenges to the nuclear deterrent arising from geopolitical considerations, evolving U.S. operational needs and employment doctrine, and emerging technology trends. The national security laboratories provide analytic capabilities in collaboration with field intelligence elements, the intelligence community more generally, and the military combatant commands.

The "Design for Effects" effort shared by Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico; Lawrence Livermore National Laboratory (LLNL) in Livermore, California; and Sandia National Laboratories (SNL) in Albuquerque, New Mexico and Livermore, California, provides improved understanding to analyze options and capabilities to support DoD. High-fidelity analytical methods such as advanced three-dimensional geophysics models developed under national security laboratory advanced computing efforts are being exercised to improve understanding of the offensive and defensive aspects of weapons effects. Specific analyses have included:

- Analysis of identified targets supporting DOE/NNSA and Defense Intelligence Agency/DRI-5;
- Pill Sources versus High-Fidelity Sources Survey (LLNL, LANL, SNL);
- Coupling Cratering/Ground Shock Fluid/Structure to finite element method/discrete element method code (LANL);
- Machine Learning approach for translating computer-aided design files to usable numerical model (LLNL);
- Shock Fluid/Structure interaction for tree models[1] – Non-Ideal Air Blast (SNL);
- Non-Ideal Air Blast analyses of four test problems (LANL, LLNL, SNL); and
- Weaponeering Options for Contingencies (LANL).

Major Technical Effort 2: Challenge Problems

Established by joint agreement between DoD and DOE/NNSA, Challenge Problems enable the national security laboratories to rebuild and rediscover the skills needed to design integrated systems with new delivery vehicles, environments, and performance requirements. Challenge Problems also exercise the range of engineering and systems design capabilities required to integrate new technologies on new delivery platforms, while accelerating the weapons life cycle from design, development, and manufacturing to certification and qualification. Nuclear weapons system design, production methods, and the technologies employed in nuclear systems are best developed synergistically considering the abilities of the production agencies

[1] Tree models study how shock and blast propagate through a forest of trees, high-rise buildings in urban areas, or other structures.

as well as the needs of the DoD services to balance capabilities, costs, timelines, and confidence in safety and performance.

Challenge Problem teams include members of various skill and experience levels across multiple disciplines and professions, including design physicists, engineers, weapon effects scientists, diagnostic and testing specialists, and those who will have to develop the prototype or produce the system. The major focus areas are training the next generation of technical staff, building multidisciplinary teams, and developing a culture that can respond quickly to new requirements. Close collaboration between designers and the production plants[2] also allows for better understanding of manufacturing and qualification impacts of design choices during system development.

Challenge Problem 1 (CP1) Hard and Deeply Buried Target Defeat

CP1 is focused on hard target defeat, an objective identified in NWC taskings. Discussions among LANL, LLNL, and SNL physics and engineering staff and DoD partners, especially U.S. Strategic Command (USSTRATCOM) and Navy Strategic Systems Programs, were held to understand needs. Concepts were developed with a range of performance, development, and manufacturing complexity. Some concepts were based on traditional approaches to the problem, while others proposed more innovative and technically challenging solutions. Further study was focused on one specific concept based upon strong interest from the military services and on the assessed ability of the production plants to respond to the production challenges. This down-selected hard target defeat concept has led to laboratory prototyping and testing activities to better understand the harsh employment environment to which the weapon is subjected and to develop technologies to mitigate this environment as reported in MTE 3.

The work performed for the CP1 Design Exercise during the past year includes:

- Development of system concepts expected to be effective at a low level of fidelity (LANL, LLNL, SNL);
- Completion of the NWC task to evaluate concepts for technical HDBT defeat for feasibility, production feasibility, delivery platform compatibility, and relative time to deployment (LANL, LLNL, SNL) as well as a preliminary weapons effectiveness assessment of these concepts (LANL, LLNL, SNL);
- Technical gap analysis to identify the leading concept-spanning technical challenges (LANL, LLNL, SNL); and
- Plans for hardware prototype development and testing activities for the leading technical challenges (LANL, LLNL, SNL, Kansas City National Security Campus in Kansas City, Missouri [KCNSC]).

---

[2] DOE/NNSA's Production Plants include the Kansas City National Security Campus, in Kansas City, Missouri; and the Pantex Plant near Amarillo, Texas.

Challenge Problem 2 (CP2) Defended Target Defeat

CP2 was developed pursuant to the FY 2018 NDAA (P.L. 115-91) language to execute a design competition to address or mitigate target defenses that may be employed by adversaries in the 2030s. The national security laboratories have responded to this challenge by creating clean-sheet designs, unconstrained by existing LEPs, to deliver new capabilities if required by the NWC and authorized by Congress. CP2 emphasizes existing and emerging threats analysis and designs development that mitigate those threats in system-level models.

The LANL approach to CP2 was to down-select quickly to a specific option, then concentrate on refining the design and taking it to prototyping, ground testing, and flight testing to gain early experience exercising the entire design-build test cycle. This design was used to demonstrate acceleration of hydrotesting, and LANL is pursuing options for rapid flight testing of engineering prototypes.

LLNL has focused on developing a process to design and assess design packages through a diverse portfolio of multi-purpose, modular, and flexible options. The designs in this portfolio can fly in multiple carriers, and LLNL is concentrating on those that can defeat prospective targets with a range of weights, yields, and other traits. All options are designed with ease of manufacturing in mind. Each option can field interchangeable parts or materials, including component reuse. Proof-of-principle work has been completed on this portfolio, and designs can be fine-tuned against a range of emerging contingencies. LLNL will prototype a down-selected option in collaboration with other DOE/NNSA design and production agencies.

SNL has focused on developing engagement models[3] to evaluate the effectiveness of various options for Defended Target Defeat under multiple possible scenarios.

