U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Fiscal Year 2025 Stockpile Stewardship and Management Plan – Biennial Plan Summary

Report to Congress
September 2024

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

Message from the NNSA Administrator

The U.S. nuclear deterrent is the cornerstone of the Nation's security, a source of assurance for our allies, and has been an essential contributor to global stability for more than 75 years. The credibility of the nuclear weapons stockpile, demonstrated through the world-class science and engineering capabilities of the nuclear security enterprise, is likewise central to the United States' strategic posture. Among the highest-priority missions of the Department of Energy's National Nuclear Security Administration (DOE/NNSA) is to maintain the safety, security, and reliability of the stockpile, a function the men and women of the enterprise have discharged faithfully since the Manhattan Project.

Although the global security landscape is more dynamic today than in recent years, our nuclear deterrent remains effective. This continuity in our posture is a testament to the agility of the nuclear enterprise and the headroom built into the U.S. strategy of deterrence. Nonetheless, evolutions *are* occurring within the enterprise, both in response to the deteriorating international security environment and in anticipation of developments that may implicate our nuclear posture. These adaptations are layered upon ongoing modernization programs to contend with aging weapons and infrastructure and provide for the enduring performance of the stockpile.

The *Fiscal Year 2025 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (FY 2025 SSMP) describes how DOE/NNSA will sustain the stockpile without underground nuclear explosive testing across the laboratories, plants, and sites that comprise the nuclear security enterprise. The report outlines plans to fulfill the requirements to produce a minimum of 80 plutonium pits per year; achieve the First Production Units of the W80-4 Life Extension Program (LEP), W87-1 Modification Program, and W93 warhead; maintain production of the B61-12 LEP and W88 Alteration 370 warheads; establish a program of record for the Sea-Launched Cruise Missile-Nuclear; and execute the B61-13 program.

DOE/NNSA's ability to perform its diverse missions depends on modern, flexible, and resilient facilities and infrastructure capable of servicing the stockpile for the next 50 years or more in the face of disruptions to operations or evolving military needs. In coordination with our Department of Defense partners, we are modernizing the stockpile and our infrastructure simultaneously. Infrastructure investments will support continuous production of nuclear materials, high explosives, and non-nuclear components. In the past year, we met 100 percent modernized warhead delivery to the Nation's warfighters, but the enterprise's capacity to deliver in the future depends on successful completion of infrastructure projects.

No less critical to the reliability of the stockpile is the workforce of the nuclear security enterprise—the cadre of scientists, engineers, machinists, craft and trade workers, and program managers whose technical skill is matched only by their dedication to our national security. DOE/NNSA is taking aggressive steps to attract and retain a workforce qualified to maintain today's deterrent and design the systems of tomorrow.

For more than 75 years, the scientific achievements of the nuclear security enterprise have revolutionized the world by expanding the limits of human knowledge while laying the foundations of national and global security. This proud heritage continues today. From the fusion breakthroughs at the National Ignition Facility to the deployment of El Capitan, the world's fastest supercomputer, the enterprise boasts an extraordinary reservoir of technical talent and creativity. With consistent support from Congress, DOE/NNSA will continue its long tradition of fulfilling the United States' nuclear deterrence mission, delivering innovative solutions to meet present and future challenges. Pursuant to statute, the FY 2025 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 Patty Murray
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 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 Tom Cole
Chairman, House Committee on Appropriations

The Honorable Rosa L. DeLauro
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 Ms. Jessica Lee, Associate Administrator for Congressional and Intergovernmental Affairs, at (202) 586-4418.

Sincerely,

Jill Hruby
Under Secretary for Nuclear Security
Administrator, NNSA

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Executive Summary

The *Fiscal Year 2025 Stockpile Stewardship and Management Plan* (FY 2025 SSMP), including its classified annex, describes the Department of Energy's National Nuclear Security Administration (DOE/NNSA) program to maintain a safe, secure, reliable, and effective nuclear stockpile over the next 25 years. DOE/NNSA publishes the Stockpile Stewardship and Management Plan (SSMP) annually, either as a detailed report or summary, in response to statutory requirements to support the President's Budget Request to Congress for Weapons Activities. This fiscal year (FY) 2025 summary report describes 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 plan and manage weapons modernization needs to meet the nuclear deterrent objectives outlined in the 2022 *National Security Strategy* (White House), the 2022 *National Defense Strategy* (DoD), and the 2022 *Nuclear Posture Review* (DoD). The SSMP details the application of the nuclear security enterprise's capabilities to address military requirements and the priorities identified in these strategic documents.

DOE/NNSA continues to modernize weapons and infrastructure. Two weapon programs are in full-scale production, delivering on time. Three other weapon programs are advancing, with one system slated for full-scale production in the late 2020s and the remaining two systems set to enter production in the early- to mid-2030s. DOE/NNSA has made more than 40 developmental plutonium pits at Los Alamos National Laboratory (LANL); the Uranium Processing Facility project has completed nearly all its procurements and is moving toward construction completion. There are infrastructure upgrades underway across the nuclear security enterprise to address the growing workload and capabilities necessary to meet requirements.

Building on decades of science and technology investments, DOE/NNSA made history by being the first to achieve fusion ignition in a laboratory and has repeated this feat multiple times, consistently demonstrating global preeminence in an area of central importance to the enterprise. Finally, DOE/NNSA brought on-line the first exascale computer, enabling the capability to tackle challenges in scientific discovery, manufacturing research and development, and national security at levels of complexity and performance that previously were out of reach.

Hiring is strong across the nuclear security enterprise, and the workforce is growing. Equally vital to DOE/NNSA's ability to hire the right people with the right skills is its ability to retain personnel over the long term. NNSA's Federal workforce, funded through the Federal Salaries and Expenses appropriation, continues to grow, providing essential financial and programmatic oversight for NNSA's expanding work scope and integration of efforts across the nuclear security enterprise.

DOE/NNSA faces several challenges in appropriately staffing the nuclear security enterprise, such as lengthy qualification periods for new hires, which further increases the importance of retention. It is difficult to replace loss of experience in the nuclear security enterprise. DOE/NNSA and its management and operating partners require enough experienced personnel to transfer knowledge and skills with respect to stockpile technologies and processes to incoming personnel, while simultaneously meeting current mission needs. These factors make maintaining a security-cleared, qualified, and technically trained workforce a complicated challenge. Recruitment and long-term retention of the workforce is critical to developing, growing, and maintaining scientific, engineering, and technical competencies.

DOE/NNSA's top priority is to deliver on its commitments in a cost-effective and responsive manner to adequately address the complexity of the international nuclear landscape. Looking forward, DOE/NNSA must transition to problem solving and the timely deployment of a modernized stockpile, after the last several decades of seeking a better understanding of an aging stockpile. DOE/NNSA will seek every opportunity to accelerate progress and modernize approaches, including improving design, production, construction, technology deployment, and both foundational and applied science.

DOE/NNSA will continue to cultivate transparent, productive, and enduring relationships with interagency, colleagues, industry stakeholders, and international allies and partners. By leveraging its innovative science and technology capabilities, DOE/NNSA will meet stockpile milestones and maintain a resilient and responsive enterprise to meet the geopolitical needs of today and tomorrow.

DOE/NNSA will:

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

With several warhead modernizations underway, DOE/NNSA is executing unprecedented complex component development and production work. These efforts keep the existing nuclear weapons stockpile safe, secure, and reliable while pursuing new capabilities.

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 explosives).
- Achieve the first production unit of the W80-4 warhead Life Extension Program (LEP) and support alignment with the Air Force's Long Range Standoff cruise missile replacement program.
- Support initial fielding of W87-0 on Sentinel, formerly known as the Ground Based Strategic Deterrent, and advance the W87-1 Modification Program (formerly called the W78 Replacement Warhead).
- Develop the W93 warhead, deployed on Mk7 re-entry body, to augment Navy forces with a more survivable weapon deployable on the Ohio-class and Columbia-class submarines.
- Increase schedule margins for delivery of W80-4, W87-1, and W93 systems.
- Qualify pit manufacturing processes and technologies to support first production unit and rate production for the W87-1.
- Execute an integrated plutonium pit production strategy to align and streamline nuclear security enterprise-wide efforts. Provide a continuous and reliable supply of nuclear weapon components and the key materials that make up the components, including plutonium, uranium, lithium, tritium, and conventional high explosives.
- Provide experimental and computational capabilities and prepare to address and mitigate any challenges that arise in the future.
- Identify new production technologies that improve legacy processes and save cost and/or schedule for warhead modernization programs and apply them to at least one nuclear explosive package component and one non-nuclear component.
- Support digital transformation and engineering capabilities to deliver a modern, reliable, comprehensive, and secure computing environment that supports the enterprise and aligns with current and future IT service delivery models.

Key Accomplishments:

- The B61-12 LEP and W88 Alt 370 program met 100 percent of deliveries to DoD. Both programs also reached their 50 percent total production milestone in 2023.
- The W87-1 Modification Program entered Phase 6.3, *Development Engineering*, and DOE/NNSA completed the first W87-1 test and evaluation units. The W87-1 is slated for deployment in the early 2030s. The W80-4 LEP reached Phase 6.4, *Production Engineering*.
- The Joint Actinide Shock Physics Experimental Research Facility, or JASPER, marked its 20th anniversary. The JASPER team has completed 193 shots, providing more than two decades of precise plutonium performance data.
- The Advanced Sources and Detectors Scorpius project at the Nevada National Security Sites (NNSS), which will generate high-speed, high-fidelity radiographic images of subcritical experiments, reached the following key milestones this year: the ribbon cutting for the Electron Beam Injector, breaking ground for the Integrated Test Stand, and delivering 24 pulsers powering the electron beam accelerator.
- The 30 Base Installation subproject of the Los Alamos Plutonium Pit Production Project, which supports the production of 30 plutonium pits per year at LANL, achieved the establishment of its formal performance baseline on schedule. This supports critical storage space that will allow workers to receive, inspect, test, store, integrate, and assemble gloveboxes and other equipment headed to the Plutonium Facility.
- The Savannah River Plutonium Processing Facility construction project reached several major milestones for process design; dismantlement and removal of equipment; and contracts for glovebox vending and construction management.
- DOE/NNSA achieved deeper cooperation under the U.S.-UK Mutual Defense Agreement across the following priority areas: future system options, predictive capability, integrated engineering and science, modern production environment, infrastructure modernization and revitalization, and workforce investment.
- The Y-12 National Security Complex (Y-12) completed 100 percent of its dismantlement and exceeded its disassembly milestones while meeting supporting part and material stream recycling needs for future program builds. It also delivered six campaigns of material in support of Naval Reactors feedstock production, and the first campaign of FY 2024 was staged for delivery ahead of schedule.
- The Pantex Plant (Pantex) authorized and completed the first production unit for the W88 Alt 940 Program; achieved 99.5 percent of FY 2023 baseline goals; reduced production downtime; and completed 103 percent of the production baseline requirements and increased output by over 72 percent in 1 year.
- The Enhanced Mission Delivery Initiative Stockpile Modernization Working Group improved processes for the W80-4 LEP, W87-1 Modification Program, and the W93. The pilot program's initial actions focused on updating roles and responsibilities in warhead product realization teams, design reviews, and production readiness reviews. The clarified roles and responsibilities helped improve working relationships, streamline processes, and avoid duplication in the warhead modernization portfolio.

Strengthen Key Science, Technology, and Engineering Capabilities

Nuclear weapons stockpile activities are supported by the technical expertise of DOE/NNSA's Federal and management and operating partner workforces. DOE/NNSA cultivates cutting-edge technical expertise in manufacturing, diagnostics, evaluation, and other areas at the plants and sites, and 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 the stockpile's safety, security, reliability, and effectiveness:
  - Deploy DOE/NNSA's first exascale computer and establish a path forward for continued leadership in advanced computing while modernizing the nuclear weapons code base.
  - Develop a roadmap for advanced inertial confinement fusion and pulsed power sustainment and expanded capabilities to meet the future requirements of the Stockpile Stewardship Program.
  - Develop an operational enhanced capability (advanced radiography and reactivity measurements) for subcritical experiments.
  - Quantify and bound the plutonium aging effects on weapon performance over time.
- Support an enduring, trusted, strategic, radiation-hardened microsystems supply and expand DOE/NNSA partnerships to leverage DOE/NNSA expertise and capabilities to address current and emerging challenges.
- Maintain and upgrade science facilities enabling continued generation of world-leading results.
- Maintain and advance state-of-the-art manufacturing technologies supporting production operations.
- Continue implementing the Stockpile Responsiveness Program to fully exercise and develop the nuclear security enterprise's workforce and capabilities.
- Nurture Strategic Partnership Programs that support other relevant needs while advancing the long-term workforces and capabilities of national security laboratories, production plants, and sites.

Key Accomplishments:

DOE/NNSA:

- The National Ignition Facility not only replicated but exceeded its groundbreaking fusion ignition of December 2022, when it produced more energy from fusion than the laser energy used to drive it. These developments mark critical progress that will advance DOE/NNSA's stockpile stewardship program.
- Diagnostics work has been completed for Crossroads, which will replace the existing Trinity supercomputer and be used by all three DOE/NNSA labs to support the stockpile stewardship program, current and planned weapons LEP activities, and future predictive weapons research and calculations.

- Critical El Capitan milestones have been authorized with the completion of the Lease to Own agreement. Lawrence Livermore National Laboratory completed the El Capitan Site Infrastructure project, and the switching infrastructure and cabinets were installed.
- Sandia National Laboratories completed final design qualification testing of Mk21 Arming Fuzing Assembly major components and supported the Flight Test Unit 4 build process and early delivery of the assembly to meet a critical flight test schedule for the Air Force.
- The Kansas City National Security Campus (KCNSC) showed it could make advanced microelectronics “chip” packages for future nuclear weapon programs and global security applications through a recent plant-directed research and development effort that fulfills one of the most significant national need areas relative to the semiconductor supply chain.

Ensure an Adaptive Workforce and Resilient Infrastructure

Planning and investing in advanced capabilities, infrastructure, and, most importantly, the workforce is critical for achieving nuclear security objectives. DOE/NNSA continues to revitalize nuclear security enterprise facilities and corresponding infrastructure to enable the DOE/NNSA workforce to create a responsive and resilient enterprise that meets national security missions today and in the future.

Near-Term and Out-Year Mission Goals:

- Implement enterprise-wide recruitment and retention strategies by incorporating hiring, compensation, and benefits flexibilities, and promoting a healthy work-life balance.
- Improve pipelines for specialized skills (e.g., machinists, electricians, radiological technicians).
- Enhance cyber infrastructure and resiliency across the enterprise.
- Relocate Y-12’s enriched uranium processing capabilities into existing facilities and the Uranium Processing Facility and extend existing key facilities’ operational lifetimes into the 2040s.
- Support long-term actinide chemistry and materials characterization and deliver the Chemistry and Metallurgy Research Replacement Project.
- Modernize lithium and tritium facilities.
- Sustain tritium production using two commercial power reactors to meet stockpile needs.
- Recapitalize the existing high explosives and nuclear weapons assembly infrastructure.
- Increase near- and long-term non-nuclear component production capacity and capabilities at KCNSC with Kansas City Short-Term Expansion Project (KC STEP) and Kansas City Non-Nuclear Component Expansion Transformation (KCNExT) to support increasing non-nuclear component scope for multiple weapons systems.
- Provide new laboratory space and equipment within the Principal Underground Laboratory for Subcritical Experimentation (PULSE) at NNSS to support the Enhanced Capabilities for Subcritical Experiments portfolio through the U1a Complex Enhancements Project and Advanced Sources and Detectors equipment project.
- Provide modern office and laboratory spaces to support the world-class workforce needed to maintain the nuclear weapons stockpile capabilities.