Major Technical Effort 3: Prototyping, Testing, and Flight Testing

The ability to rapidly produce and test prototypes is integral to accelerating the nuclear weapons life cycle for new capabilities or for the employment of modern technologies to maintain current missions. In executing SRP's legislated objective, DOE/NNSA relies on the prototyping definition provided under the now repealed 50 U.S. Code § 2660, *Design and use of prototypes of nuclear weapons for intelligence purposes,* which authorized within section (b)(2):

> **(A)** Design and system engineering activities of full-scale engineering prototypes (using surrogate special nuclear materials), including weaponization features as required.
>
> **(B)** Design, system engineering, and experimental testing (using surrogate special nuclear materials) of above-ground experiment test hardware.

[3] Models of the engagement of a military system to evaluate its effectiveness against other weapons, counter measures or its effectiveness against a target under a specific launch to target environment including intervening atmospheres, weather, mountains, etc.

(C) Design and system engineering of scaled or subcomponent experimental test articles (using special nuclear materials) for conducting experiments at the Nevada National Security Site.

This prototyping authority is consistent with the Section 3118 of the 2018 NDAA, which prohibits experiments that could produce a nuclear yield. In accordance with this guidance, SRP is focused on efforts necessary to evaluate integrated technologies, representative modes, or prototype systems in a high fidelity and realistic operating environments. This includes system specific efforts that help expedite technology transition from the laboratory to consideration in line-item acquisition programs. Emphasis is on proving component and subsystem maturity prior to downselect by an acquisition program for integration in major and complex systems and may involve risk reduction initiatives.

The context established by CP1 inspired an ambitious prototyping and testing program executed through collaborations between LANL, LLNL, SNL, and KCNSC. SNL has fielded several experiments on the Davis Gun at White Sands Missile Range to examine ground penetration issues and shock mitigation techniques to validate codes in this harsh environment.

Small, focused tests have been performed at LLNL and other external facilities. These tests will culminate in a hyper-velocity sled-track test at Holloman High Speed Test Track at Holloman Air Force Base. During FY 2020, LLNL added a target development test to an already established experiment for the Weapon Survivability subprogram. The data generated from this test led to a redesign of embedded wire diagnostics in a high explosives (HE) test. Equation-of-state data obtained from rapidly prototyped samples then led to a redesign of targets to be fielded in FY 2021. Lessons learned in each phase directly contributed to the successes of the following phase at a pace that would not have been possible if each test were designed to meet LEP-grade standards. Technical staff have gained experience in the realities of field testing, in which a lack of resources on-hand can force compromises and creative solutions to successfully complete experiments in a constrained availability window.

CP2 is driving rapid prototyping capabilities to demonstrate innovative production technologies and processes. LANL is pursuing an effort to greatly decrease the time required to execute hydrotests and smaller scale HE testing. An initial demonstration was completed in 10 months, less than half the normal completion time. Ultimately, LANL and LLNL are pursuing efforts to decrease hydrotesting times down to a few months. CP2 is also creating new capabilities development such as flash X-ray radiography on a centrifuge to measure displacements and deformations of an accelerated object in situ. In these demonstration activities, SRP is accepting risk by fielding previously unproven diagnostics, technologies, fabrication methods, and assembly techniques in its hydrotesting program.

LANL is pursuing commercially provided flight services as platforms to enable rapid prototyping and testing of near full-scale engineering prototypes to bring systems and technologies to maturity for future consideration. KCNSC and LANL have been collaborating to explore new, rapid manufacturing techniques to provide prototype and support hardware to support these tests. A first experiment of a proposed series, called REDX-1, was executed in 13 months from verbal concept proposal to payload design, development, and integration on a commercially provided rocket. It was successfully launched from Spaceport New Mexico and recovered in White Sands Missile Test Range on August 11, 2021. Flight data were successfully transmitted via a LANL CUBESAT[4] and more complete data were recovered with the payload. A second flight test is planned for July 2022 and a third in November of 2023, both using larger payloads and integrating technologies of interest for further development.

For potential inclusion in future activities, DOE/NNSA is engaged in discussions through the NWC for SRP to work with the Office of the Under Secretary of Defense for Research and Engineering to identify pre-acquisition technology development, test and system integration efforts that are of mutual benefit.[5] Potential collaborations include: 1) DOE/NNSA aeroshell prototyping capability for environmental testing and qualification processes, 2) overlapping requirements for data-bus architectures and modular systems, 3) overlapping interest in sensors and electronics that have implications for nuclear safety and use control, and 4) overlapping interest in sensors and data collection for flight testing.

KCNSC is operating a Technology Integration Demonstrator program that uses digital engineering to design, simulate, fabricate, and test new components on a time frame of months rather than years. KCNSC then subjects payloads containing these new components to real-world testing environments on sounding rockets. This fast cycle allows new materials to be developed and tested in real-world conditions and is generating data to improve simulation models.

SNL prototyping and testing efforts include:

- Re-establishing an aeroshell prototyping capability;
- Prototyping and testing of advanced radar antenna;
- Prototyping and testing a next-generation fuze design; and
- Establishing new ground test capability at the SNL Superfuge centrifuge facility to better encompass future mixed environments through the full stockpile-to-target sequence.

Major Technical Effort 4: Technologies for Production Responsiveness

MTE 4 encompasses efforts specifically important to furthering production responsiveness. This effort includes design for manufacturability, digital engineering techniques, novel approaches to materials production, advanced manufacturing processes, development of

---

[4] CUBESATs are lightweight, small volume satellites using commercial-off-the-shelf components. They are relatively inexpensive to build and place into orbit. CUBESATs are used for communications, research, and national security needs and are built by universities, the U.S. Government, commercial entities, and the national laboratories.

[5] One of the earliest and continuing challenges in standing up SRP and collaborating with DoD has been identifying DoD partners who are not principally engaged in system acquisition efforts where SRP lacks formal line-item authorization. Instead, SRP sees its proper role as earlier prototyping and testing to understand how technologies function or need further development when tested in integrated systems and/or in realistic environments or in a production environment.

architectures that accelerate production and maintainability, and efforts to accelerate qualification and acceptance of components and systems.