Key Accomplishments:

DOE/NNSA:

- DOE/NNSA leveraged flexible acquisition authorities and met critical equipment procurement milestones to address immediate capacity issues at the KCNSC through the KC STEP. DOE/NNSA also began implementation of a lease-purchase strategy to acquire a co-located manufacturing campus at KCNSC to ensure sufficient capacity plus margin in the future.
- Marking significant progress toward completing a co-located facility for performing high explosive science and technology development at Pantex, the High Explosive Science and Engineering Facility held a structural steel "topping out" ceremony for a Technology Development and Deployment Laboratory. Placing the uppermost piece of structural steel is a key milestone in building construction.
- The NNSS' Mercury Building 2, dedicated this year, is a state-of-the art, 13,000-square-foot facility housing the site's Operations Command Center and Emergency Operations Center, including support for Nye County Dispatch.
- There was an official groundbreaking for the new, 245,000-square-foot Lithium Processing Facility at Y-12. It will replace a nearly 80-year-old facility, ensuring the continuity of lithium capabilities, reducing annual operating costs, and increasing process efficiencies using safer and more agile equipment. It will also feature updated technology to support a new lithium process.
- In 2023, the Uranium Processing Facility at Y-12 saw the delivery and staging of the four microwave casting furnaces in the main process building. This equipment will improve current Y-12 processes with greater quality control and better protection during production processing. Upon delivery of this key equipment, Uranium Processing Facility deliveries were over 96 percent complete.
- The KCNSC's Supply Chain Management Center was awarded an Excellence Gold Award by DOE/NNSA's Office of Infrastructure for its innovative construction and infrastructure services support strategy. Initiatives in FY 2023 resulted in $439 million in total cost savings across NNSA and DOE's Office of Environmental Management.
- Sixty-seven shipments of transuranic waste were completed at LANL, with a total of 760 containers or drums. Current storage volume is at 28 percent, allowing space for the ongoing production mission.
- The Savannah River Field Office provided effective safety oversight of tritium shipments to the Defense Department, 100 percent on time with zero defects. The SRS performed six extractions, received a record-high 11 tritium-producing burnable absorber rod casks from the Tennessee Valley Authority, and completed advanced planning and procurement for the calendar year 2025 outage that will replace significant infrastructure.
- NNSA worked collaboratively with DOE's Office of Environmental Management to prepare the FY 2025 SRS Landlord Transition from DOE to NNSA. This complex project includes oversight of 18 subgroups covering more than $200 million and approximately 100 Federal and support service contractor employee positions.

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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 2025 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 Department of Defense 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 international security environment has continued to destabilize due to geopolitical events and the actions of the United States' strategic competitors, including heavy investment in new nuclear capabilities. Russia has increasingly displayed nuclear norm-breaking behavior through its unprovoked invasion of Ukraine, a non-nuclear weapon state, and subsequent takeover of a Ukrainian nuclear power plant. This takeover, and reports that Russia intends to move nuclear weapons into Belarus, are especially concerning. Other nations have also invested in their nuclear capabilities. Analysis of China's nuclear program suggests that it could achieve peer status within a decade. North Korea's missile testing continues at a significant pace. Iran enriches uranium to a higher level faster than ever before, making negotiations a challenge. These destabilizing behaviors create an increasingly complex geopolitical environment that is evolving and uncertain. Therefore, nuclear weapons will continue to provide a unique deterrence effect on international security that no other element of U.S. power can achieve for the foreseeable future.

Ensuring that the U.S. strategic deterrent remains safe, secure, and effective without underground nuclear explosive testing and that the United States' deterrence commitments to its allies remain strong and credible requires a 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). It is only through the alignment of the priorities, programs, and funding of these two Departments that U.S. nuclear forces can meet deterrence and assurance requirements.

The weapons comprising the U.S. nuclear stockpile are assessed to be safe, secure, reliable, and effective. However, continued science and infrastructure investments are needed to ensure that the stockpile can provide a timely response to threat developments, advance technology opportunities, and maintain effectiveness over time. Revitalizing the nuclear security enterprise, including its workforce, infrastructure, production capacity and capability, and scientific base, is key to achieving these goals. DOE/NNSA is undertaking a risk-informed, complex, and time-constrained modernization and recapitalization effort to support continued mission success in response to the priorities identified in the 2022 *Nuclear Posture Review*.

1.1 Overview

DOE/NNSA is authorized to manage the Nation's nuclear stockpile by the *Atomic Energy Act of 1954* (42 U.S. Code § 2011 *et seq.*) and the *National Nuclear Security Administration Act* (50 U.S. Code § 2401 *et seq*.) (also known as the NNSA Act). DOE/NNSA's enduring missions are to design and deliver the Nation's nuclear stockpile, to forge solutions that enable global security and stability, to harness the atom to power a global naval fleet, and to leverage transformative technologies to address emerging challenges. 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 has two primary purposes:

- Document DOE/NNSA's plans to:
  - Maintain the current stockpile;
  - Modernize the stockpile as necessary to respond to evolving deterrent needs;
  - Advance science that enables stockpile stewardship to enhance the potential performance and understanding of the stockpile's aged, modified, and modernized nuclear weapons;
  - Maintain and modernize supporting infrastructure; and
  - Sustain DOE/NNSA's highly skilled workforce.
- Provide DOE/NNSA's formal response to multiple statutory and administrative reporting requirements, which can be found in Appendix A, "Requirements Mapping," including:
  - The annual life extension program (LEP) reporting requirement from the Explanatory Statement accompanying the *Consolidated Appropriations Act, 2017* (Pub. L. 115-31); and
  - 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* (Pub. L. 117-81).

1.2 Policy Framework Summary

The NNSA Act (50 U.S. Code § 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."

The *2022 National Defense Strategy* and accompanying *2022 Nuclear Posture Review* states that as long as nuclear weapons exist, the fundamental role of U.S. nuclear weapons is to deter nuclear attack on the United States and its allies and partners. The *2022 Nuclear Posture Review* reiterates that the United States will maintain nuclear forces that are responsive to the threats it faces and affirmed that the role of nuclear weapons is to deter strategic attacks, assure allies and partners, and achieve U.S. objectives if deterrence fails.

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 remains a top priority for DoD, DOE/NNSA, and the Nation.

The *2022 Nuclear Posture Review* defines three pillars to help create a more resilient and adaptive nuclear security enterprise. The first is improved coordination and integration between DoD and DOE/NNSA. The Nuclear Weapons Council is developing and implementing a *Deterrent Risk Management Strategy* to align resources, schedules, goals, and efforts, in coordination with other relevant stakeholders. The overarching purpose of the strategy is to ensure that the U.S. nuclear deterrent is always safe, secure, reliable, and effective.

The second pillar is production-based resilience to reimagine the enterprise for the future. In the past, DOE/NNSA envisioned and took concrete steps to realize an enterprise that was better aligned with perceived future requirements, such as sustaining existing warheads rather than routinely replacing stockpile warheads with new designs. Production facilities were closed and consolidated and many elements of the nuclear security enterprise were rebuilt for a much smaller capacity. Tremendous investments were made in science, computing, and engineering capabilities to help sustain the existing stockpile without resorting to underground nuclear explosive testing. Today's enterprise will be developed to be flexible and to scale more readily while being more resilient to outages and failures. Achieving production-based resilience will require taking advantage of revolutions in fields such as manufacturing, metrology, information technology, engineering, physics, chemistry, and biology to incorporate new technologies and processes into the production complex. Critical capabilities to be addressed include plutonium pits, secondaries, non-nuclear components, explosives, and uranium processing.

The third pillar is the Science and Technology Innovation Initiative, which focuses on integrating science and technology into the design and production phases of the nuclear weapon lifecycle. This initiative also accelerates technology maturation.

1.3 Nuclear Weapons Stockpile

The nuclear stockpile's size and composition continues to respond to U.S. national security requirements, though the average stockpile warhead age remains high. Many weapons systems are past their original design life expectancy and require stockpile management activities to assess, surveil, and maintain their condition to ensure weapons are operable and extend weapon lifetimes. With several major warhead modernization activities underway, DOE/NNSA is working to reduce average warhead age while meeting emerging challenges on a timeline that does not put the nuclear deterrent at risk.

The current stockpile consists of active weapons maintained to meet military requirements and inactive weapons used to augment or replace warheads in the active stockpile as necessary. Retired weapons awaiting dismantlement 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. **Table 1–2** reflects the current types of warheads and their respective programs.

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

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	Nonstrategic 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
B61-12	Strategic bomb	F-15, F-16, F-35, B-2 bomber, certified NATO aircraft	LANL/SNL	Air to surface	Air Force
B83-1 [b]	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
LLNL = Lawrence Livermore National Laboratory
NATO = North Atlantic Treaty Organization
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.

[b] The *2022 Nuclear Posture Review* directed the retirement of the B83-1. Specific details of the B83-1 retirement and dismantlement plan remain classified.

Table 1–2. Current U.S. nuclear weapons Life Extension and Modernization Programs

Warhead	***Type***	***Current Status***	***Laboratories***	***Mission***	***Service***
B61-12	LEP	Phase 6.6	LANL/SNL	Air to surface	Air Force
W88 Alt 370	Alt	Phase 6.6	LANL/SNL	Underwater to surface	Navy
B61-13	Modification	Phase 6.3	LANL/SNL	Air to surface	Air Force
W80-4	LEP	Phase 6.4	LLNL/SNL	Air to surface	Air Force
W87-1	Modification	Phase 6.3	LLNL/SNL	Surface to surface	Air Force
W80-4 Alt-SLCM	TBD	TBD	TBD	Underwater/surface to surface	Navy
W93	Acquisition	Phase 2	LANL/SNL	Underwater to surface	Navy

Alt = alteration
LANL = Los Alamos National Laboratory
LEP = life extension program
LLNL = Lawrence Livermore National Laboratory
SNL = Sandia National Laboratories
W80-4 Alt-SLCM = W80-4 Alteration for the Nuclear-Armed Sea-Launched Cruise Missile

1.4 Overall Strategy, Objectives, and Prioritization of Weapons Activities

DOE/NNSA continues to execute nuclear warhead modernization efforts in conjunction with the modernization of DoD delivery platforms. DOE/NNSA is modernizing existing capabilities and infrastructure and re-establishing capabilities retired after the Cold War; this approach allows the flexibility necessary for future policy decisions on nuclear modernization as the United States adjusts to evolving international threats. DOE/NNSA must also enhance science, technology, and engineering capabilities to address emerging challenges, improve the efficiency and effectiveness of production processes, and provide a credible deterrent despite unanticipated risks or technological surprises. 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 immediate action to reestablish and recapitalize these capabilities. The increased workload at many facilities needed to meet current requirements has already required upgrades to power distribution systems, water systems, and other general facility needs.

DOE/NNSA uses several strategies to sustain and maintain the stockpile and support DOE/NNSA mission priorities, including:

- Assessing the stockpile annually through science-based stockpile stewardship by:
  - Assessing whether the current and future nuclear stockpile’s safety, reliability, and performance can be assured without underground nuclear explosive testing;
  - Renewing, developing, and enhancing science capabilities to assess the effects of aging, remanufacturing and material options, and evolving threat environments on warhead performance; and
  - Maintaining readiness to conduct an underground nuclear explosive test, if required, to assess the safety and performance characteristics of the Nation’s stockpile, or if otherwise directed by the President.
- Extending the nuclear deterrent’s life through modernizations:
  - Replacing obsolete technology;
  - Enhancing stockpile safety and security; and
  - Meeting military requirements.
- Assuring capabilities to support the nuclear deterrent in the near- and long-term (as discussed in Chapter 3, “Weapons Activities Capabilities that Support the Nuclear Security Enterprise”) by:
  - Developing modern materials and design and manufacturing options to enable a more modern and efficient production complex;
  - Renewing and sustaining critical production, manufacturing, and research capabilities; and
  - Assuring a stable, reliable, and trusted domestic supply chain for nuclear weapon materials, components, and subsystems.
- Advancing innovative experimental platforms, diagnostic equipment, and computational capabilities by:
  - Maintaining cutting-edge technical expertise and capabilities to support a responsive and resilient enterprise;

- Providing the safe and secure transport of nuclear weapons, weapon components, and special nuclear materials to meet mission requirements;
- Implementing enterprise-wide recruitment and retention strategies that incorporate hiring, compensation, and benefits flexibilities while promoting a healthy work-life balance; and
- Enhancing cyber infrastructure and resiliency across the enterprise.

The Integrated Stockpile Model in **Figure 1–1** 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.

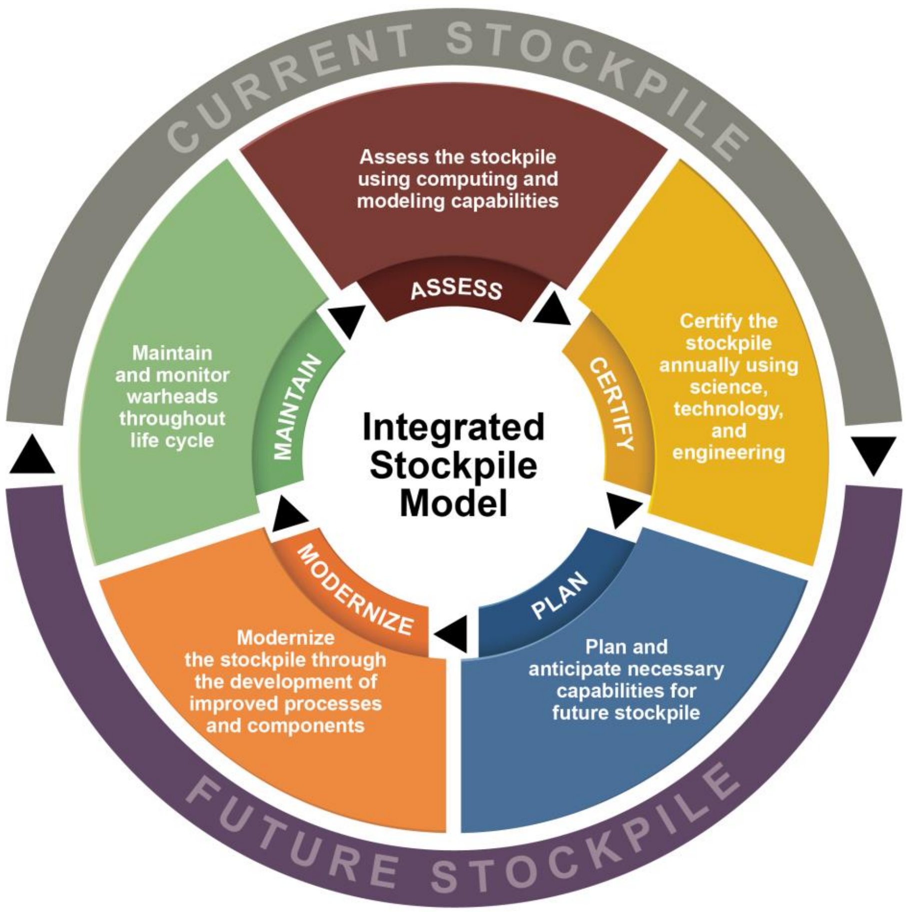

Figure 1–1. Integrated stockpile model

Weapons Activities efforts developed in support of the *2022 Nuclear Posture Review* include:

- **Define the Capability to Effectively Engage and Defeat Hard 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. In the near term, the new B61-13 program fulfills a commitment to leverage available nuclear and non-nuclear capabilities while DOE/NNSA determines future options.
- **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 deploy new technologies

that improve safety and security, address material obsolescence, and improve warhead manufacturability. In fiscal year (FY) 2022, DOE/NNSA matured select technologies and furthered system test and qualification planning. In FY 2023, the Nuclear Weapons Council authorized entry into Phase 6.3, *Development Engineering*.

- **Develop the W93.** The W93 Modernization Program was 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 the safety, security, and flexibility needed 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 support 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. Certification of the W93 will not require additional underground nuclear explosive testing.

  Carrying out the W93 program is vital for continuing the United States' 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.

- **Develop the W80-4.** 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 improving the bomber force's delivery and survivability capabilities.

Synchronized with DoD delivery platform replacement programs, DOE/NNSA is sustaining and delivering the warheads necessary to support the Nation's strategic and non-strategic nuclear capabilities by:

- Completing the B61-12 LEP;
- Completing the W88 Alteration 370;
- Maintaining the synchronization of DOE/NNSA's W80-4 warhead with DoD's LRSO cruise missile program;
- Delivering the B61-13, SLCM-N, W87-1, and W93 warheads to support the air-, land-, and sea-based legs of the triad[1]; and
- Exploring future warhead options to meet required military characteristics based on the threats and vulnerabilities posed by potential adversaries, including possible common reentry systems for Air Force and Navy systems.

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

1.5 Summary of the Stockpile Stewardship and Management Plan Execution

Due to the complex international nuclear landscape, the nuclear security enterprise must increase its responsiveness. Every opportunity to accelerate progress and modernize approaches to the aging U.S. stockpile must be explored as the United States transitions to problem-solving and the timely deployment of a new stockpile. There is room to improve approaches to design, production, construction, technology deployment, and both foundational and applied science. Beyond the recapitalization of key production and design, assessment, and certification capabilities, this transition will also require investment in multiple facilities to upgrade power distribution systems, water systems, and other critical functions to support increased workloads and improved processes.

DOE/NNSA will continue to carry out robust risk management strategies within the nuclear security enterprise so that the deterrent is capable despite significant uncertainties and unanticipated challenges. This proactive approach requires developing and sustaining a set of initiatives and activities that will build resilience in the stockpile, production capabilities, and science and technology capabilities over time.

DoD is continuing to make progress on the first recapitalization of the triad since the end of the Cold War. This effort cannot be accomplished alone; consistent, ongoing schedule integration between the warhead and delivery programs managed by DOE/NNSA and DoD respectively is key to delivering timely and cost-effective capabilities that meet the Nation's defense needs. The partnership between DoD and DOE/NNSA continues to be managed through the Nuclear Weapons Council, which has made tremendous progress in aligning priorities, schedules, and investments between the departments to ensure the nuclear deterrent's future viability.

DOE/NNSA is implementing plans to renew essential material and technology development and manufacturing capabilities to meet DoD near- to intermediate-term warhead delivery requirements and maintain workforce competency and safety. DOE/NNSA's plans focus on five capability areas:

- Establishing a pit production;
- Re-establishing high explosives synthesis;
- Modernizing and enhancing facilities to meet near- and long-term needs for tritium;
- Modernizing production for secondary assemblies and radiation cases along with replacing the current lithium production facility; and
- Modernizing and enhancing non-nuclear component research, development, testing, and production.

DOE/NNSA will further bolster its manufacturing capabilities by assuming primary management responsibility for the Savannah River Site (SRS) in FY 2025, beginning the transition of SRS to an enduring mission site.

Figure 1–2 shows the timeline for key infrastructure and capability investments.

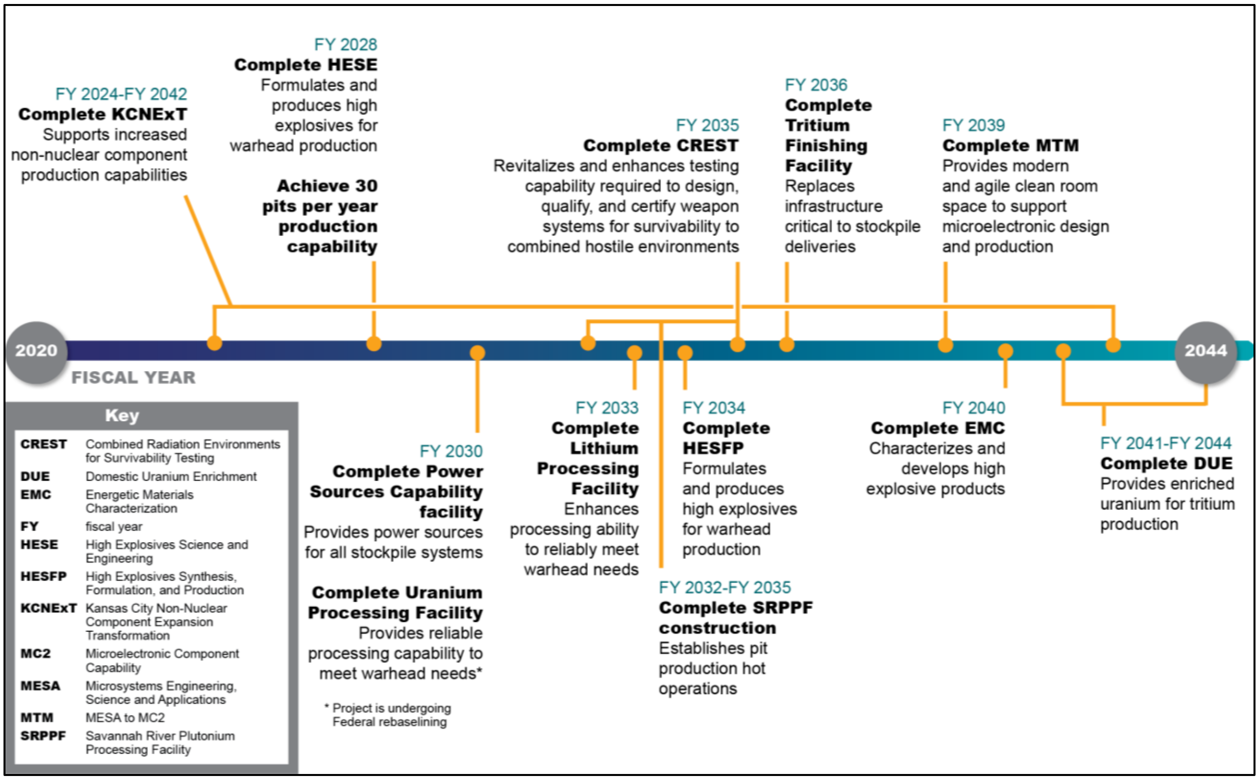

Figure 1–2. Timeline for key infrastructure and capability investments

To support focus areas, other key considerations include investing in new processes, technologies, and tools for warhead design, qualification, certification, and production in accordance with stringent and evolving stockpile specifications and requirements. The increased number of concurrent weapon systems in development requires:

- Maturing new options with shortened development cycles;
- Advancing the ability to predict weapon performance in configurations without underground nuclear explosive testing;
- Evaluating the impact of new materials and processes, reusing aging components in future systems, and enhancing production throughput; and
- Continuing and increasing the modernization and expansion of production infrastructure to support increased production scope and increased number of weapon system builds.

Pursuing only the priority activities previously described would not exercise all phases and aspects of the joint nuclear weapons lifecycle. DOE/NNSA must continue to devote effort to less time-sensitive activities to transfer knowledge and skills to the next generation of nuclear weapon designers and engineers, accelerate and enhance the weapon lifecycle, and strengthen integration between DoD and DOE/NNSA to sustain all required capabilities. These capabilities are described in the following chapters.

Chapter 2
Stockpile Management

This chapter summarizes activities that 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 capabilities that underpin these efforts.

Figure 2–1 provides an overview of the Stockpile Management major subprograms:

- **Stockpile Sustainment** performs single-system and multi-system sustainment activities for all warheads in the current stockpile, including limited life component (LLC) exchanges, surveillance activities, warhead maintenance and repairs, minor alterations, significant finding investigations (SFI), weapons reliability reporting, comprehensive annual assessments of the stockpile's health, and warhead qualification and delivery system integration activities.
- **Stockpile Major Modernization** includes life extension programs (LEPs) to extend the lives of current stockpile weapons, modification programs (Mods) to change the operational capabilities of stockpile systems, major alterations (Alts) which alter stockpile systems without changing their operation capabilities, and warhead acquisition programs that provide modernized warhead capabilities designed to meet military requirements that cannot be met with other stockpile systems.
- **Weapons Dismantlement and Disposition (WDD)** manages the dismantlement of retired weapons and the disposition of weapon components, which generates components and materials for Weapons Activities, including modernization programs, and other DOE/NNSA mission areas.
- **Production Operations** provides the base capabilities to enable weapon operations (e.g., assembly, disassembly, and production) for warhead modernization, sustainment, and WDD programs. The Production Operations program is not specific to one material stream or weapon program but funds the workload that spans multiple weapon systems at nuclear security enterprise sites. Production Operations also coordinates closely with the Production Modernization program (see Chapter 3, "Weapons Activities Capabilities That Support the Nuclear Security Enterprise"), which focuses on materials (e.g., uranium, tritium, high explosives) and nuclear and non-nuclear component modernization.
- **Nuclear Enterprise Assurance (NEA)** ensures that the nuclear security enterprise actively manages subversion risks to the nuclear weapons stockpile and associated design, production, and testing capabilities.

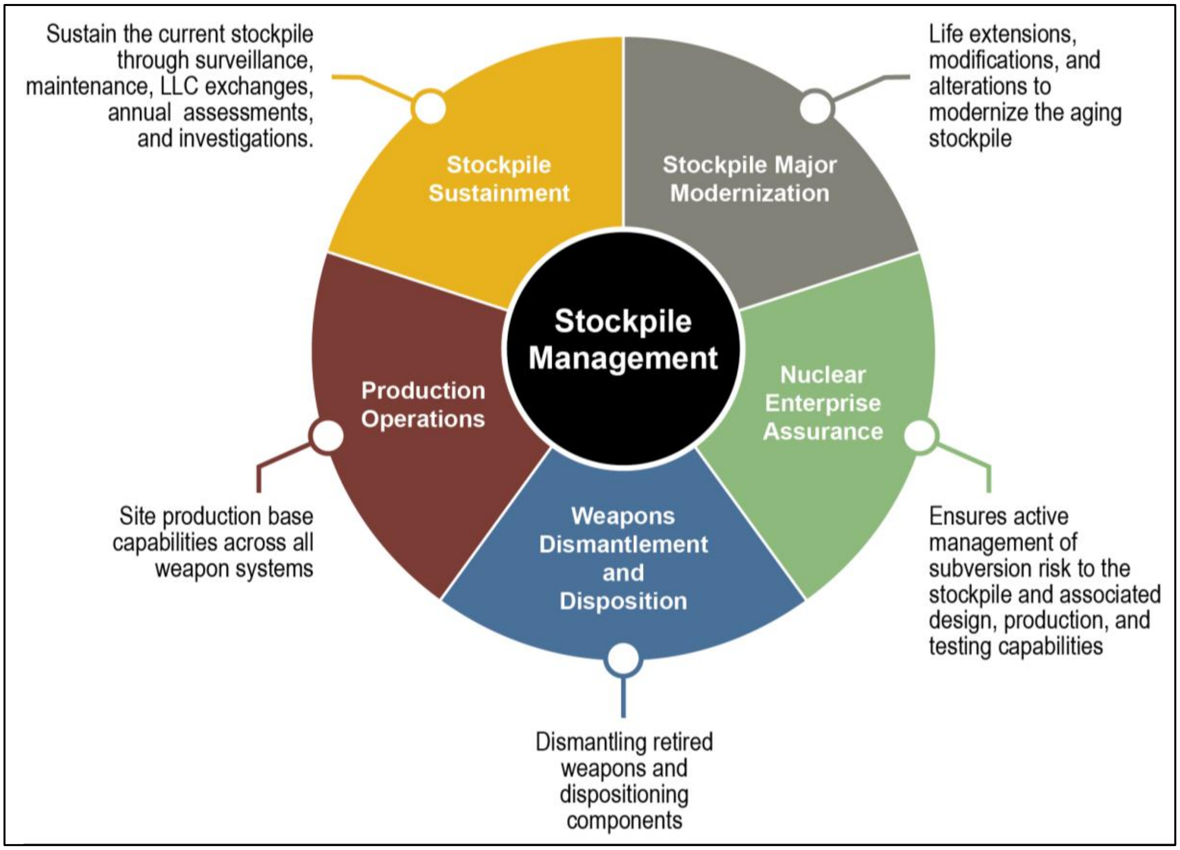

Figure 2–1. Stockpile Management major subprograms

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 activities. These individual capabilities and the linkages to stockpile management are described at length in Chapter 3 and Appendix B, "Weapons Activities Capabilities." Chapter 4, "Infrastructure and Operations," and Appendix C, "Workforce Retention," address infrastructure and the workforce at an enterprise level and discuss the need to sustain the health of these two specific elements to support the stockpile mission work.

2.1 Stockpile Sustainment

Stockpile sustainment activities focus on the health of the stockpile and include surveillance, annual assessments, investigations, and routine maintenance to ensure weapons remain safe, secure, and effective over their projected lifecycles. Weapons in the stockpile must be updated or replaced through modernization programs. See the classified annex for additional information on stockpile sustainment.

Stockpile Sustainment Accomplishments

- *Exceeded milestone commitments for Stockpile Surveillance of Air and Mission Delivery Systems for pit, detonator cable assemblies, pit high-resolution computed tomography, valve/actuator, and Integrated Surety Architecture (ISA) component testing in fiscal year (FY) 2023.*
- *Sandia National Laboratories (SNL) met or exceeded surveillance testing needs to support each weapon certification as part of the Annual Assessment Report process.*
- *Completed Annual Assessment Cycle 27.*

2.1.1 Assessing the Stockpile

The status of the stockpile is evaluated through continual, multi-layered assessments of the safety, reliability, performance, 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 (e.g., hydrodynamic and subcritical experiments), and computer simulation/modeling. Assessments also evaluate the effects of aging on performance and safety as well as quantify performance thresholds, uncertainties, and margins. Assessors gather a body of evidence to evaluate performance at the part, component, subsystem, and system levels to determine whether performance requirements are met. These 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 nation's nuclear forces underpin integrated deterrence and enables the U.S., our allies, and our partners to confront aggressive and coercive behavior."*
>
> Testimony of General Anthony J. Cotton, Commander of U.S. Strategic Command, to the Senate Armed Services Committee
>
> – March 8, 2022

The Annual Stockpile Assessment Reporting Process is codified in 50 United States Code (U.S. Code) § 2525, *Annual assessments and reports to the President and Congress regarding the condition of the United States nuclear weapons stockpile*, which requires the directors of the three national security laboratories to conduct independent annual assessment reviews on the state of all stockpile systems for which they are responsible. It also requires the Commander of the U.S. Strategic Command (USSTRATCOM) to assess the stockpile each year based in part on input from the national security laboratories. This process is not a recertification of the weapons in the stockpile, rather it is an assessment of each system's existing certification basis. Anomaly detection is also included in the annual assessment. When anomalies are discovered in DOE/NNSA surveillance data, the resulting SFI report is incorporated into the reviews of each weapon system investigated. Each annual assessment builds on previous years' experience and incorporates state-of-the-art capabilities and new information 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 interlaboratory peer review by 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. These findings 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.

In FY 2024, Annual Assessment Cycle 28 was completed. The three DOE/NNSA national security laboratory directors certified that the stockpile remains safe, secure, and effective and that underground nuclear explosive testing is not required to resolve any identified issues within the stockpile at this time.

2.1.1.2 Weapon Reliability

DOE/NNSA publishes an annual *Weapons Reliability Report*, which provides an updated summary of reliability and yield characteristics of all weapons in the stockpile. The report is the source document for weapon reliability, while the *Major Assembly Releases* are the source documents for weapon yield. The purpose of the *Weapons Reliability Report* is to communicate to stakeholders the assessed reliability, reliability risks, and effects of test limitations. In addition to updated reliability tests and corresponding risk information, the report incorporates data from surveillance activities as part of the *Annual Assessment Report* review process, serving as the principal DOE/NNSA report on weapon systems reliability that USSTRATCOM uses for strategic planning actions.

2.1.1.3 Advanced Certification and Qualification

Advanced Certification develops improved tools and methods to ensure the continued safety and reliability of the current stockpile and prospective systems for stockpile modernization or acquisition without further underground nuclear explosive testing. This subprogram delivers assessment methods, 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 modeling and simulation codes against improved physics models and hydrotest and subcritical experimental data. These activities enhance DOE/NNSA's understanding of a weapon system's performance, improve the quantification of margins and uncertainties, and advance the fidelity and agility of certification methods.

Prior to their introduction into the stockpile, DOE/NNSA qualifies nuclear weapons components, subsystems, and integrated systems to the military characteristics and stockpile-to-target sequence environmental requirements, including normal, abnormal, and hostile environments. Qualification plans for each stockpile system specify the experimental data, modeling, simulation capabilities, and production data required to ensure system safety, security, reliability, and performance.

In the absence of existing qualification methods, Advanced Qualification activities anticipate needs and develops the tools, capabilities, and material fabrication options that enable increased responsiveness and enhanced analysis for replacement or new material/components. These activities address the qualification challenges for advanced manufacturing methods, replacement materials, and new systems architectures. These activities also use methods to streamline qualification processes to reduce costs, downtime, timescales, resources, floor space, and testers and to standardize methods and requirements across warhead systems. Advanced Certification and Qualification activities promote the close coordination between design and production agencies to capture qualification challenges early in the development process and design for easier manufacturing and relaxed specifications, where possible, without compromising certification needs.

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 and 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, M/U, which is defined as the ratio of margin (M) to uncertainty (U). Margin is the difference between a parameter's expected value and the requirement that ensures some aspect of warhead performance is met. Uncertainty, in the context of quantification of margins and uncertainties analysis, is the degree to which these values are known, including the variation that exists due to design tolerances, manufacturing processes, or other unknowns. Stockpile Research, Technology, and Engineering activities evaluate approaches to characterize margin, reduce uncertainty where possible, and quantify the remaining risk. These tasks are achieved by performing experiments in areas such as material properties to provide data for improving the reliability of the models used to simulate warhead operation. In summary, quantification of margins and uncertainties provides insight into the performance of components and systems relative to requirements and adds further confidence to the assessment process.

2.1.2 Stockpile Surveillance

Surveillance activities provide data to evaluate the safety, security, reliability, and performance of weapons in the current stockpile in support of annual assessments. The cumulative body of this data supports future stockpile decisions using the assessment activities described above. The surveillance program has six goals:

1. Identify manufacturing and design defects that could affect safety, security, reliability, or performance;
2. Assess risks to the safety, security, reliability, and performance of the stockpile;
3. Determine the margins between design requirements and performance at the system, component, and material levels;
4. Identify aging-related changes and trends at the subsystem, component, and material levels;
5. Further develop capabilities for predictive assessments and provide lifetime estimates of stockpile components and materials; and
6. 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 use. 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 Department of Defense (DoD) custody are disassembled and inspected in support of reliability and safety assessments. 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 provide important clues about the aging and health of the weapons while advancing knowledge and understanding of the stockpile, thus informing future weapon design.