Digital Engineering. SRP prototyping activities use digital engineering capabilities to transfer data and design information across the Nuclear Security Enterprise to the maximum extent possible. Model-based systems engineering and machine learning are also being adopted to accelerate design for manufacturability.

Materials production technologies are pursued to provide new materials or materials production processes for critical and hard-to-produce products:

- **HE production.** LLNL and LANL have developed HE formulations with improved energy delivery that could replace conventional HE (CHE) in future systems. The national security laboratories are working to accelerate scale-up of synthesis, formulation, and qualification of candidate insensitive HE (IHEs) to reduce the reliance on CHEs in future system designs. LLNL is accelerating the development of a high explosive designated LX-22 as a new main-charge formulation, and LANL is working to scale up synthesis of the IHE DAAF[6] and formulate it into a new IHE, PBX 9701.
- **Continuous flow process to support HE synthesis and production**. In addition to working on component-level HE manufacturing technologies, LLNL is working on advanced synthesis and formulation methodologies to optimize control over the feedstock material, improve quality control and production yields, and reduce costs and schedule risks.
- **Additive manufacturing of polymers**. Additive manufacturing of polymers and polymer-based composite materials has rapidly advanced in the past few years. Under SRP, LLNL is leveraging these advances in the polymer enclave to rapidly produce bespoke components on a regular basis to accelerate testing.
- **Uranium alloys production.** Electron Beam Cold Hearth Melting is a technology that significantly reduces waste and accelerates timelines in the alloying and recycling of uranium alloys. A collaboration between the Y-12 National Security Complex (Y-12) in Oak Ridge, Tennessee and LLNL procured, installed, and commissioned a system at Y-12 which then demonstrated its utility in producing three billets of "binary," an alloy of particular interest for weapons production. This technology is being transferred to DOE/NNSA's Office of Production Modernization for further development as a production technology. In FY 2022 SRP will demonstrate the ability to take an ingot from this production process and roll it into binary plate so that it is available for follow-on fabrication needs.

[6] Diaminoazoxyfurazan, or DAAF, is an energetic compound which DOE/NNSA has begun to investigate for formulation into new IHE that may have better safety and energy delivery characteristics than the explosives formulations currently employed in the U.S. stockpile.

Advanced manufacturing technologies

- **Uranium component manufacture**. LLNL and Y-12 are collaborating on additive manufacturing of uranium components to enable rapid prototyping and production of parts for hydrotesting at the national security laboratory level and production of some components at the production plants.
- **Additive manufacture of HE main charge**. HE manufacturing and qualification represent a significant fraction of the development and production effort. DOE/NNSA is developing and demonstrating new additive manufacturing technologies that will enable control of the properties of energetic material components. This development will increase product quality control, increasing yield and reducing production schedules. This effort is a collaboration between LLNL and Pantex Plant (Pantex) near Amarillo, Texas.
- **Digital twins to accelerate production**. Digital twins are virtual representations of production machines that mimic the specific behavior of a piece of equipment. They can be used to simulate new toolpath programming without risking equipment damage, explore tool capabilities, train new personnel, and explore the impact of programming on the product quality. SRP develops digital twin technology for additively manufactured polymers and HE.
- **Acceleration of nuclear production processes and safety basis analysis**. Virtual Reality and Augmented Reality tools will be used to lay out and walkthrough nuclear production and assembly processes and procedures to accelerate the fidelity and quality of procedural development and understand and resolve safety basis issues more quickly and before substantial resources are committed to production tooling and facility allocation.

Ameliorating the qualification burden. SRP joined with the Advanced Certification and Qualification program on an initiative to reduce the burden of qualification while maintaining confidence in the deterrent. A DOE/NNSA/national security laboratory/production plant workshop held in April 2020 explored issues and opportunities, and SRP has started several technical initiatives within this MTE. A follow-on workshop is planned for late FY 2022 to evaluate early progress and identify next steps to improve qualification methods.

Rapid qualification with in-situ inspections. Qualification of materials and components is time-intensive at the production plants and can consume more resources than component manufacturing itself. On-machine inspections allow characterization of the material, parts, and components during manufacture. DOE/NNSA is developing and deploying optical- and spectroscopy-based on-machine inspection techniques for parts manufacturing. With appropriate testing during manufacturing, a part or component would be "born qualified" and allow characterization of components that are too complex to be inspected in their completed configuration. These efforts are collaborations between LLNL, Pantex (for additively manufactured HE), and KCNSC (for additively manufactured metals).

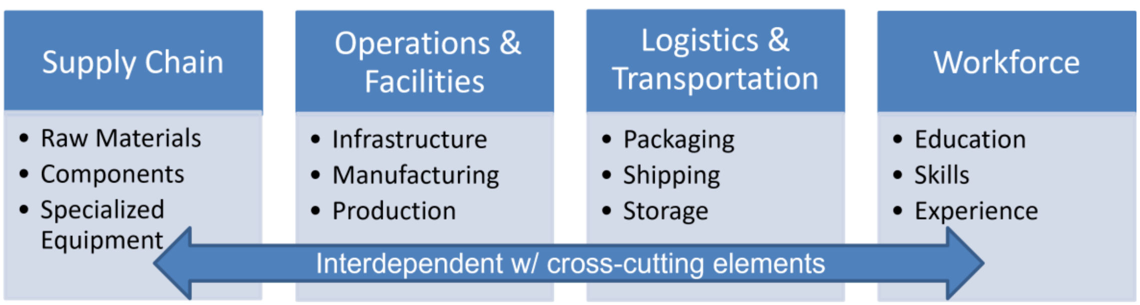
VII. Conclusion

SRP is responsible for exercising and enhancing capabilities through the entire nuclear weapons lifecycle to improve the responsiveness of the United States to future threats, technology trends, and international developments not addressed by existing LEPs. SRP invests a significant amount of its funding on efforts to address issues in design for manufacturability, digital engineering, component, and system prototyping and testing including hydrotesting and flight testing, production technology, advanced manufacturing processes and accelerating certification and qualification processes. In collaboration with DoD, SRP seeks to identify efficiencies and improve responsiveness to ensure that the United States is prepared to address emerging threats to its nuclear deterrent including the ability to design, produce, and qualify such weapons.

Appendix F
Industrial Base

F.1 Framework

The nuclear security enterprise industrial base (NIB) is the global industrial capacity and capability that enables research and development, design, production, shipping, sustainment, and modernization of nuclear weapons components, subsystems, and materials to support the U.S. nuclear deterrent. The Department of Energy's National Nuclear Security Administration (DOE/NNSA) monitors the NIB through a framework consisting of four pillars (supply chain, operations and facilities, logistics and transportation, workforce). DOE/NNSA uses these pillars to identify the full scope of industrial base challenges to maintaining the nuclear stockpile, including those that are internal to the nuclear security enterprise, such as material production and workforce management, and external, such as vendor resiliency. The activities listed under the pillars in **Figure F–1** indicate the types of activities that are considered when examining the NIB.



- **Supply Chain** includes the procurement of raw materials, special design and commercial off-the-shelf components, and specialized equipment; includes the acquisition process
- **Operations** includes the infrastructure required to process materials, manufacture and test sub-components and components then assemble those components into a final weapon, and the ability to disassemble and reuse weapon components upon retirement
- **Logistics** includes the ability to handle and transport a range of materials, the delivery of warheads to/from customers and the storage of strategic materials
- **Workforce** includes the specialized education, skills, training and experience required within the nuclear security enterprise; recruitment and retention of cleared personnel; and processes to ensure critical knowledge is maintained and transferred across the enterprise

Figure F–1. The nuclear security enterprise industrial base framework

F.2 Risk Management

Risk management is an area of increased attention across the nuclear security enterprise. Programs and sites within the enterprise employ varying methods to identify, characterize, monitor, and manage risks. These include efforts such as program-specific risk matrices; supply chain focused risk matrices that track risks from raw material procurements through product acceptance; and implementation of supplier transparency software for a more proactive approach to supply chain risk management. There are also significant efforts underway to standardize the methods used for risk management such as the Supply Chain Risk Management Team that is working to standardize the methods used to identify, monitor, and respond to supply chain risks. The Supply Chain Risk Management Team supports larger DOE/NNSA initiatives that are addressing all the pillars of the NIB to create an overarching process to make risk management practices more rigorous.

F.2.1 Monitoring

The NIB is complex and multi-faceted; many diverse groups within the enterprise are monitoring and acting on industrial base issues that are specific to their own programs or activities. This necessarily narrow focus does not always offer a broad view of the industrial base picture. Therefore, as a part of a more centralized industrial base management focus, DOE/NNSA leverages its Integrated Planning Group to increase data sharing across the various program offices, working groups, and teams to increase coordination and collaboration and to gain more detailed insight concerning industrial base challenges. In addition, information sharing occurs across the enterprise in areas such as risk management and issues related to the industrial base, as well as reciprocity of vendor qualifications to reduce the burden on vendors who do business with multiple laboratories, plants, or sites.

F.2.2 Mitigation

Within the Stockpile Stewardship and Management Plan – Biennial Plan Summary, each of the four NIB pillars are addressed in additional detail in their relevant sections along with actual or potential challenges (risks) and mitigation strategies. While not a complete index of references, some examples follow:

- Supply Chain challenges are discussed throughout but primarily in Chapter 3, “Weapons Activities Capabilities.”
- Operations and Facilities challenges are discussed primarily in Chapter 3, “Weapons Activities Capabilities”; Chapter 4, “Infrastructure and Operations”; and Chapter 5, Section 5.7, “Infrastructure and Operations.”
- Logistics and Transportation challenges are primarily discussed in Chapter 2, “Stockpile Management”; and Chapter 3, Section 3.7, “Transportation and Security Portfolio.”
- Workforce challenges are primarily discussed in Chapter 3, “Weapons Activities Capabilities”; and Appendix C, “Workforce Retention.”

F.3 Interagency Coordination

DOE/NNSA participates in numerous Interagency forums to include the Joint Industrial Base Working Group, which acts as the advisory committee to the Department of Defense (DoD)-led Industrial Base Council. The Council functions as the principal advisory forum on prioritized industrial base matters for DoD to ensure industrial base readiness and resiliency. DOE/NNSA provides a representative to the Joint Industrial Base Working Group and participates in multiple cross-cutting sector working groups related to nuclear weapons.

DOE is a statutory member of the Committee on Foreign Investment in the United States (CFIUS), an interagency committee that reviews certain transactions involving foreign investment in the United States to determine the effect of such transactions on the national security of the United States. For each transaction subject to CFIUS jurisdiction, the Department of Treasury, as CFIUS Chair, assigns a lead agency to review the transaction; DOE is a lead on approximately 25 percent of transaction reviews, mostly in the energy sector, but with numerous cases impacting the nuclear weapons complex annually.