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 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,

> ***Common HEATT Achieves First Production Unit***
>
> *Designed by SNL and manufactured by Kansas City National Security Campus (KCNSC), the Common High Efficiency Adaptable Telemetry Transmitter (HEATT) achieved First Production Unit in August 2023, with advanced capabilities exceeding legacy transmitter functionality. The Common HEATT transmits 1.5 times more data, with expanded bandwidth, increases radio frequency power output, and supports multiple systems. The Common HEATT supports joint test assembly (JTA) test flights by transmitting system performance data, DOE/NNSA and DoD interface data, and diagnostic and environmental data directly correlated to receiving station capabilities.*

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, their components, and the comprising materials. 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 Test Equipment

Custom sets of test equipment (i.e., 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, they collect data on the components and subsystems' performance for product acceptance. The data collected are used as input to assess performance and assert the continued certification of the weapon system as safe, secure, reliable, and effective.

In FY 2023, surveillance activities conducted testing on all weapon systems using data collection from flight tests, laboratory tests, and component evaluations. The data are used as part of the annual assessment process to assess the stockpile reliability without underground explosive nuclear explosive testing.

2.1.2.4 Anomaly Investigative Process

When anomalies that could adversely affect weapon safety, security, reliability, or performance are discovered in surveillance data or identified and reported to DOE/NNSA by DoD, technical analyses are conducted to determine whether observations warrant an SFI. Investigations can include historical data modeling, 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, including the status of any corrective actions taken.

2.1.3 Maintaining the Stockpile

Maintaining the current stockpile involves many ongoing activities:

- Completing LLC exchanges of gas transfer systems (GTSs), power sources, and neutron generators, as required, to sustain system functionality and performance;
- 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; and
- 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 their expected 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. Compared to historical GTSs, modern GTS designs increase weapon performance margins, which improves maintenance efficiency and enhances 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. R&D efforts also assure newly designed GTS products can be loaded in the production facilities and meet weapon systems' performance characteristics. In parallel to these R&D efforts, production facilities are maintained for component fabrication, gas-loading operations, GTS surveillance, and tritium recovery from end-of-life GTSs.

Power Sources

Current and future planned nuclear weapons require 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 manufactured within the DOE/NNSA complex. This capability supports nuclear weapons and other national security missions, including prototyping and parts development, all lifecycle 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 is an integrated design and production agency and manages the neutron generators' entire lifecycle to meet DOE/NNSA's requirements, including scientific understanding through design, development, qualification, production, surveillance, dismantlement, and disposal.

2.1.3.2 Integrated Surety Architecture

The Integrated Surety Architecture (ISA) 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 to address the maximum number of future shipments. ISA is a DOE/NNSA requirement for over-the-road shipment of any nuclear weapon planned to be in the active stockpile after 2025.[1]

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

2.1.3.3 DoD-DOE Integration

The W87-0 will be the first warhead deployed on the LGM-35A Sentinel, formerly known as the Ground Based Strategic Deterrent, replacing the aging Minuteman III intercontinental ballistic missile system. This effort will require extensive qualification and integration activities to ensure the W87-0 will function as designed in the new Sentinel environments. In addition to ground and flight tests, warhead subsystem production will ramp up to replace hardware consumed in Sentinel qualification.

2.2 Stockpile Major Modernization

Stockpile major modernization activities are performed through a series of planned LEPs, Mods, Alts, and warhead acquisition programs enabled by a strong set of science, technology, engineering, and production capabilities. **Figure 2–2** displays these plans, which fully reflect the priorities established and formally authorized by the Nuclear Weapons Council. Some of the modernization programs listed do not have approved first production units' dates and instead use notional first production units' dates for planning purposes, which have been coordinated with DoD. See the classified annex for additional information on stockpile major modernization.

> ***Stockpile Major Modernization Accomplishments***
>
> - *B61-12 achieved 65 percent of life of program canned subassembly production and 50 percent completion milestone for all remaining components in FY 2023.*
> - *The W88 Alt 370 reached the 50 percent completion milestone for system-level assemblies in the first quarter of FY 2024.*
> - *W80-4 program entered Phase 6.4,* Production Engineering, *in March 2023 and completed Long Range Standoff cruise missile/W80-4 warhead joint flight testing.*
> - *W87-1 program received Nuclear Weapons Council approval to enter Phase 6.3,* Development Engineering, *in May 2023.*

The current long-term vision for the nuclear weapons stockpile is to build additional flexibility for the Nation and 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 manufacturing, assimilate an advanced digital enterprise that promotes system modernization activities, and exercise capabilities through the Stockpile Responsiveness Program (see Appendix D, "Stockpile Responsiveness Program"). These improvements will enhance the Nation's ability to counter adversaries' capabilities, stockpile aging, unforeseen weapon issues, and variables associated with supporting U.S. hedge capabilities.

Qualified options for materials, components, and systems must be developed to meet resilience requirements for the U.S. nuclear deterrent, matured in advance to be viable for consideration, and available when needed to support 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, advance qualification and certification processes, and improve the responsiveness of the nuclear security enterprise's cycle time and digital design tools. These science-based enabling efforts are described in Chapter 3.

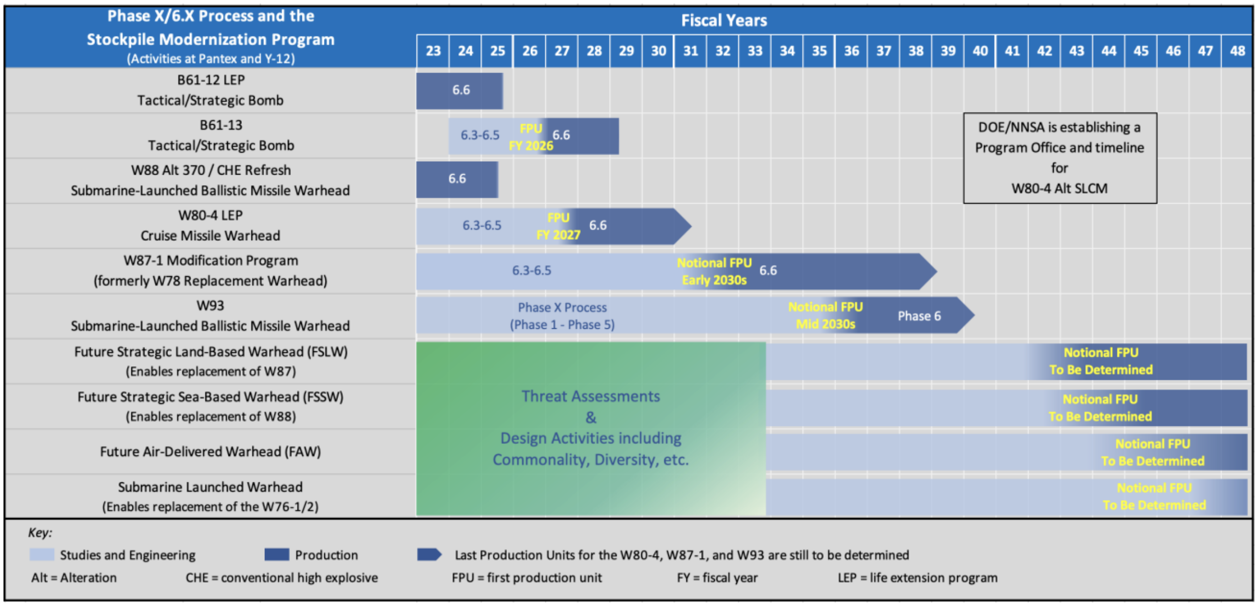

Figure 2–2. DOE/NNSA Warhead Activities[2]

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

DoD and DOE/NNSA's responsibilities for the development, testing, and production of proposed nuclear weapons were originally established through the 1953 joint agreement between the Atomic Energy Commission and DoD, which introduced the concept of weapon acquisition phases.

Nuclear weapons have been historically developed, produced, maintained, retired, and dismantled in a process known as the *Phase X Process* (formerly the Nuclear Weapons Life Cycle). The seven-phase process includes procedures for program study, development, production, sustainment, and nuclear weapons systems dismantlement and has not been exercised in its entirety since the end of the Cold War, with the United States executing only Phases 6, *Full-Scale Production/Sustainment*, and 7, *Retirement, Dismantlement, and Disposition*, in recent decades. The Nuclear Weapons Council has approved the *Phase 6.X Process* for non-routine Alts, Mods, and LEPs, which defines the framework for refurbishment activities of existing nuclear weapon systems. This process uses the same phases from the Nuclear Weapons Life Cycle, all occurring during Phase 6 of the weapon's lifecycle. Until recently, all DOE/NNSA's Major Stockpile Modernization activities have been guided by the *Phase 6.X Process*.

Emerging DoD requirements for future systems necessitated updated procedural guidelines defining the full seven-phase *Phase X Process*, which revised the original agreement and the joint DoD and DOE/NNSA procedures governing the full lifecycle for nuclear weapons. The new process is being used for the first time on the W93 program. These phases, and the relationship between the *Phase 6.X Process* and the Nuclear Weapons Life Cycle, are shown in **Figure 2–3**.

[2] The *National Defense Authorization Act for Fiscal Year 2024, December 2023* authorized a nuclear-armed, sea-launched cruise missile (SLCM-N) achieving "initial operational capability, as defined jointly by the Secretary of the Navy and the Commander of the United States Strategic Command, by not later than September 30, 2034." DOE/NNSA is working with Navy Strategic Systems Programs through the Nuclear Weapons Council to develop the scope and schedule for the SLCM-N warhead and will incorporate the schedule in subsequent SSMP updates.

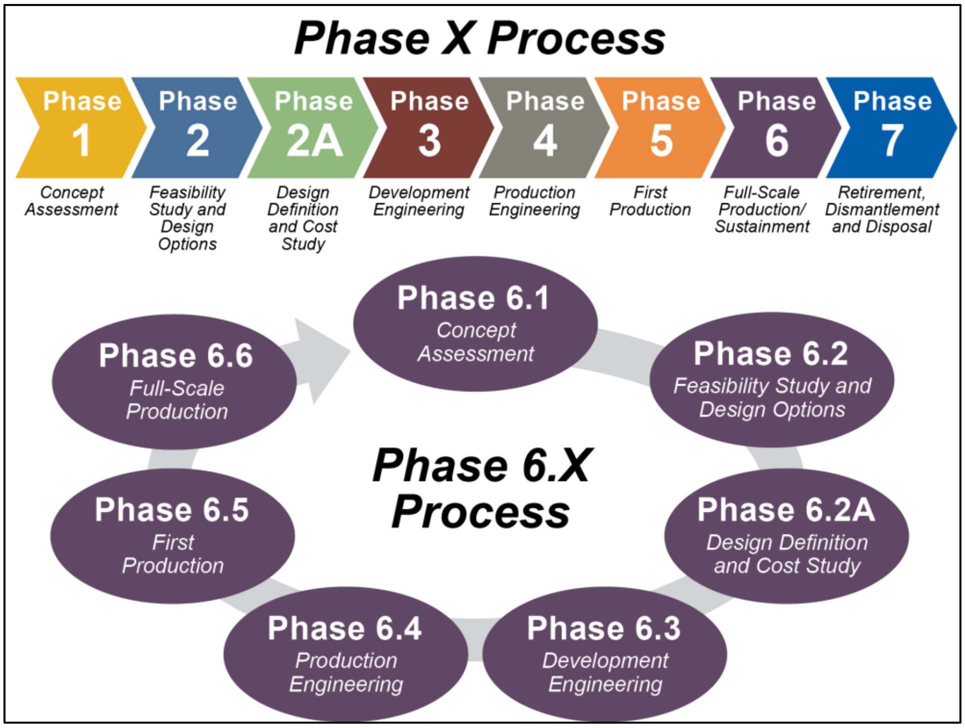

Figure 2–3. ***Phase X*** **and** ***Phase 6.X Processes***

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.

> ***B61-12 LEP Program Completes Last Production Unit of TYPE 3 Trainers***
>
> *The trainers are used to certify Air Force personnel and bases prior to delivery of the actual weapon systems. Trainers give Airmen the essential ability to familiarize themselves with loading the weapon on delivery platforms, as well as maintaining the weapon. The B61-12 LEP team supported and produced 3 different Type 3 Trainer versions with a total build of more than 100 military training weapons.*
>
> *Achieving the last production unit milestone came as the result of collaborative efforts spanning across nuclear security enterprise sites and teams, which included multiple members from KCNSC, SNL, Los Alamos National Laboratory (LANL), Pantex Plant (Pantex), and DOE/NNSA.*

2.2.2.1 Status

DOE/NNSA delivered the B61-12 LEP first production unit in November 2021 and received Nuclear Weapons Council authorization to enter Phase 6.6, *Full-Scale Production*, in June 2022. The B61-12 LEP has now completed 65 percent of life of program canned subassembly production and reached the 50 percent completion milestone for all remaining components in FY 2023. The program met DoD shipment delivery requirements in 2023 and is projected to maintain system level shipments in future years. The B61-12 LEP released an Aircraft Compatibility Control Document documenting compatibility certification with the F-15E, B-2A, F-35A, F-16 MLU, and German AF PA-200. The program is continuing certification activities for the Italian AF PA-200 and the B-21 bomber. The program is scheduled to complete production and close out in FY 2026. The B61-12 was assessed within the Annual Assessment review for the first year in FY 2023.[3]

2.2.3 B61-13 Program

The B61-13 will replace some of the B61-7s in the current stockpile. The B61-13 will have a yield similar to the B61-7 and higher than the B61-12. The B61-13 will provide the President with additional options against certain harder and large-area military targets, even while we work to retire legacy systems such as the B83-1 and the B61-7. In the near term, the B61-13 fulfills the *Nuclear Posture Review* commitment to leverage available nuclear and non-nuclear capabilities while DoD implements its new strategy for defeat of hard and deeply buried targets. The B61-13 will not increase the overall number of weapons in the U.S. stockpile. The number of B61-12s to be produced will be lowered by the same amount as the number of B61-13s produced.

2.2.3.1 Status

The B61-13 Program planned completion is FY 2028 with First Production Unit planned for FY 2026. Near-term activities include establishing the B61-13 Program framework and structure, and beginning requirements and development engineering.

2.2.4 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 maintain readiness. The W88 Alt 370 Program modernizes the arming, fuzing, and firing subsystem; improves surety; replaces the conventional high explosive and associated materials; incorporates a lightning arrestor connector; and provides trainers, JTAs, 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.

> ***W88 Alt 370 Accomplishment***
>
> *KCNSC completed the last production unit for multiple conventional high explosive (CHE) Refresh components to support W88 Alt 370 weapon assembly operations at Pantex. Through close collaboration with LANL, KCNSC has completed CHE Refresh components early to support W88 Alt 370 weapon assembly operational needs at Pantex.*

2.2.4.1 Status

The W88 Alt 370 completed the system-level first production unit in July 2021 and conducted the final review for the Design Review and Acceptance Group in October 2021. The Nuclear Weapons Council formally accepted the W88 Alt 370 into the stockpile in December 2021 and authorized entrance to Phase 6.6 in June 2022. In January 2022, DOE/NNSA delivered an initial operational capability quantity of W88 Alt 370 Reentry Body Assemblies to the Navy and has continued to meet all scheduled deliveries since then. The W88 Alt 370 reached the 50 percent completion milestone for system-level assemblies in the first quarter of FY 2024. The program is scheduled to complete production in the fourth quarter of FY 2025 and will transition from modernization to sustainment in FY 2026.

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[3] The *National Defense Authorization Act for Fiscal Year 2024, December 2023* authorized a B61 nuclear gravity bomb variant referred to as the B61-13. DoD's *Fact Sheet of B61 Variant, October 27, 2023* explains that the B61-13 will not increase the size of the U.S. stockpile because "the number of B61-12s to be produced will be lowered by the same amount as the number of B61-13s produced."

2.2.5 W80-4 Life Extension Program

The W80-4 LEP will deploy on the Air Force's AGM-181 Long Range Standoff Cruise Missile. This integrated program will replace the aging AGM-86 Air-Launched Cruise Missile and the W80-1 warhead. The Long Range Standoff Cruise Missile 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 warhead will be the first program to introduce additively manufactured metal and polymer components into the stockpile.

2.2.5.1 Status

The W80-4 LEP continues in Phase 6.4, *Production Engineering*, maturing designs and transitioning into the manufacturing process. Final design reviews for the last major component will be completed in early FY 2025. Qualification of component production processes, including certified tooling and testers, is scheduled to continue. Joint testing will continue in FY 2025 to ensure the weapon meets DoD requirements. System qualification of the W80-4 is on schedule to meet the first production unit in FY 2027.

2.2.6 W80-4 Alteration for the Nuclear-Armed Sea-Launched Cruise Missile Program

In accordance with Section 1640 of the FY 2024 *National Defense Authorization Act*, DOE/NNSA is coordinating with DoD to meet congressional direction and establish a program of record for the W80-4 Alt-SLCM. While DoD has not yet selected a W80-4 Alt-SLCM delivery platform, DOE/NNSA continues to collaborate with the Navy, USSTRATCOM, and other DoD partners through the Nuclear Weapons Council to determine warhead requirements.