Appendix G
Glossary

abnormal environment, abnormal and hostile environment, abnormal conditions—An environment, as defined in a weapon's stockpile-to-target sequence and military characteristics, in which the weapon is not expected to retain full operational reliability, or an environment that is not expected to occur during nuclear explosive operations and associated activities.

additive manufacturing—A manufacturing technique that builds objects layer by layer, according to precise design specifications, compared to a traditional manufacturing technique in which objects are carved out of a larger block of material or cast in molds and dies.

advanced manufacturing—Modern technologies necessary to enhance secure manufacturing capabilities and provide timely support for critical needs of the stockpile.

alteration (Alt)—A material change to, or a prescribed inspection of, a nuclear weapon or major assembly that does not alter its operational capability, yet is sufficiently important to the user regarding assembly, maintenance, storage, or test operations to require controlled application and identification.

annual assessment—The authoritative method to evaluate the safety, reliability, performance, and military effectiveness of the stockpile by subject matter experts based upon new and legacy data, surveillance, and modeling and simulation. It is a principal factor in the Nation's ability to maintain a credible deterrent without nuclear explosive testing. The Directors of the three national security laboratories complete annual assessments of the stockpile, and the Commander of the U.S. Strategic Command provides a separate assessment of military effectiveness. The assessments also determine whether underground nuclear explosive testing must be conducted to resolve any issues. The Secretaries of Energy and Defense submit the reports unaltered to the President, along with any conclusions they deem appropriate.

arming, fuzing, and firing—The electronic and mechanical functions that ensure a nuclear weapon does not operate when not intended during any part of its manufacture and lifetime, but also ensure the weapon will operate correctly when a unique signal to do so is properly activated.

artificial intelligence—Computer systems able to perform tasks intelligently, similar to humans, such as visual perception, speech recognition, decision-making, and translating between languages.

B61—An air-delivered thermonuclear gravity bomb.

B61-12 Life Extension Program (LEP)—An LEP to consolidate four families of the B61 bomb in the active stockpile into one and improve the safety and security of the oldest weapon system in the U.S. arsenal.

calciner—A dry thermal treatment process to convert low-equity enriched uranium liquids to a dry stable form for storage.

certification—The process whereby all available information on the performance of a weapon system is considered and the laboratory directors responsible for that system certify, before the weapon enters the stockpile, that it will meet, with noted exceptions, the military characteristics within the environments defined by the stockpile-to-target sequence.

component—An assembly or combination of parts, subassemblies, and assemblies mounted together during manufacture, assembly, maintenance, or rebuild. In a system engineering product hierarchy, the component is the lowest level of shippable and storable entities, which may be raw material, procured parts, or manufactured items.

conventional high explosive—A high explosive that detonates when given sufficient stimulus by a high-pressure shock. Stimuli from severe accident environments involving impact, fire, or electrical discharge may also detonate a conventional high explosive. See also “insensitive high explosive.”

critical decision (CD)—The five levels a DOE project typically progresses through, which serve as major milestones approved by the Chief Executive for Project Management. Each CD marks an authorization to increase the commitment of resources and requires successful completion of the preceding phase. These five phases are CD-0, Approve Mission Need; CD-1, Approve Alternative Selection and Cost Range; CD-2, Approve Performance Baseline; CD-3, Approve Start of Construction/Execution; CD-4, Approve Start of Operations or Project Completion.

cybersecurity—The physical, technical, administrative, and management controls for providing the required and appropriate levels of protections of information and information assets against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional. Cybersecurity also ensures the required and appropriate level of confidentiality, integrity, availability, and accountability for the information stored, processed, or transmitted on electronic systems and networks.

depleted uranium (DU)—Uranium from which most of the fissile isotope uranium-235 has been removed. It is required for nuclear component production to maintain and modernize the stockpile through life extension, modification, and limited life component exchange programs.

design agency—Any of the management and operating partners in the nuclear security enterprise who serve as lead designers for nuclear weapon components or systems, usually one of the three national security laboratories.

design life—The length of time, starting from the date of manufacture, during which a nuclear weapon is designed to meet its stated military requirements.

dismantlement and disposition—Disassembling retired weapons into major components that are then assigned for reuse, storage, surveillance, or disposal.

downblending—Processing highly enriched uranium into a uranium byproduct that contains less than 20 percent uranium-235.

down-select—The process of narrowing the range of design options during the *Phase 6.X Process*, culminating in a final design (normally exercised when moving from Phase 6.1 to 6.2, from Phase 6.2 to 6.2A, and from Phase 6.2A to 6.3). Down-selecting involves analysis of the option’s ability to meet military requirements, and assessment of schedule, cost, material, and production impacts.

electrorefining—An electrochemical metal purification system designed to provide a replacement capability for the current metal purification process.

enriched uranium—Uranium that contains higher concentrations of the fissile uranium-235 isotope than natural uranium. It is required at varied enrichment levels for national security and medical isotope production.

exascale computing—Computing systems capable of at least one exaFLOPS, or one billion billion calculations per second. Such capacity represents a thousand-fold increase over the first petascale computer that came into operation in 2008. See also “floating point operations per second (FLOPS).”

first production unit—The first system, subsystem, or component manufactured and accepted by NNSA as verifiably meeting all applicable quality and qualification requirements. The first production unit for a weapon is a production milestone. For milestone completion, two events must occur: (1) DoD or the Nuclear Weapons Council accepts the design and (2) DOE/NNSA verifies that the first produced weapon meets the design specifications.

fiscal year (FY)—The Federal budget and funding year that starts on October 1 and goes to the following September 30.

fission—The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial energy.

floating point operations per second (FLOPS)—The number of arithmetic operations performed on real numbers in a second; used as a measure of the performance of a computer system.

fusion—The process whereby the nuclei of two light elements, especially the isotopes of hydrogen (i.e., deuterium and tritium), combine to form the nucleus of a heavier element with the release of substantial energy and a high-energy neutron.