2.2.7 W87-1 Modification Program

The W87-1 will be deployed on the LGM-35A Sentinel, which will initially be fielded with the W87-0. The W87-1 will replace the aging W78 warhead by modifying the existing legacy W87-0 design. By the time the W78 is replaced, it will be the oldest weapon in the stockpile without a life-extension refurbishment. 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 warhead is named the W87-1 to reflect that it has a similar primary design to the W87-0 and will fly in a similar reentry vehicle. The W87-1 is based on previously tested nuclear components and will provide enhanced safety and security compared to the W78 and focus on ease of production by employing advanced manufacturing techniques for key components. The W87-1 Mod will meet DoD and DOE/NNSA requirements for performance, safety, reliability, and security and is slated to deploy on the Sentinel between FY 2031 and FY 2032.

2.2.7.1 Status

In FY 2022, the program completed the Weapon Development Cost Report and set the initial program baseline in October 2022. An initial nuclear explosive safety design review was completed in FY 2022, providing feedback to optimize nuclear safety aspects of the W87-1 design. The W87-1 system Conceptual Design Review was completed in December 2022; in May 2023, the W87-1 program received Nuclear Weapons Council approval to enter Phase 6.3, *Development Engineering*. The program continues product and system maturation through holding component conceptual design reviews, which were largely completed in FY 2023. The W87-1 has also been advancing Technical Readiness Levels by completing the first series of thermal and mechanical system ground tests.

2.2.8 W93 Program

The W93 modernization program addresses an evolving set of Navy ballistic missile requirements by incorporating modern technologies that improve safety and security and ease of manufacturing, maintenance, and certification. All key nuclear components will be based on currently deployed and/or previously tested nuclear designs, as well as extensive stockpile component and materials experience. It will not require underground nuclear explosive testing to certify. The program is utilizing the *Phase X Process* for integrated nuclear weapons system acquisition, rather than the *Phase 6.X Process*.

2.2.8.1 Status

The Nuclear Weapons Council authorized the program to proceed into Phase 2, *Feasibility Study and Design Options*, in May 2022. Phase 2's scope for FY 2024 includes maturing DoD military characteristics and stockpile-to-target sequences to inform DOE/NNSA requirements, technical trade decisions, component down-selections, and production concepts. The W93 Design Agencies and Production Agencies will continue to improve integration engagements for requirements definition. The W93 assessment of the available technical trade-space is facilitating decisions of major subsystem designs and potential component designs. The formulation of programmatic schedules, resourcing, business practices, and risk management practices is also underway. The W93 Design Agencies are supporting the product realization teams for manufacturing of pre-development components in support of the W93 down select process.

2.2.9 Future Warheads

DOE/NNSA is coordinating with DoD to define the appropriate 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).

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2.3 Weapon Dismantlement and Disposition

Weapon Dismantlement and Disposition (WDD) activities disassemble retired weapons into major components. Those components are then assigned for reuse, storage, surveillance, or additional disassembly and subsequent disposition of constituent parts and materials. The dismantlement schedule for retired nuclear weapons is critical in that it provides the materials and components required for the stockpile (in particular, LEPs, Mods, and Alts) and considers the needs of other weapon programs for these materials. WDD also maintains the proficiency of technicians, balances work scope at the production sites, and frees up footprints from retired weapons, allowing space for performance of experiments, research, and testing for mission requirements.

Weapons Dismantlement and Disposition Accomplishments

- *Pantex completed 112 percent of the FY 2023 Baseline.*
- *Pantex staffing increased to support FY 2024 commitments.*
- *Pantex supported all W80 Alt Diversions.*
- *Completed all planned W84 weapons dismantlement.*

Dismantlement rates are affected by many factors, including weapon system complexity, availability of qualified personnel, equipment, facilities, logistics, policy and directives, and legislative requirements. DOE/NNSA's current 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. See the classified annex for additional information on WDD.

2.3.1 Status

DOE/NNSA continues to dismantle retired weapons and dispose of resulting components and materials, supporting DoD return schedules and meeting the needs of the LEPs and material demand requirements. As detailed in the FY 2025 Stockpile and Stewardship Management Plan's (SSMP) classified annex, DOE/NNSA is on track to dismantle several weapons systems to meet downstream requirements for material and/or weapon parts. DOE/NNSA's disposition schedules are also on track, and several disposition projects are ahead of schedule. Moreover, DOE/NNSA developed return schedules to remove additional 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 planned for the warhead modernization, sustainment, and WDD programs. Production Operations' goal is to maintain the base capability required to sustain the stockpile through robust management, production process engineering, manufacturing, production technology resources, and production equipment maintenance. The program accomplishes this goal by maintaining the tools and personnel necessary for supporting component manufacturing, assembly, disassembly, maintenance, quality, and production data management for all nuclear weapons in the stockpile and modernization efforts.

> ***Production Operations Accomplishments***
>
> - *Experienced significant workload increases resulting in over 3.6 million hours of support for base capability.*
> - *Executed over 20 thousand work orders enabling more than 90 percent availability of production and quality equipment.*
> - *Completed over 67 thousand analytical lab samples in support of material movement and surveillance activities.*

At individual enterprise sites, Production Operations sustains base capabilities at required capacities for the nuclear security enterprise's production mission, mainly through a multifaceted skilled labor force. The program provides critical funding to support approximately 2,000 full time equivalents who are essential for multi-weapon preventive and corrective production equipment maintenance, calibrations, quality assurance, qualification, production logistics, manufacturing execution systems, process flow, and scheduling activities. While the base capability at seven sites is not all the same, some activities in the Production Operations portfolio include, but are not limited to, metrology, calibration, and analytical services, procurement activities, production scheduling and workload planning, weapons, component storage, maintaining and updating manufacturing execution systems, packaging and shipping operations, quality engineering, and material management. The Production Operations program heavily coordinates with other programs within DOE/NNSA, such as those leading Infrastructure and Operations modernization activities as well as Capabilities-Based Investments, to ensure adequate capacities, space, and equipment are in place. The base capabilities for the New Brunswick Laboratory are also funded out of Production Operations.

Production Operations, in coordination with the sites, also manages a suite of modeling capabilities through the Enterprise Modeling and Analysis Consortium. Production Operations maintains internal DOE/NNSA modeling and analysis efforts for assessing nuclear security enterprise capacity and health. Production Operations created and currently manages the Enterprise Capacity Analysis and Production Capability Health tools. Outputs of these modeling tools inform infrastructure investment, identification, and prioritization, as well as workforce requirements to support future system and capability planning. Production Operations manages data standardization and integration activities that underpin these modeling and analysis efforts. See the classified annex for additional information on production operations.

2.4.1 Status

Production Operations is expanding the nuclear security enterprise's base capability to provide the increased workforce necessary to meet the ramp up in stockpile modernization activities. Production Operations coordinates with other programs who are leading infrastructure projects and capital equipment procurements that may affect weapon program schedules. Production Operations advocates for increases in production capacity where needed. The program continues to lead enterprise capacity and health modeling and analysis to align with concurrent Defense Program priorities and future investments with the increasing stockpile demand signal.

Production Operations has successfully delivered on requirements while supporting the weapons activities during peak production, increasing requirements for stockpile surveillance data, and modernizing the various nuclear security enterprise sites for an uncertain geopolitical future. The program will require corresponding future growth across the nuclear security enterprise to support and maintain increased operations.

2.5 Nuclear Enterprise Assurance

The NEA ensures the nuclear security enterprise actively manages subversion risks to the nuclear weapons stockpile and associated design, production, and testing capabilities. Through nuclear weapon digital assurance, the NEA enables risk-managed adoption of leading-edge technologies to meet emerging military requirements and reduce modernization schedules and costs.

The NEA focuses on technical and governance activities for the assurance of digital systems integral to weapon systems, operational technologies directly related to weapons, and capabilities that cross-cut multiple weapons programs, sites, and supply chains. The NEA program has four major activity levels:

1. Assurance Evaluations
2. Tools and Capabilities
3. Policy, Requirements, and Oversight
4. Workforce Standards

Nuclear Enterprise Assurance Accomplishments

- *Developed and exercised methods to scale assurance evaluations to meet the needs of design, production, and testing across the nuclear security enterprise.*
- *Partnered with DoD to develop tools and training necessary to assure complex cyber-physical production equipment (i.e., operational technology)*
- *Stood up the NEA Division and developed a capability, execution, and NNSA/DoD partnership strategy. Developed draft requirements for the cyber assurance of nuclear weapons.*
- *Created an initial nuclear security enterprise assurance workforce development plan to address a national shortage of subject matter experts skilled in full-spectrum assurance relevant to nuclear weapons.*

See the classified annex for additional information on the NEA.

2.5.1 Status

DOE/NNSA has focused resources on development of NEA risk discovery tools and methods. The DOE/NNSA Science Council commissioned a JASON Summer Study to technically inform the development of a nuclear weapon information technology threat model as a risk discovery aid. The DOE/NNSA NEA Division partnered with the DOE/NNSA Office of Information Management to conduct experiments aimed at improving cyber-attack detection and response for operational technology systems used to produce and test nuclear weapon products. DOE/NNSA continues to establish, update, and expand NEA training as well as institute nuclear weapon information technology policies, requirements, and oversight.

Chapter 3
Weapons Activities Capabilities that Support the Nuclear Security Enterprise

This chapter focuses on the Weapons Activities capabilities required to accomplish the mission described in Chapter 2, "Stockpile Management." The Department of Energy's National Nuclear Security Administration (DOE/NNSA) capabilities are the foundation for an effective nuclear deterrent that adapts and responds to a dynamic security environment, emerging strategic challenges, and geopolitical and technological changes. The Department of Defense (DoD) supplements DOE/NNSA Weapons Activities capabilities with specific efforts, including providing platforms for flight tests.

The Weapons Activities capabilities described in this chapter directly support *NNSA Strategic Vision* Mission Priority #1:[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. Each of these activities occurs within a safety framework established and monitored by DOE/NNSA.

More than 30 key Weapons Activities capabilities support the Integrated Stockpile Model introduced in Chapter 1, Figure 1–1, and each capability may support multiple parts of this model. This interdependency between model activities and capabilities, and among the capabilities themselves, is described throughout this chapter. **Figure 3–1** shows the seven interdependent areas defined in this document, each containing a suite of capabilities that, when 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 compromised.

DOE/NNSA evaluates Weapons Activities capabilities across the four elements to assess and support continued investment in their health. That evaluation is reflected in this chapter and continues in Chapter 4, "Infrastructure and Operations."

Many of the capabilities described are unique to the nuclear security enterprise. The highly specialized materials, varied 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 maintain these niche functions. For some capabilities, the overall capacity for testing and production must be increased to

[1] https://www.energy.gov/sites/default/files/2022-05/20220502%20NNSA%20Strategic%20Vision.pdf

meet the demands of several concurrent modernization programs. In addition, the national security requirements for nuclear weapons require trusted domestic vendors for certain materials and processes.

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

Figure 3–2. Weapons Activities capability elements

The Office of Defense Programs recently constructed a Science and Technology Investment Strategy to meet the future needs of the nuclear security enterprise. Within this strategy, there are four pillars that enable execution of stockpile-based stockpile stewardship (as shown in **Figure 3–3**). Each of these four pillars relates to one or more Weapons Activities capabilities areas described in this chapter:

- Experimental Science: leverages historical underground test data and generates new data needed to advance understanding of the physics associated with weapon design, weapon assessment, and weapon qualification, which increases confidence in the certification of nuclear weapons.
- Computational Science: provides high-performance computing and simulation approaches employing modern data-driven techniques and methods (including machine learning and artificial intelligence) to both advance science, technology, and engineering tools and provide a fundamental capability to design, certify, sustain, and assess U.S. nuclear warheads.
- Technology and Engineering: enables the design, development, certification, and qualification of materials, processes, subsystems, and systems for representative weapon environments.
- Production Science: supports the application of research, development, test, and evaluation tools and capabilities to readily enable production processes and materials that increase DOE/NNSA's ability to sustain at-rate production.

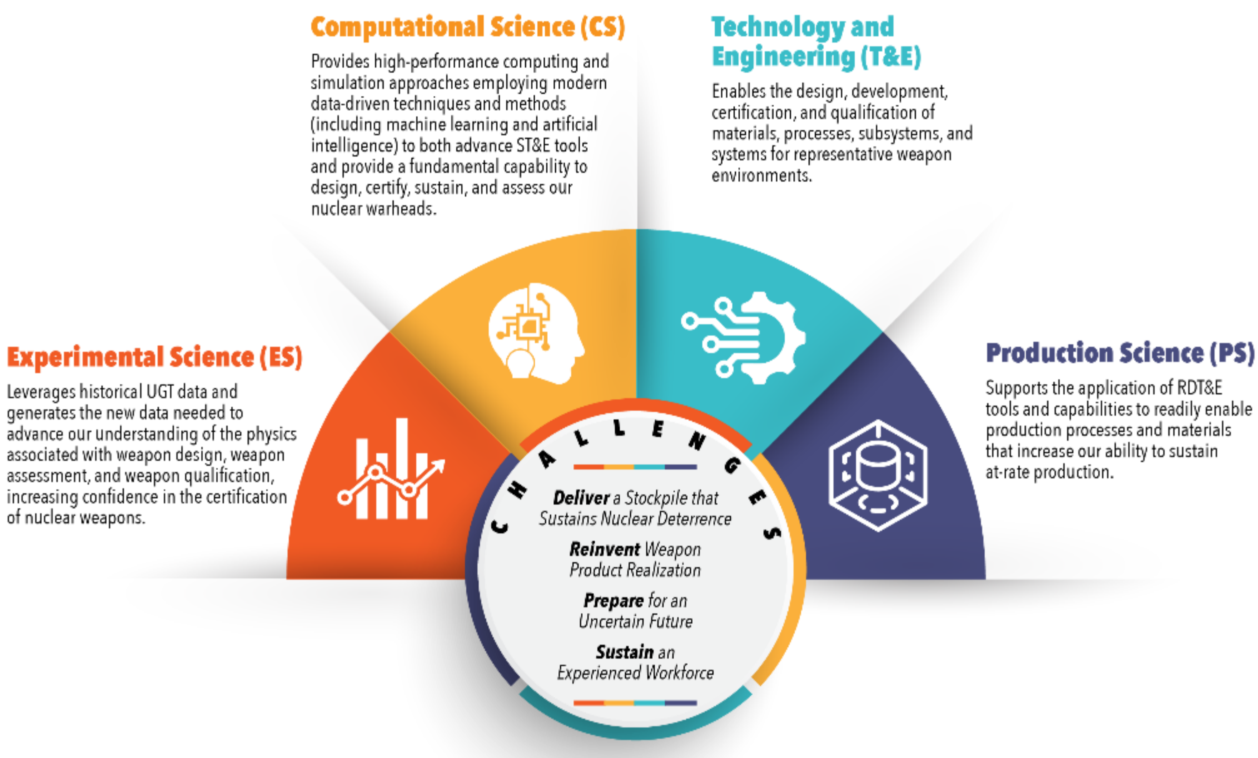


Figure 3–3. The Science and Technology Investment Strategy's approach to meeting the future needs of the nuclear security enterprise

This chapter describes the Weapons Activities capabilities areas, including their constituent capabilities, their specific support to the nuclear deterrent mission, and how they link and integrate with other areas and capabilities. See Chapter 4 and Appendix C, "Workforce Retention," for an enterprise-level overview of major infrastructure investments and the supporting workforce tied to Weapons Activities capabilities. In Chapter 4, Section 4.2.2, 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. Stockpile system certification is dependent on individual war reserve parts qualification, including pits. Given the unique environments and physical properties generated in and experienced by nuclear weapons, these capabilities are essential in the absence of underground nuclear explosive testing for understanding whether the stockpile can continue to meet national security needs. These Weapon Science and Engineering capabilities are also 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, reliable, and flexible nuclear deterrent. Advances in the understanding of weapons physics allow designers more flexibility, provide more accurate models and simulations, enhance engineering and operational safety, enable manufacturing efficiencies for pits and other weapon components, and increase confidence in performance. These activities also serve to train the next generation of weapons designers and engineers.

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

Understanding atomic, nuclear, and radiochemical properties relevant to weapons is critical to enhancing computationally based predictive capabilities and designing validation experiments that increase confidence in simulation models. New measurements, theory developments, and evaluations of data that impact or inform the models can reduce uncertainties in predictive simulations for annual assessment. Flexibility in future stockpile options will benefit from reassessments of historic nuclear explosive test data used to validate and constrain weapons simulations. Quantifying uncertainty is critical to the certification strategy for future stockpile options and assessments of the existing stockpile as weapons age.