Future Years Nuclear Security Program (FYNSP)—A detailed description of the program elements (and associated projects and activities) for the fiscal year for which the annual budget is submitted and the four succeeding fiscal years.

gas transfer system (GTS)—A warhead component that enables tritium, a radioactive isotope of hydrogen, to boost the yield of a nuclear weapon.

high energy density (HED) physics—The physics of matter and radiation at very high energy densities, i.e., extreme temperatures and pressures.

high explosives (HE)—Materials that detonate, with the chemical reaction components propagating at supersonic speeds. High explosives are used in the main charge of a weapon primary to compress the fissile material and initiate the chain of events leading to nuclear yield. See also “conventional high explosive” and “insensitive high explosive.”

high performance computing (HPC)—The use of supercomputers and parallel processing techniques with multiple computers to perform computational tasks.

ignition—The point at which a nuclear fusion reaction becomes self-sustaining—that is, more energy is produced and retained in the fusion target than the energy used to initiate the nuclear reaction.

information technology (IT)—The equipment or interconnected system or subsystem of equipment used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information. Information technology includes computers, ancillary equipment, software, firmware, and related procedures, services, and resources.

infrastructure—For the purposes and scope of the SSMP, infrastructure refers to the comprehensive inventory of facilities, structures, utilities, equipment, and other physical assets required to operate the national security enterprise in service to its national security missions.

insensitive high explosive (IHE)—A high explosive substance that is so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible.

integrated design code (IDC)—A simulation code containing multiple physics and engineering models that have been validated experimentally and computationally. An IDC is used to simulate, understand, and predict the behavior of nuclear and non-nuclear components and nuclear weapons under normal, abnormal, and hostile conditions.

joint test assembly (JTA)—(1) An electronic unit that contains sensors and instrumentation that monitor weapon hardware performance during flight tests to ensure that the weapon components will function as designed. (2) An NNSA-developed configuration, based on NNSA-DoD requirements, for use in the flight test program.

life cycle—The series of stages through which a component, system, or weapon passes from initial development until it is consumed, disposed of, or altered to extend its lifetime.

life extension program (LEP)—A program that refurbishes warheads of a specific weapon type to extend the service life of a weapon. LEPs are designed to extend the life of a warhead by 20 to 30 years, while increasing safety and security.

lightning arrestor connector—Advanced interconnected nuclear safety devices designed to limit voltage during lightning strikes and in other extreme, high-voltage, high-temperature environments.

limited life component (LLC)—A weapon component or subsystem whose performance degrades with age and must be periodically replaced. Examples are gas transfer systems, power sources, and neutron generators.

line-item project—A distinct design, construction, betterment and/or fabrication of real property for which Congress will be requested to authorize and appropriate specific funds.

lithium—A soft, lightweight, silvery-white alkali metal (symbol: Li) used as a target element in nuclear weapons. Lithium reacts with a neutron to produce tritium. It is considered a strategic material in nuclear weapon manufacture.

machine learning—A type of artificial intelligence characterized by computer algorithms that improve automatically through experience, so the computer learns without being explicitly programmed.

Manufacturing Readiness Level—A means of communicating the degree to which a component or subsystem is ready to be produced. Manufacturing Readiness Levels represent many attributes of a manufacturing system (e.g., people, manufacturing capability, facilities, conduct of operations, and tooling). There are nine Manufacturing Readiness Levels, with the lowest being product development and the highest being steady-state production.

military characteristics—Required characteristics of a nuclear weapon upon which depend its ability to perform desired military functions, including physical and operational characteristics, but not technical design characteristics.

modernization—The changes to nuclear weapons or infrastructure due to aging, unavailability of replacement parts, or the need to enhance safety, security, and operational design features. In the context of the physical infrastructure that support the nuclear security missions, modernization refers to recapitalization and refurbishment investments to restore and refresh aging facilities, structures, utilities, equipment, and other physical assets to a state that fully supports mission functionality and underpins key Weapons Activity capabilities into the future.

modification (Mod)—A program that changes a weapon's operational capabilities. A Mod may enhance the margin against failure, increase safety, improve security, replace limited life components, and/or address identified defects and component obsolescence.

national security laboratories—Los Alamos National Laboratory, Sandia National Laboratories, and Lawrence Livermore National Laboratory. These laboratories guide research and development on behalf of DOE/NNSA Mission needs and address science and engineering challenges, from basic science questions through weapons design and production. They also support nuclear counterterrorism and counterproliferation.

network—In relation to information technology and cybersecurity, a network is composed of a communications medium responsible for the transfer of information and all components attached to that medium.

network monitoring—The use of a system that constantly monitors a computer network, providing vulnerability management and policy compliance tools; operating system, database, and application logs; and compilation of external threat data. A key focus is monitoring and managing user and service privileges, directory services, and other system configuration changes. Network monitoring also provides log auditing and review of incident responses.

non-nuclear components—The parts or assemblies designed for use in nuclear weapons or in nuclear weapons training that do not contain special nuclear material; such components (e.g., radiation-hardened electronic circuits or arming, fuzing, and firing components) are not available commercially.

nuclear explosive package—An assembly containing fissionable and/or fusionable materials, as well as the main charge high-explosive parts or propellants capable of producing a nuclear detonation.

nuclear forensics—The investigation of nuclear materials to find evidence for the source, trafficking, and enrichment of the material.

nuclear security enterprise—The physical infrastructure, technology, and workforce at the national security laboratories, the nuclear weapons production sites, and the Nevada National Security Site, that sustain the research, development, production, and dismantlement capabilities needed to support the nuclear weapons stockpile.

Nuclear Weapons Council—The joint DOE/DoD Council composed of senior officials from both Departments who recommend the stockpile options and research priorities that shape national policies and budgets to develop, produce, surveil, and retire nuclear warheads and weapon delivery platforms, and who consider the safety, security, and control issues for existing and proposed weapons programs.

nuclear weapons stockpile—Both active and inactive nuclear warheads. Active warheads include strategic and non-strategic weapons maintained in an operational, ready-for-use configuration, ready for possible deployment within a short timeframe, with logistics spares.

neutron generator—A limited life component that provides neutrons at specific times and rates to initiate weapon function.

Other Program Money (OPM)—Funding that is found outside of a life extension program (LEP) funding line (in other program lines), but is directly (uniquely) attributed to an LEP. Such funding would not be needed were it not for the LEP, although the activity or effort might still be done at some future point along a different timeline.

out-years—The years that follow the 5-year period of the Future Years Nuclear Security Program.

Phase 6.X Process—A time and organizational framework to manage the existing nuclear weapon systems that are undergoing evaluation and implementation of refurbishment options to extend their stockpile life or enhance system capabilities. The *Phase 6.X Process* consists of sub-phases that correspond to Phases 1 through 6 of the nuclear weapons life cycle.

physical security—The physical or technical methods that protect personnel; prevent or detect unauthorized access to facilities, material, and documents; protect against espionage, sabotage, damage, and theft; and respond to any such acts that occur.

pit—The critical core component in the primary of a nuclear weapon that contains fissile material.

power source—Compact, specialized, limited-life components that fulfill power requirements for current and future planned nuclear weapons and life-extended warheads.

primary—The first stage of a two-stage nuclear weapon.

production sites—Savannah River Site, Y-12 National Security Complex, Kansas City National Security Campus, and Pantex Plant sites produce most of the designed weapon components and assemble weapons. (Production sites are sometimes also referred to as production facilities, plants, and agencies.)

programmatic infrastructure—Specialized experimental facilities, computers, diagnostic instruments, processes, and capabilities that allow the nuclear security enterprise to carry out research, testing, production, sustainment, and other direct programmatic activities to meet national security missions.

qualification—The process of ensuring that design, product, and all associated processes are capable of meeting customer requirements. Qualification authorizes the listed items for an intended use (i.e., War Reserve, Training, Evaluation, etc.), and it generally includes national security laboratory (design) review of production and inspection processes. Qualified items are reviewed for possible requalification after a significant process change or if production is inactive for 12 months.

recapitalization—In the context of physical infrastructure that supports nuclear security missions, recapitalization refers to investments in existing facilities, structures, utilities, equipment, and other assets that upgrade, renew, or otherwise improve and extend the usable life of the asset.

reservoir—A vessel containing deuterium and tritium that permits its transfer as a gas in a nuclear weapon.

Safeguards Transporter (SGT)—A highly specialized trailer designed to safeguard nuclear weapons and special nuclear materials while in transit.

secondary—The second stage of a two-stage nuclear weapon that provides additional energy release in the form of fusion, and is activated by energy from the primary.

security—An integrated system of activities, systems, programs, facilities, and policies to protect classified matter, unclassified controlled information, nuclear materials, nuclear weapons, nuclear weapon components, and DOE's and its contractors' facilities, property, and equipment.

security system—The combination of personnel, equipment, hardware and software, structures, plans and procedures, etc., used to protect safeguards and security interests.

service life—The duration of time that a nuclear weapon is maintained in the stockpile from Phase 5/6.5 (*First Production*) to Phase 7 (*Retirement, Dismantlement, and Disposition*). Service life can include the terms "stockpile life," "deployed life," and "useful life."

significant finding investigation (SFI)—A formal investigation by a committee, chaired by an employee of a national security laboratory, to determine the cause and impact of a reported anomaly and to recommend corrective actions as appropriate.

special nuclear material (SNM)—Plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235. The Nuclear Regulatory Commission defines three categories of quantities of SNM according to the risk and potential for its use in the creation of a fissile explosive. Category I is the category of the greatest quantity and associated risk; Category II is moderate; Category III is the lowest.

stockpile sustainment—The activities responsible for the day-to-day health of the stockpile, including surveillance, annual assessments, and routine maintenance, to ensure weapons remain safe, secure, and reliable for their projected lifecycle.

stockpile-to-target sequence—The order of events involved in removing a nuclear weapon from storage and assembling, testing, transporting, and delivering it to the target. The term also refers to a document that defines the logistical and employment concepts and related physical environments involved in delivering a nuclear weapon to a target.

subcritical experiment—An experiment specifically designed to obtain data on nuclear weapons for which less than a critical mass of fissionable material is present and, hence, no self-sustaining nuclear fission chain reaction can occur, consistent with the Comprehensive Nuclear Test Ban Treaty.

surety—The assurance that a nuclear weapon will operate safely, securely, and reliably if deliberately activated and that no accidents, incidents, or unauthorized detonations will occur. Factors contributing to that assurance include model validation for weapon performance based on experiments and simulations, material (e.g., military equipment and supplies), personnel, and execution of procedures.

surveillance—Activities that provide data for evaluation of the stockpile, giving confidence in the Nation's deterrent by demonstrating mission readiness and assessment of safety, security, and reliability standards. These activities may include laboratory and flight testing of systems, subsystems, and components (including those of weapons in the existing stockpile, newly produced weapons, or weapons being disassembled); inspection for unexpected wear or signs of material aging; and destructive or nondestructive testing.

sustainment—An NNSA program to modify and maintain a set of nuclear weapon systems (see "stockpile sustainment"). In the context of physical infrastructure that supports the nuclear security missions, sustainment refers to the set of activities over an asset's lifetime that provide for maintaining, operating, refurbishing, upgrading, and recapitalizing that asset until retirement and disposition.

technology maturation—Advancing laboratory-developed technology to the point where it can be adopted and used by U.S. industry.

test readiness—The preparedness to conduct underground nuclear explosive testing if required to ensure the safety and effectiveness of the stockpile, or if directed by the President for policy reasons.

tritium—A radioactive isotope of hydrogen whose nucleus contains two neutrons and one proton. It is produced in nuclear reactors by the action of neutrons on lithium nuclei.

uranium—A naturally occurring radioactive, metallic element (symbol: U) that is found in the earth as a mineral ore. It has three primary isotopes: uranium-238, -235, and -234. It is a strategic material, with several uses related to nuclear weapons and therefore is critical to national security.

uranium enrichment—The process of increasing the concentration of the uranium-235 isotope in a sample of uranium by separating it from uranium-238.