DOE/NNSA uses the high-shot-rate Omega Laser Facility to develop platforms for Stockpile Stewardship Program applications, train the next generation of stewards and designers, understand the physics of burning plasmas, and test new measurement techniques for aboveground facilities.

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 the ability to explore atomic physics processes that occur in nuclear weapons and 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 data for stockpile performance and safety assessments. Nuclear forces are a challenging area for theoretical understanding and necessitate experimental measurements. Data are collected at large experimental facilities such as LANSCE, other DOE national laboratories (e.g., Argonne National Laboratory, Lawrence 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 Sites (NNSS).

Radiochemistry is the study of radioactive materials and their interactions; it 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 is 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 materials for nuclear reaction measurements and an important element of the diagnostic capabilities used by high energy density (HED) experiments.

3.1.1.1 Status

DOE/NNSA has a strong understanding of atomic physics at the limits of high and low temperatures and high and low densities. Between these extremes, there is uncertainty in fundamental theories, with minimal benchmarked data to inform them. These uncertainties in basic properties lead to increased risk regarding final integrated simulation outputs.

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 enabling the expansion of predictive methods for determining nuclear properties of radioactive materials that are difficult to measure. Support for fast neutron facilities at Los Alamos National Laboratory's (LANL's) LANSCE facility remains imperative, as reaction product measurements provide additional accuracy for nuclear data and code validation.

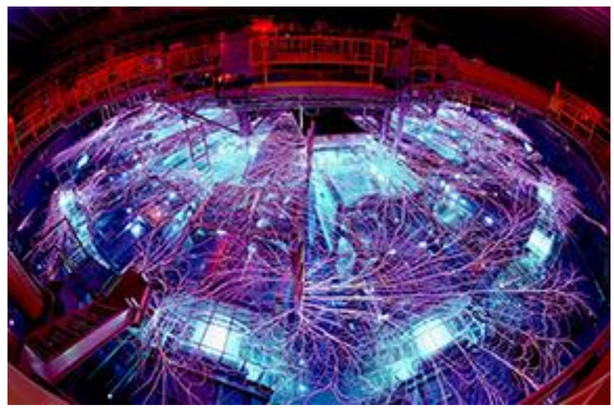
Nuclear data evaluation is an established methodology that requires high-quality measurements coupled with theoretical reaction calculations to improve predictive simulations. Data evaluators reconcile newly acquired measurements with existing data and physics models to determine "best value" quantities and uncertainties. DOE/NNSA has developed a new methodology for organizing and accessing detailed nuclear data that is now being adopted as a new global standard.

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 the measurements required to evaluate 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.

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

The Materials Science capability aids in understanding how all materials in a nuclear weapon system perform in diverse and extreme environments throughout the weapon system's entire lifecycle. This capability plays a key role in resolving stockpile and production issues, determining compatibility, validating computational models, and developing new materials (e.g., materials produced through advanced manufacturing, materials designed to replace environmentally hazardous and/or difficult to manufacture legacy materials). Materials Science experiments contribute to stockpile surveillance, where the effects of aging materials must be detected and evaluated to support the stockpile annual assessment. Evaluations of aging effects factor into pit reuse scenarios and ultimately into needs for new pit manufacturing. When materials used in the stockpile must be replaced due to aging issues or obsolescence, new materials are developed, studied, and qualified for insertion into the stockpile and are vital to extending the life of the weapon systems. Many materials, including many non-nuclear materials, used in past system designs are difficult to procure today for a variety of reasons. The qualification of new or replacement materials reduces risks and may improve the overall safety and reliability of the stockpile.



Z provides pulsed power, which is a technology that concentrates electrical energy and turns it into short pulses of enormous power, which are then used to generate X- and gamma rays. Photo: Randy Montoya

Within the Materials Science and Actinide Science capabilities, 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 stockpile materials in relevant regimes require specialized facilities such as NIF, Z, LANSCE, Joint Actinide Shock Physics Experimental Research (JASPER), Shock Thermodynamics Applied Research Facility (STAR), and Technical Area (TA)-55 gas gun facilities. The data generated from these studies is used to create and validate models that contribute to a more confident prediction of weapon performance and is increasingly being used for material replacement decisions and define requirements for components qualification. This area of work also makes significant use of DOE/NNSA-stewarded capabilities in sensitive data collection at the DOE Office of Science, such as the High-Pressure Collaborative Access Team and the Dynamic Compression Sector capabilities at the Advanced Photon Source. Infrastructure investments in partnership with the DOE Office of Science are increasing the value of these DOE/NNSA-stewarded capabilities. Additionally, actinide science, the study of physics and chemistry of elements from actinium to lawrencium, is important to understand the production and compatibility for both manufacturing and targets for focused experiments.

The High Explosives and Energetics (HE&E) 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.

The Chemistry and Chemical Engineering capability encompasses the study of the fundamental composition, structure, bonding, and reactivity of matter in each 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 the materials that are currently fielded in stockpile warheads, and 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.

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, as well as 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 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 production of samples and targets is a principal constraint to the rate of experimental execution, limiting the ability to address important questions such as those regarding plutonium manufacturing and aging.

Some urgent infrastructure needs are being addressed, such as upgraded plutonium facilities, the new Uranium Processing Facility, and renovated radiological space.

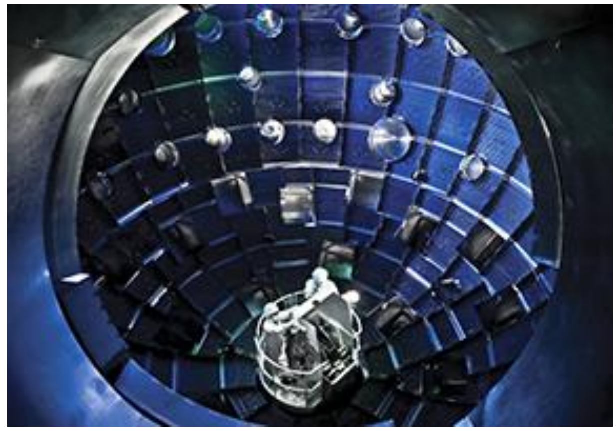
Plans have been developed to recapitalize HE facilities, including the HE Applications Facility, Site 300, and the Detonator Production Facility.

The capability's scope presents challenges in maintaining an expert workforce and modern facilities. Sustaining the workforce requires active partnering with academic institutions and industry. Many personnel with the knowledge, skills, and abilities in the capabilities previously discussed have retired, creating knowledge gaps. Furthermore, onboarding that allows significant training time in specialized areas, and stable investments in programs that support foundational applied sciences, are required. Qualified scientists and engineers must acquire specialized knowledge and hands-on laboratory training. While the relevant science and engineering programs at universities have increased in some instances (e.g., actinide science), most academic programs do not address the specific needs of the nuclear security enterprise, necessitating training and knowledge transfer between existing employees and new hires.

3.1.3 High Energy Density Science and Plasma Physics

HED science is the study of matter and radiation in high pressure, temperature, and density regimes, including those produced in a functioning nuclear weapon. HED experiments provide data required to validate weapon physics models in simulation 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. HED experiments support scientific development and judgment of weapons-related issues as well as promote the development of skills in experimentation, design work, fabrication, instrumentation, and other related areas.

Plasma physics is the study of systems containing separate ions and electrons that exhibit a collective behavior, such as those generated by the extremely high temperatures encountered in nuclear weapons. Experiments explore the physical processes that occur in plasma states to validate computational models and improve understanding of matter and radiation properties under HED conditions.



Inside the NIF at Lawrence Livermore National Laboratory, a service system lift allows technicians to access the target chamber interior for inspection and maintenance. Photo: Philip Saltonstall

Inertial confinement fusion (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. Understanding the physics of higher-yield ICF platforms and exploring the boundaries of what is possible are key goals for HED science. ICF capabilities necessitate specific facility and diagnostic investments, development activities, and workforce skill sets. NIF, Z, and Omega continue to use ICF capabilities to create HED conditions and push the boundaries of what is accessible in the laboratory. The demonstration of fusion ignition and associated generation of multi-megajoule yields at NIF provide a first-of-its-kind capability across the globe.

Advancing HED science and plasma physics includes characterizing and understanding perturbations prevalent in plasmas and thermonuclear environments, investigating material behaviors in HED regimes presently inaccessible through other techniques, improving the predictive capability of science and engineering models in these regimes, using HED sources to expose objects to intense environments, and developing high-fidelity diagnostics and advanced experimental platforms.

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 enabled important advances in determining plutonium properties at relevant pressures, addressing key questions on aging and remanufacturing, and producing unique data on responses to radiation environments for the evaluation of weapon survivability. 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 for HED science and plasma physics has been achieving a robust burning fusion plasma, which is key to enabling the technology required to significantly shrink the gap between laboratory experiments and weapons environments. Several ICF experiments have been conducted at NIF to help bridge this gap, with sustained successful experiments achieving fusion ignition—the first on December 5, 2022. The understanding developed at each stage of experimental performance along the path to a robust burning fusion plasma provides critical knowledge and constraining data for simulations and access to material properties and outputs unachievable anywhere else in the world. The achievement of fusion ignition at NIF also expands the range of physical conditions that can be accessed in HED experiments, providing the opportunity to improve the fundamental understanding of processes ranging from radiochemical measurements to matter-radiation interactions in extreme environments. Current experimental and computational HED and ICF science and plasma physics efforts will establish a foundation for next-step decisions on capability investments and program balance needed to realize long-term stockpile goals for a modern, flexible, responsive, reliable, and resilient deterrent. Sustainment at the NIF and Z, and expanded capabilities at the NIF, are core components of the long-term strategy for the experimental work supporting the Stockpile Stewardship Program.

The workforce of scientists with training in HED and ICF science and plasma physics has become stronger over the last decade, as has the highly skilled workforce of technicians to support these complex facilities, diagnostics, and experiments. A concern for future workforce development and growth, particularly within plasma physics, is that only a small number of university programs offer relevant training, though several of these institutions are offering 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 by generating stockpile-relevant environments to qualify materials, components, systems, and hardened electronics in hostile environments; providing a range of information for weapon assemblies and components that can inform predictive capabilities; and exploring and implementing new options for the stockpile as external threats evolve.

Lasers and pulsed-power machines deliver intense pulses of energy into small-scale sample 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, when coupled with relevant measurement techniques, support studies that affect design codes enhancement, new components and systems qualification, and improvement of weapon performance assessments. Experiments in the various facilities directly inform material choices for warhead modernizations and resolve stockpile questions.

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

Accelerator technology supports the stockpile by providing high-fidelity 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 Enhanced Capabilities for Subcritical Experiments (ECSE) at the Principal Underground Laboratory for Subcritical Experimentation (PULSE), previously referred to as the U1a Complex; the Dual-Axis Radiographic Hydrodynamic Test facility (DARHT); LANSCE; the Flash X-ray capability at the Contained Firing Facility (CFF); Saturn; and the High-Energy Radiation Megavolt Electron Source (HERMES III).

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. NIF, Z, and Omega have reached a point where some subsystems and components are approaching obsolescence. Refurbishing and recapitalizing these facilities and equipment with minimal pause in operations will be necessary to sustain a key role in maintaining a strong deterrent. Beyond HED facility sustainment, the recent achievement of fusion ignition at NIF provides a unique tool to address the stockpile stewardship program mission and ensure confidence in an evolving and aging nuclear deterrent. Modest enhancements currently being planned to increase laser performance and nuclear yields at NIF will enable enhanced experimental weapons physics conditions that have not been accessible since the cessation of underground nuclear explosive testing.

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 (e.g., CFF/Flash X-Ray, DARHT, Z, and LANSCE) are aging and cannot provide the full range of test capabilities that will be 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.

A new electron accelerator, Scorpius, is planned to come online at NNSS in 2030. Scorpius will be used to take radiographs of weapon implosion using plutonium. This will allow scientists to better identify the effects of plutonium aging and ensure the proper functioning of the nuclear stockpile. Data from Scorpius' subcritical experiments will support safety and other updates to nuclear weapons.

Maintaining and enhancing accelerator facilities such as LANSCE, Saturn, and HERMES III is 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. 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, HED science, and other national security applications. 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 that is 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 acquire the high-fidelity data required to validate aspects of stockpile stewardship computational capabilities. As HED facilities better replicate weapons environments, additional diagnostics must be developed to operate within these environments and study plasma behavior achieved in the laboratory. The breadth of experiments performed at hydrodynamic and subcritical experiments (HSE) facilities is increasing; 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 must be developed to investigate this wide range of parameters. Accurate diagnostic measurements of shocked material experiments and HED science experiments are critical to validate the simulations used to assess 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 response of materials and components 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 quantified and reduced to inform decisions made for stockpile modernization. A broader range of higher performance diagnostics is still needed to address the increasing breadth of experiments and provide high-quality data for the weapons activity programs.

As HED facilities increase yields, new diagnostics must be developed to study new plasma conditions created in the laboratory and must be designed and engineered to withstand the increasingly challenging radiation environments generated by higher yields. 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. To meet these challenges, a National Diagnostics Working Group of more than 100 scientists from Lawrence Livermore National Laboratory (LLNL), LANL, and Sandia National Laboratories (SNL) and national laboratory and academic partners from 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.

Continued enhancement of experimental diagnostics and sensors is needed to advance stockpile science and quantify simulation uncertainties. Experimental diagnostics also push the boundary of what is possible and inspire concepts for future experimental advances. More diagnostics per experiment allow acquisition of requisite data from fewer experiments and more efficient use of shared, limited experimental facility resources. To support this, DOE/NNSA continues to invest in infrastructure to support the continued health of existing diagnostics; hire and train the next generation of diagnostic scientists who will push the frontier of measurement science; support the supply chain of specialized equipment uniquely required for HED and HSE diagnostics; and develop advanced and transformational diagnostics.

3.1.6 Hydrodynamic and Subcritical Experiments

The HSE capability provides data on the hydrodynamic behavior of weapon systems or components without creating nuclear yield, which provides vital data on material behavior under low-energy density extreme conditions (e.g., in imploding primaries). 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.

HSEs are used to characterize the primary performance and safety of nuclear weapons and to assess findings from stockpile surveillance. The data are used for the stockpile annual assessment and certification decisions before a weapon enters the stockpile. These experiments, with their associated diagnostics and measurement methodologies, 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 DOE/NNSA sites that provide the experimental infrastructure for hydrodynamic (e.g., DARHT, CFF) and subcritical experiments (e.g., PULSE). These specialized facilities are operating at near capacity, and the complex is aging. The demand for an increase in the collection of experimental data required by multiple DOE/NNSA programs stresses the physical infrastructure and the workforce. Capacity must be increased to allow DOE/NNSA to meet a greater demand and 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 the higher-fidelity, more-predictive computational simulation capabilities that are used to qualify primaries without underground nuclear explosive tests. Due to 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.

Scorpius is being developed for ECSE to deliver images of plutonium, which is not possible using existing radiographic capabilities. Complementary neutron diagnostic capabilities are also being developed as part of ECSE for deployment in subcritical experiments.

The PULSE Complex Enhancements Project provides PULSE 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 Scorpius with complementary diagnostics and a 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 for hydrodynamic experimental capabilities are actively under development to modernize DARHT and provide a potential second axis at the CFF. 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 Strategies	*Future Strategies*
All		
Developing and retaining a robust and diverse workforce trained for the foundational and applied research requisite to DOE/NNSA missions.	Sustain hiring and retention efforts focused on foundational and applied research needs. 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.

Challenges	***Strategies***	
	Current Strategies	***Future Strategies***
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. Use quantitative uncertainty analysis to prioritize additional investments both in physics model development and in additional experimental capabilities.	Extend state-of-the art complex models to better understand existing and new 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		
Reducing uncertainty in the behavior of matter between low and high temperature to enhance certainty in simulated outputs.	Advance fundamental theoretical and experimental research at universities and national laboratories to reduce and quantify uncertainties.	Develop new and innovative experimental platforms.
Generating sufficient benchmark data to verify certain phenomena that will increase certainty in simulated outputs.	Develop 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).
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 innovative experimental and modeling/simulation 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.

Challenges	*Strategies*	
	Current Strategies	***Future Strategies***
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.	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. Invest in recapitalization and modernization at DOE/NNSA-stewarded experimental facilities and investments in tailored functionality at light sources.	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.	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 HE development processes and facilities 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.
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.

Challenges	*Strategies*	
	Current Strategies	***Future Strategies***
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.
Obtaining required materials because they are no longer available due to obsolescence or supplier interest.	Re-engineer obsolete materials and use microreactors to produce specialty materials in the right quantities and improve safety or identify and qualify replacement materials.	Identify and leverage next generation disruptive technologies.
Improving the ability to predict the effects of aging 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.
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.

[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 Strategies	***Future Strategies***
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.
Resolving inconsistency among tabulated plasma data for certain properties of relevant 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 domestic development of 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 lifecycle.	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.
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.