Verification and validation—Independent procedures that are used together for checking that a product, service, or system meets requirements and specifications, and that it fulfills its intended purpose. For example, in the context of software testing, verification provides evidence of the correctness of computer codes in solving pertinent equations, while validation assesses the adequacy of the physical models used to represent reality. Verification and validation is also applied to nuclear weapons to ensure that they fulfill their intended function with sufficient precision to meet military and other specifications.

W76-1 LEP—A life extension program for the W76 submarine-launched ballistic missile warhead, delivered by a Navy Trident II.

W78—An intercontinental ballistic missile warhead, delivered by an Air Force Minute Man III LGM-30.

W80-4 LEP—A life extension program for the W80 warhead aboard a cruise missile, delivered by the Air Force B-52 bomber and future launch platforms.

W88—A submarine-launched ballistic missile warhead, delivered by a Navy Trident II.

W88 Alteration (Alt) 370—An Alt of the W88 warhead to replace the arming, fuzing, and firing components and to refresh the conventional high explosive main charge.

W87-1—An intercontinental ballistic missile warhead designed to replace the W78 and support the Air Force's ground-based strategic deterrent missile system planned to replace the Minuteman III.

warhead—The part of a missile, projectile, torpedo, rocket, or other munition that contains either the nuclear or thermonuclear system intended to inflict damage.

War Reserve—Nuclear weapons and nuclear weapon material intended for use in the event of war.

Weapons Activities—Sustaining, modernizing, and dismantling nuclear weapons; maintaining and modernizing production operations; and optimizing the scientific tools underpinning these efforts. The term also refers to the portion of the NNSA budget covering these activities.

Appendix H
Acronyms and Abbreviations

ACRR	Annular Core Research Reactor
Alt	alteration
AoA	Analysis of Alternatives
ASC	Advanced Simulation and Computing
ASD	Advanced Sources and Detectors
ATDM	Advanced Technology Development and Mitigation
BCR	Baseline Cost Report
CAS	Central Alarm Station
CBI	Capability Based Investments
CD	Critical Decision
CFF	Contained Firing Facility
CFIUS	Committee on Foreign Investment in the United States
COVID-19	Coronavirus Disease 2019
CREST	Combined Radiation Environments for Survivability Testing
CSTART	Center for Security Technology, Analysis, Response, and Testing
D&I	disassembly and inspection
DA-PA	design agency-production agency
DARHT	Dual-Axis Radiographic Hydrodynamic Test
DIW	Direct Ink Write
DM	deferred maintenance
DNS	Defense Nuclear Security
DoD	Department of Defense
DOE	Department of Energy
DU	depleted uranium
DUE	domestic uranium enrichment
DUF_4	depleted uranium tetrafluoride
DUF_6	depleted uranium hexafluoride
ECP	Exascale Computing Project
ECSE	Enhanced Capabilities for Subcritical Experiments
FY	fiscal year
FYNSP	Future Years Nuclear Security Program
GAO	Government Accountability Office
GTS	gas transfer system
HE	high explosives
HE&E	high explosives and energetics
HED	high energy density
HESE	high explosives science and engineering
HEU	highly enriched uranium
HPC	high performance computing
HPDU	high purity depleted uranium

HSE	hydrodynamic and subcritical experiments
ICF	inertial confinement fusion
IDC	integrated design code
IMI	Infrastructure Modernization Initiative
IT	information technology
IWEC	Integrated Weapon Evaluation Capability
JTA	joint test assembly
KCNSC	Kansas City National Security Campus
kV	kilovolt
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LAP4	Los Alamos Plutonium Pit Production Project
LEP	life extension program
LEU	low-enriched uranium
LLC	limited life component
LLNL	Lawrence Livermore National Laboratory
LRSO	long range standoff
M&O	management and operating
MESA	Microsystems Engineering, Science and Applications
MFFF	Mixed Oxide Fuel Fabrication Facility
MGT	Mobile Guardian Transporter
MIE	major item of equipment
Mod	modification
MRL	manufacturing readiness level
NEA	Nuclear Enterprise Assurance
NIB	nuclear security enterprise industrial base
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
OCIO	Office of the Chief Information Officer
OMB	Office of Management and Budget
Omega	Omega Laser Facility
OT	operational technologies
Pantex	Pantex Plant
PF-4	Plutonium Facility
PPBE	planning, programming, budget, and evaluation
ppy	pits per year
R&D	research and development
RACR	Radiography/Assembly Capability Replacement
RPV	replacement plant value
S&S	Safeguards and Security
SAR	Selected Acquisition Report
SFI	significant finding investigation
SGT	Safeguards Transporter
SIRP	Security Infrastructure Revitalization Program
SLCM	Sea-launched Cruise Missile
SME	subject matter expert
SNL	Sandia National Laboratories

SNM	special nuclear material
SRPPF	Savannah River Plutonium Processing Facility
SRS	Savannah River Site
SRT&E	Stockpile Research, Technology, and Engineering
SSMP	Stockpile Stewardship and Management Plan
STA	Secure Transportation Asset
STEM	science, technology, engineering, math
STS	stockpile-to-target sequence
TA	Technical Area
TPBAR	tritium-producing burnable absorber rod
TRL	technology readiness level
TVA	Tennessee Valley Authority
U1a	U1a Complex
USSTRATCOM	U.S. Strategic Command
WBN	Watts Bar nuclear reactors
WDCR	Weapon Design and Cost Report
WDD	Weapons Dismantlement and Disposition
WEPAR	West End Protected Area Reduction
WR	War Reserve
Y-12	Y-12 National Security Complex
Z	Z pulsed power facility

Appendix I
List of Figures and Tables

List of Figures

List of Tables

DOE/NA-0128

A Report to Congress

Fiscal Year 2023 Stockpile Stewardship and Management Plan – Biennial Plan Summary

April 2023

U.S. Department of Energy
National Nuclear Security Administration
1000 Independence Avenue, SW
Washington, DC 20585