Challenges	*Strategies*	
	Current Strategies	*Future Strategies*
Hydrodynamic and Subcritical Experiments		
Obtaining multi-frame penetrating radiographs on hydrodynamic experiments with plutonium pits.	Design, build, and install a novel radiographic capability to close ECSE gaps.	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.	Develop photofission methodology to combine neutron reactivity measurement with radiography.
Obtaining the necessary higher cadence operation and time delivery of hydrodynamic and subcritical experimental data needed to support stockpile and certification activities.	Execute current program plans for facility enhancements to provide increased experimental capacity and operational efficiency.	Increase staffing and future investments in facility enhancements to include facilities that produce the test articles for the hydrodynamic and subcritical experiments.
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.
Overcoming operational issues associated with the increased capabilities for and cadence of subcritical experiments at the NNSS PULSE site.	Develop national plans to address operational issues.	Complete long-term planning for experimental capabilities at PULSE, 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
PULSE= Principal Underground Laboratory for Subcritical Experimentation
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 3.1) 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

El Capitan

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 performance of weapon systems and components as well as the fundamental physical processes critical to nuclear operation. It also includes R&D in computer architecture design and engineering, data management and analytics, machine learning and artificial intelligence, and mathematical sciences to support developing and operating the HPC systems.

For DOE/NNSA, an 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.), often developed independently from one another by component vendors and deployed by the HPC system integrator.

> *As mandated by Congress in the* William M. (Mac) National Defense Authorization Act for Fiscal Year 2021, *a committee was established by the National Academies of Sciences, Engineering, and Medicine to review "the future of computing beyond exascale computing to meet national security needs at the National Nuclear Security Administration." In the context of NNSA mission needs, the committee was asked to evaluate future technology trajectories as well as the U.S. industrial base required to meet those needs. As a result, in May 2023, the committee published its report, "Charting a Path in a Shifting Technical and Geopolitical Landscape – Post-Exascale Computing for the National Nuclear Security Administration."*
>
> *The committee believes that bold and transformative actions will be required for NNSA to continue to succeed in its evolving mission and has summarized these actions in three general recommendations:*
>
> *Recommendation 1 (HPC Roadmap): NNSA should develop and pursue new and aggressive comprehensive design, acquisition, and deployment strategies to yield computing systems matched to future mission needs. NNSA should document this computing roadmap and have it reviewed by a blue-ribbon panel within a year after publication of this report and updated periodically thereafter.*
>
> *Recommendation 2 (Investment in Research): NNSA should foster and pursue high-risk, high-reward research in applied mathematics, computer science, and computational science to cultivate radical innovation and ensure future intellectual leadership needed for its mission.*
>
> *Recommendation 3 (Partnerships and Workforce): NNSA should develop an aggressive national strategy through partnership across agencies and academia to address its workforce challenge.*
>
> *Embracing these recommendations will require vision, strategy, and advocacy to meet post-exascale challenges. NNSA needs to fundamentally rethink its advanced computing research, engineering, acquisition, deployment, and partnership strategy. An extension of the strategy developed over the past 30 years will be insufficient for future mission success.*

3.2.1.1 Status

As detail levels increase in simulation codes, especially those with three-dimensional features, and the need increases for large ensembles of simulations (tens of thousands or more) for studies such as uncertainty quantification, computing resources and times to reach solution increase dramatically. These increasing computing needs present a challenge in providing mission and experimental 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 strategy includes 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 retains 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.

DOE/NNSA will officially enter the exascale era in 2024, with the deployment of El Capitan at LLNL—the first exascale system in the Nation aimed at serving the national security mission. More than a decade of DOE investment in the Exascale Computing Initiative has resulted in the development of new software and applications that will be ready to run on El Capitan, including next-generation weapons performance, effects, and re-entry codes supporting the Office of Defense Programs mission.

HPC platforms like El Capitan have evolved 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 continues to develop new technology models that are more energy efficient. Artificial intelligence and cognitive simulation capabilities are also being developed, along with related infrastructure that will greatly magnify traditional simulation's capabilities and influence DOE/NNSA's post-exascale hardware roadmap. For this reason, an integrated approach is key to incorporating advanced technology innovations to support the future mission. Artificial intelligence technologies have the potential to transform and revolutionize all aspects of this area through coordinated code and platform evolution. This would provide more detailed simulations of the aging stockpile, offer the ability to simulate and capture response across the full weapon lifecycle, and capture distinctions between weapons as designed, built, and delivered. Quantum computing,[3] which is more forward-looking but significantly less mature, could have a similar effect, but will require more focused attention from DOE/NNSA to explore its potential benefits to the weapons missions.

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 DOE/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 can solve 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.

Deploying more advanced platforms increases 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 line-item construction projects. The Exascale Computing Facility Modernization project was a line-item construction project that upgraded the LLNL computing facility with increased power and cooling capability in preparation for El Capitan and subsequent post-exascale architectures. Exascale Computing Facility Modernization provides sufficient cooling and power to allow both initial installation and overlap of multiple exascale systems as they are sited and decommissioned in the future. The nuclear security enterprise continues to manage and coordinate code development and facility upgrades with system acquisitions to allow use of the DOE/NNSA HPC platform as the technology progresses into the exascale era and beyond.

[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.

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 is 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. They play a central role in assessing a nuclear explosive package's performance and safety and the reliability of a full warhead system in the stockpile-to-target sequence (STS) environments. 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 by employing 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 underground 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, 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. These simulations directly support the assessment mission, as well as the 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, so must the simulation capabilities underpinning the stockpile.

Simulations with improved predictivity that support stockpile certification and modernization also address significant finding investigations and safety scenarios, which rely 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 and provide enhanced integration between codes. Improved physical models are needed to address responses to hostile environments and analyses of manufacturing, production, and assembly/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, can require from days to months to complete on existing Advanced Technology System machines. As the simulation detail increases into the mesoscale, exascale-class computing and increased use of artificial intelligence methods will be necessary to resolve these simulations in the timeframe required. In response, DOE/NNSA developed a new generation of IDCs under the Exascale Computing Initiative and Advanced Simulation and Computing's (ASC's) Advanced Technology Development and Mitigation Program starting in 2014. Culminating in 2021 and continuing as part of the base ASC Program, these codes embody new capabilities in numerical methods, software design, and programming models that are optimized for exascale systems. They are increasingly being introduced for production use in experimental design, annual assessments, and design of the modernized stockpile such as the W80-4 and W87-1.

DOE/NNSA also continues to pursue the Advanced Machine Learning Initiative (AMLI) with the overall goal of improving simulation capabilities in weapons design, production, qualification, and certification, as well as stockpile assessment through advanced data-driven analyses. This collaborative initiative is supporting important research aimed at increasing DOE/NNSA's agility in countering threats, enabling greater exploration of the design space, and improving predictive capabilities, while potentially lowering the overall cost of physics simulations and data analytics. Early demonstrations in AMLI are creating efficiencies in design and stockpile surveillance and opening new research opportunities in high-fidelity, multi-disciplinary, and large-scale computing. AMLI will improve DOE/NNSA's ability to assess current and new environments for weapon systems and reduce design margins in environmental specifications prior to experimental data being available.

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 currently underway addresses the need for large-scale simulations while utilizing computing resources to achieve the goal of improved performance and understanding of future platform requirements. In addition to improving understanding of current and future platform requirements, the mission objectives for this initiative include enhancing recognition of workflow needs and advancing physics-based understanding of relevant applications. The initiative is leveraged by the ASC Program to determine the limitations and scaling potential of DOE/NNSA's assessment capabilities. It is assessing what can and cannot be achieved with computing platforms, codes, and qualified personnel, and 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 Strategies	*Future Strategies*
Developing new physics, engineering, and materials applications needed to support the evolving stockpile, which will require additional computing capabilities. This will include higher fidelity modeling of non-nuclear components that will be needed to address interactions in new cross-domain environments.	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.	Refocus resources that were dedicated in the past decade on preparing for exascale toward algorithm and method development to address challenges and take advantage of unprecedented compute power.
Developing new ways for weapons to be certified in an evolving threat space. This will require credible simulation capabilities.	Coordinate with customers through the *Nuclear Posture Review* implementation to understand the new needs for threat response and to respond with credible simulation capabilities.	Model and develop complex workflows of loosely coupled simulation capabilities to accurately model as-delivered performance in the face of hostile environments, including combined threats, including those identified in coordination with *Nuclear Posture Review* implementation.

Challenges	***Strategies***	
	Current Strategies	***Future Strategies***
Stockpile Modernization and Production programs adopting next generation code and developing the ability to mechanistically simulate the material response of weapons effects, aging, and manufacturing.	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. Ensure performance of IDCs and supporting codes on increasingly powerful platforms to allow quicker time-to-solution for applications of simulation enhancements.	Apply agile approaches to code development, such as generative AI (e.g., customized large language models) to rapidly develop source code, code input files, and documentation with the goal of dramatically increasing the rate of new capability development while increasing the usability for developers and users. Engage Defense Programs mission programs early and often to fold their requirements into design and development of new code features. Place a high priority on code usability and user experience.
Performing rapid evaluations of new materials and modeling of advanced manufacturing techniques.	Continue current efforts to model additive manufacturing processes and couple these with molecular dynamics and mesoscale modeling to enhance their use. Continue to improve the verification and validation basis for advanced manufacturing simulation through improved test problems, experiments, and code comparisons.	Develop and mature artificial intelligence and machine-learned techniques that can capture these effects efficiently to improve production simulation capabilities with built-in capabilities to provide quantitative risk assessment.
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. Develop programming model abstractions that allow architecture-specific programming to be insulated from the code developer. Utilize performance-portable abstraction layers to prevent vendor lock-in and to greatly ease transitions between computing platforms and vendor-specific programming models.	Evolve HPC tools for next generation IDCs to achieve sophisticated programming models, software designs, and numerical algorithms. Reinvigorate partnerships with HPC silicon and software providers to ensure paradigm shifts in the computing industry do not leave DOE/NNSA applications stagnating. Pursue co-design activities while continuously adapting algorithms to emerging architectural innovations (e.g., low-precision, dataflow, cloud).
Providing adequately structured and sized facilities and supporting infrastructure (space, power, and cooling) exascale, commodity, and next-generation HPC platforms.	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.	Address infrastructure and develop a multi-decadal roadmap for HPC facility needs for computing facilities, including support for SCIF-based HPC. Pursue computing technologies that reduce demands on power and cooling.
Responding to more specialized hardware designs from industry to avoid large code modifications or mitigate the need for wholesale rewrites.	ASC must stay current with, and continue to influence, the computing industry to ensure continued performance of the IDCs on the next-generation compute platforms. Foster partnerships with various vendors and strengthening the vendor base to meet future DOE/NNSA compute needs.	Increase awareness of the work performed within the DOE/NNSA sites. Increase efforts to work with students even earlier in their careers.

Challenges	Strategies	
	Current Strategies	Future Strategies
Recruiting and retaining qualified personnel, given high demand in multiple industries for computational skill sets.	Work with M&Os to offer competitive salaries, improved benefits, and flexible work schedules.	Increase awareness of the work performed within the DOE/NNSA sites. Increase efforts to work with students even earlier in their careers.
Increasing demand on computational capacity and capability to run complex radiation models.	Develop 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 computing capacity if needed. Develop more efficient and integrated workflows to share computational resources across the national laboratories.

AI = artificial intelligence
ASC = Advanced Simulation and Computing
HPC = high performance computing
IDC = integrated design code
M&O = management and operating
SCIF = Sensitive Compartmented Information Facility

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 to meet all military requirements and endure all predicted environments and to verify and validate 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 (Section 3.1) and the Weapon Simulation and Computing areas (Section 3.2) capabilities in one of the three areas routinely supports 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 performance, qualify and certify changes to the stockpile (i.e., life extensions and modernization), evaluate the nuclear weapon programs of foreign states, and respond to emerging threats, unanticipated events, and technological innovation. This capability includes potential concept exploration to satisfy requirements and detailed development of design, development, production, and certification processes. It also encompasses evaluating weapon outputs and effects.

Weapon Physics Design and Analysis efforts make use of physics codes developed through the Weapon Modeling and Simulation area (as described in the previous section). Improving, verifying, and validating these tools requires data and knowledge acquired through historical underground tests, surveillance of the stockpile, and scaled non-nuclear tests including hydrodynamic, subcritical, and HED experiments. Advances in diagnostics and experimental capabilities are required to obtain suitable high-fidelity data. These capabilities are critical as they underpin the Weapon Physics Design and Analysis capability.

The Weapon Physics Design and Analysis capability provides the foundational tools and methods necessary to design and analyze nuclear explosive packages, determine the state of constituent materials and components, assess our current stockpile, and certify new warheads.

3.3.1.1 Status

Requirements for DOE/NNSA's current systems will evolve in the future due to component aging or remanufacture, the rapidly evolving threat environment, and the growing need to transition to alternate materials and technologies. This will require Weapons Physics Design and Analysis tools to continue to annually assess the current stockpile while also expanding predictive capabilities to assess and certify system performance without underground nuclear explosive testing. The ability to provide timely analysis to support warhead development timelines is critical.

DOE/NNSA must develop new methods for certifying designs that differ substantially from those for which DOE/NNSA has an extensive nuclear explosive test history.

3.3.2 Weapon Engineering Design, Analysis, and Integration

The Weapon Engineering Design, Analysis, and Integration capability supports 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 is employed during several phases of the weapons lifecycle, including concept exploration, design, development, and production. It also encompasses delivery 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 non-nuclear subsystem-level requirements 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 fully exercised. Because modernization activities prior to the W87-1 Mod have been focused on extending the life of current stockpile weapons (which constrained the options considered to minimize deviance from the original, underground tested design), there has been a decline in capability to develop warhead concepts to address military requirements that differ from those addressed by current stockpile systems. One approach DOE/NNSA is using to rectify this shortfall is the Stockpile Responsiveness Program, which generates new solutions to address new military requirements. By exercising the technical capabilities required for all nuclear weapon stages—including design, testing, and production—across the nuclear security enterprise and working in concert with DoD, DOE/NNSA can recruit, train, and retain the next generation of weapon designers and engineers, improve integration across the complex, and prepare to meet future demands.

> ***Digital Engineering***
>
> *SNL and Kansas City National Security Campus (KCNSC) partnered to select and develop tools to automate KCNSC Design-For-Manufacturing guides. The result of this partnership was a digital-engineering software tool to support the guides for machined parts. The rulesets in these software tools are derived from guides and align with KCNSC's capabilities and production experience as well as industry standards and lessons learned from previous projects and programs. This new tool will identify potential manufacturing issues earlier in the process, thereby eliminating production issues downstream and decreasing overall production time. The growing Advanced Simulation and Computing Exascale capability, combined with artificial intelligence, will accelerate this digital engineering revolution.*

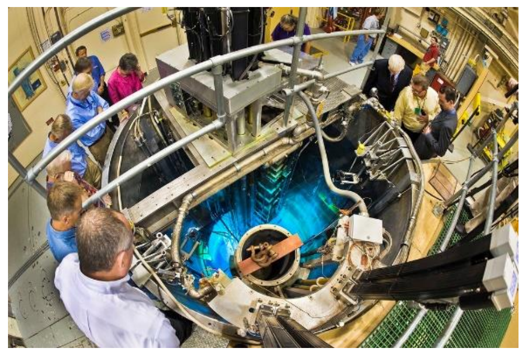
To meet challenges and needs of more rapid and increased scope of weapon design, development, and production activities, DOE/NNSA is actively implementing solutions through digital transformation with limited scale demonstrations that will be expanded across the nuclear security enterprise. This is in coordination with initiatives to define 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 deposition, and electromagnetics. This capability is integral to 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 will 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 STS environments and the effects of those 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.



Annular Core Research Reactor can expose test objects to a mixed photon and neutron

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 infrastructure supporting the environmental test and engineering sciences facilities. For example, DOE/NNSA is pursuing the Combined Radiation Environments for Survivability Testing (CREST) capability to replace the end-of-life Annular Core Research Reactor facility, with conceptual designs currently being developed. This new capability will support DOE/NNSA testing in multiple radiation environments using the same experimental platform.

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 manufacturing 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. DOE/NNSA has made great strides in accomplishing Presidential-level directives related to surety. The optical initiation project is a surety technology that potentially has simultaneous safety and use control benefit, thus efficiently contributing to meet multiple high-level requirements with one technology.

DOE/NNSA performs assessments that integrate weapon and venue security and control capabilities to understand how to best allocate resources to meet evolving security 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.

3.3.4.1 Status

A variety of surety technologies and approaches have been, or are, currently under development to improve the safety, security, and use control of nuclear weapons. The program focuses on cost reduction of components and tailoring the technology options to expectations for future systems. Several core technologies have been identified for cost reduction efforts, and experiments have proven the viability of 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. 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. DOE/NNSA must also keep pace with evolving trends in microelectronics production to maintain a trusted supply of hardened microelectronics for nuclear weapon applications. To address these requirements, 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, Science and Applications (MESA) complex at SNL currently provides trusted, strategic radiation-hardened microelectronics for the stockpile. 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

	Strategies	
Challenges	***Current Strategies***	***Future Strategies***
Developing and exercising physics, engineering, chemistry, and materials science personnel's skills in design and hardware integration (rather than assessment).	Implement activities such as Certification Readiness Exercises, design practicums, and other integrated system design and engineering efforts.	Enhance design experience through robust advanced and exploratory demonstrators where there is a hardware realization element. Emphasize the cooperative DA/PA teams to work on design studies, SRP exercises, and inclusion of digital engineering.
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 ECSE 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, integration of simulation results, certification, design, evaluating discrepancies, detecting anomalies, document generation, and enhancing current solutions.
Maintaining a trusted supply of hardened microelectronics for nuclear weapon applications.	Execute the MESA Extended Life Program Plan, which prioritizes key tool revitalization within MESA and coordination to ensure tool or facilities replacement activities are performed to minimize impact to production deliveries. Perform active prioritization of production operations in concert with research and development activities to ensure deliveries to active weapon systems.	Leverage commercial-off-the-shelf technologies where possible in parallel to developing the next generation of strategic radiation hardened microelectronics that will enable reduced design cycles, accelerate modernization efforts, and meet production demands. Establish qualification basis, high producibility, and reliability confidence in new microelectronic capabilities in response to new needs coming from future nuclear weapon systems to minimize the barrier to qualification. Utilize and build upon SRP, exascale computing, advanced testing facilities, digital engineering, advanced concepts efforts, enclaves, etc.
Shortening weapon design cycles while the number of concurrent modernization programs increase.	Support digital transformation demonstration projects at individual sites, or site to site, driving faster, integrated and more efficient cycles of design, testing and production.	Enhance digital transformation throughout the digital communication and collaboration infrastructure across the nuclear security enterprise.
Obtaining electronic parts, raw materials, and related tools with an increasingly unreliable global supply chain.	Focus on tracking, forecasting, and resolving relevant issues in the microelectronics supply chain through the Electronic Parts Program and the Material of Concern subgroup.	Evaluate long-term solutions, including external vendors, in-house capabilities, and strategic partnerships to ensure access to what is needed.

ACRR = Annular Core Research Reactor
DA/PA = design-agency/production-agency
ECSE = Enhanced Capabilities for Subcritical Experiment
HED = high energy density
MESA = Microsystems Engineering, Science and Applications
SRP = Stockpile Responsiveness Program

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, HE, energetics, hazardous materials, lithium, and other metal and organic materials needed for nuclear weapons. The current stockpile maintenance and modernization programs will continue to require special nuclear material (SNM), HE, and other energetic components and materials into the distant future. The nuclear security enterprise must maintain reliable production, science, technology, and engineering capabilities, integrated infrastructure, and logistics (i.e., handling, storage, delivery, and supply chain management) for raw materials and War Reserve (WR) products. Additionally, both focused and integral weapon science experiments increasingly require the ability to acquire, process, and transport materials in an efficient manner that enables key data collection activities.

SNM-based and high explosive products must be handled, packaged, processed, manufactured, and inspected, and these capabilities require many specialized facilities and program support throughout the nuclear security enterprise. The obsolescence, age, or severely degraded nature of many of the facilities required to produce and process SNM and HE 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.

Concurrent with the development of 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 in cooperation with the Kansas City National Security Campus (KCNSC), the advanced manufacturing facility at SNL for non-nuclear components, and the energetics enclave expansion at LLNL in collaboration with Pantex Plant (Pantex).

3.4.1 Plutonium Management

Maintaining confidence in the nuclear warheads that comprise 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.

Per 50 U.S. Code § 2538a, DOE/NNSA is mandated to manufacture no fewer than 80 WR pits per year (ppy) by 2030. 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 will meet this required manufacturing capacity by producing 30 WR ppy at LANL using the existing Plutonium Facility (PF-4) and 50 WR ppy at the Savannah River Site (SRS) using the repurposed Mixed Oxide Fuel Fabrication Facility (MFFF), now called the Savannah River Plutonium Processing Facility (SRPPF). Both facilities meet the stringent building design standards necessary to support pit manufacturing.

Pit Production Modernization Accomplishments

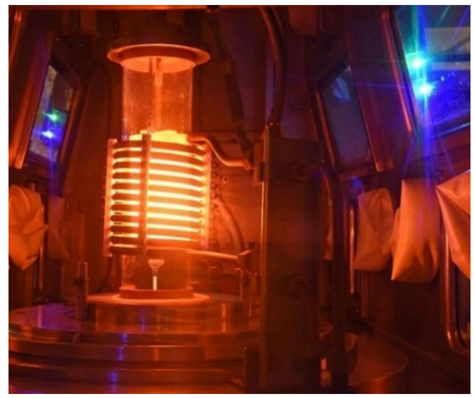
- *LANL: Completed nine developmental pit builds and started an additional six builds in FY 2023*
- *SRS: Implemented the SRPPF Critical Decision (CD)-3X strategy to ramp up site preparation and long-lead procurement scope; improved the overall project schedule and continued to mature the SRPPF design*
- *LLNL: Certified the design and issued top level Quality Engineering Releases to support the first production unit*
- *KCNSC: Completed the non-nuclear components and began WR manufacturing in support of the first production unit*

This two-site approach 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 this two-pronged approach for pit production, DOE/NNSA is on a path to produce a minimum of 30 ppy at LANL and a minimum of 50 ppy at 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.



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

There are three key requirements LANL and SRPPF must achieve to establish the WR pit production capability: completion of infrastructure and equipment investment projects, demonstration of WR-quality pit manufacturing capability, and demonstration of the ability to manufacture at full-rate capacity while maintaining WR quality control.

Because LANL is already conducting plutonium operations at PF-4, its work to meet the three key requirements largely overlaps. However, since SRPPF must undergo commissioning to start plutonium operations, it will meet the three key pit production requirements sequentially. LANL and SRPPF are partnering to share manufacturing capability development knowledge to reduce the time required for SRPPF to establish a rate production capability once infrastructure investments are completed.

In addition to the Los Alamos Plutonium Pit Production Project (LAP4) line-item project at LANL and the SRPPF line-item project at SRS, DOE/NNSA is recapitalizing other existing facilities through a series of reinvestment projects at both sites. These investments include line-item projects to replace aging infrastructure for pit production and operations support, waste processing, and qualification processes. For example, the Transuranic Liquid Waste project is replacing the aging liquid waste processing facility at LANL. Additionally, the Chemistry and Metallurgy Research Replacement project is maintaining continuity in analytical chemistry and material characterization capabilities by transitioning these activities from the nearly 70-year-old Chemistry and Metallurgy Research Facility to PF-400, known as the Radiological Laboratory/Utility/Office Building and PF-4. In conjunction, LANL is reducing risk in chemistry and metallurgy research by removing the nuclear material inventory and preparing the facility for cold standby operations. LLNL's Plutonium Facility (Superblock) and NNSS's Device Assembly Facility are supporting first production unit and rate production by performing pit certification activities.

[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 a minimum of 30 WR ppy. There are several key steps to delivering a rate production capability at LANL:

- Advance the science and mature the engineering to meet design agency specifications in support of delivering a WR first production unit;
- 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 minimum of 30 WR ppy production rate;
- Develop and implement an enhanced equipment maintenance and replacement program to anticipate and minimize equipment downtimes as operational utilization increases;
- Maintain and update PF-4 to ensure facility availability, reliability, and continued compliance with all relevant safety requirements. Continue to buy-down deferred facility maintenance across the plutonium support facilities and infrastructure;
- Construct additional access points for personnel and vehicles to support the increases in workforce required to execute the pit production mission;
- Hire, train, and retain the workforce required to produce pits, maintain and operate facilities, provide security for pit production activities and materials, and provide a broad range of support functions, and;
- Provide components and support for the experiments and evaluations required to certify pit design specifications.

Plutonium metal purification, casting, machining, and assembly are performed at PF-4. PF-400, formerly called the Radiological Laboratory/Utility/Office Building, was upgraded to a Hazard Category 3 facility in fiscal year (FY) 2023 to support plutonium chemistry operations for plutonium component production, surveillance, and science missions. PF-4 is available 24/7 for scheduling programmatic work, facility maintenance, equipment installation, and construction activities to accommodate increased operations. DOE/NNSA will also continue to 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 Approach at Savannah River Site to Producing 50 War Reserve Pits Per Year

DOE/NNSA will reach a minimum of 50 WR ppy production as close to 2030 as possible by repurposing the former MFFF into the planned SRPPF, which will be a safe, secure, compliant, and efficient pit production facility. The design for the SRPPF Main Process Building is expected to achieve the 60 percent design complete milestone in calendar year 2024, using knowledge gained from LANL, LLNL, and other sites. DOE/NNSA is planning to establish a cost and schedule baseline in FY 2026.

SRPPF will be a Security Category I/Hazard Category II structure that provides an opportunity to achieve pit production in a facility designed to meet stringent security and safety requirements for plutonium operations. There are several key steps to completing the SRPPF project, revitalizing supporting SRS infrastructure, and establishing an enduring production mission:

- Complete six interrelated construction subprojects;
- Implement a revised tailoring strategy, executing the six subprojects through a Critical Decision (CD) phasing strategy (CD-3X). By using a phased approach, site preparation and other routine work and lower risk activities can begin early to prepare for later construction activities and keep the project on schedule;

- Hire and train the workforce necessary to establish and sustain the SRS pit production mission;
- Begin production operations upon CD-4, *Approve Start of Operations or Project Completion*, to enable delivery of a first production unit pit;
- Recapitalize supporting infrastructure across SRS;
- Establish the institutional systems at SRS necessary to build WR pits;
- Establish and manage SRS pit production interfaces across the nuclear security enterprise, and;
- 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 development and construction of a High-Fidelity Training and Operations Center (HFTOC). The HFTOC will reduce the time required from CD-4 to delivery of the first production unit pit by facilitating operator training and qualification as well as supporting certification activities in non-nuclear 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 at SRS will require a skilled workforce. Estimates indicate design and construction activities will require approximately 5,000 staff. Sustained production of a minimum 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.

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 of 50 ppy requirement at SRS. Essential to this process will be transitioning an existing facility into the SRS HFTOC, which is expected to be completed prior to completion of the SRPPF Main Process Building. The HFTOC will enable unclassified and classified training in a non-nuclear environment, allowing qualification of the personnel on the procedures ultimately used to build and handle pits in the SRPPF Main Process Building. LANL is supporting the training rotation pipeline for the SRS pit production mission through a knowledge transfer program initiated in FY 2020. This knowledge transfer program will form the foundation of the HFTOC 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 staging and storage facilities, efficient transport processes, safe and secure disposal pathways, and unique equipment and facilities for R&D activities. Overall support of mission needs is achieved through coordination with other capability areas, including Weapon Science and Engineering. The existing aging storage facilities are approaching the end of their useful life and storage capacity, and supporting infrastructure has exceeded its life expectancy. DOE/NNSA has identified required actions and investments to extend the existing infrastructure's use while analyzing longer-term solutions.

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 Strategies	***Future Strategies***
Reestablishing pit production capacity in time to meet W87-1 schedule.	Continue to invest in LANL plutonium facilities and workforce needs to meet pit production milestones.	Drive continued improvement in executing equipment installation projects and workforce investments to support future pit production needs.
Reconfiguring PF-4 for pit production capacity requirements to upgrade aging equipment and infrastructure while maintaining facility operations and sharing limited resources. Repurposing the former MFFF at SRS into a plutonium pit production facility that will achieve a minimum production rate of 50 WR ppy.	Implement a tailored approach for the LAP4 projects and SRPPF project to achieve CD-4, and execute engineering, procurement, and construction activities through multiple subprojects. 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.
Upgrading infrastructure within SRS' F-Area to sustain and support capabilities required by the plutonium pit production facility.	Pursue investment in F-Area utilities: • Service Water System (resize and restore) • Domestic Water (resize) • 13.8 kV Distribution (reconfigure) • Sanitary Wastewater System (upgrade/upsize)	Ongoing assessments by the SRPPF Project continue to refine the specific demands on these systems. Funding was obtained in FY 2024 to begin the design and planning work to make these infrastructure projects executable in FY 2025–2026 timeframe. Additionally, long-term assessments of the overall health of the systems feeding F-Area are in progress. Integrate these systems/utilities into the sitewide campus master plan being developed as SRS transitions from Environmental Management to NNSA.
Missing schedule requirements for rate production due to delays in the LANL and SRPPF projects and the Plutonium Modernization Programs.	Transition all engineering, procurement, and construction to a new Construction Management contractor at SRPPF. A Construction Management subcontract was awarded in September 2023. Implement an integrated master schedule for equipment and facility investments at LANL and SRPPF to sustain schedule and task alignment between project and program. Accelerate training facilities for operations and maintenance staffing.	The Machine Training Center at SRS has begun core competency development activities with high-precision machines. Additional equipment will be brought online in FY 2024. Development of a schedule from the present through rate production is occurring in FY 2024. Acceleration opportunities in Feed Stock selection have been identified and are being analyzed for cost benefit analysis.

Challenges	Strategies	
	Current Strategies	***Future Strategies***
Scheduling impacts due to limited supply chain for gloveboxes, and limited availability for vendors to accommodate LANL and SRPPF construction.	NNSA established the glovebox working group to work with M&Os and fabricators to streamline processes and increase capacity. Early interface with vendors to supply design and fabrication support. Utilize existing warehouse space at LANL to assemble gloveboxes, and utility and equipment components prior to installation in PF-4.	Per Uranium Processing Facility lessons learned, LANL and Savannah River Nuclear Solutions are imbedding supply chain, quality, and engineering personnel into the vendor shops and project planning functions to facilitate resolution of schedule, quality, and technical issues. Construct and utilize additional required functional warehouse and storage facilities to support equipment installation acceleration.
Executing environmental testing/surety/qualification of plutonium pits without underground nuclear explosive testing.	Establish equipment, experimental platforms, and systems to evaluate additional normal and abnormal environments that pits could experience.	Use and expand thermal and mechanical testing capabilities to evaluate newly manufactured and legacy pits in the STS of environments. Leverage the ongoing investment in the ECSE Program to demonstrate the certification uncertainty achieved with one-point and multi-point safety.
Aging plutonium support facilities at Pantex could impact assembly throughput due to equipment obsolescence and limited handling and staging capacity.	Recapitalize the existing Pantex storage facilities and infrastructure at SRS and LANL. Implement an enhanced maintenance program for production equipment while continuing to execute equipment reconfiguration projects at LANL. Establish a robust and dedicated program for assessing, planning, and funding programmatic equipment as production utilization increases.	Construct long-term material staging solutions at Pantex. Construct the planned infrastructure investments for plutonium support infrastructure at LANL and SRS.

CD = Critical Decision
ECSE = Enhanced Capabilities for Subcritical Experiments
kV = kilovolt
LAP4 = Los Alamos Plutonium Pit Production Project
MFFF = Mixed Oxide Fuel Fabrication Facility
M&O = management and operating
PF-4 = Plutonium Facility
ppy = pits per year
SME = subject matter expert
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 science research, weapon components and fuel for naval reactors, commercial power reactors (for tritium production), and commercial and research reactors (for medical isotope production).

An HEU metal button

3.4.2.1 Uranium Modernization

HEU is needed to support stockpile programs, naval reactors, nonproliferation programs, and Mutual Defense Agreement obligations. The Uranium Modernization Program 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)—an aging facility that does not meet modern nuclear safety and security standards. 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; and
- Investing in key systems such as casting, machining, metal recovery and purification systems, and storage capabilities to ensure long-term reliability.

> ***Uranium Modernization Accomplishments***
>
> - *Nuclear Fuel Services contract—The Nuclear Regulatory Commission approved Nuclear Fuel Services' License Amendment Request to establish an enriched uranium oxide-to-metal purification and conversion capability in FY 2026. This supplemental capacity will significantly mitigate program risks.*
> - *Building 9212 Transition—Placed the Oxide Conversion Facility into cold standby and removed the hydrogen fluoride cylinder from the facility, significantly reducing safety risk associated with Building 9212.*
> - *Enriched Uranium Allocation Working Group—Lead and hosted the first annual group to adjudicate and achieve concurrence on excess material allocations across the nuclear security enterprise.*

3.4.2.1.1 Status

DOE/NNSA manages and operates the Nation's primary uranium processing and storage capabilities, as well as 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. At 80 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 recovery and purification 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 these processes to increase safety and efficiency, ensuring future material needs can be met. The planned modernized HEU material flow is shown in **Figure 3–4**.

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. The Uranium Processing Facility's Mechanical/Electrical Equipment Building and Process Support Facility will provide utilities and other support systems.

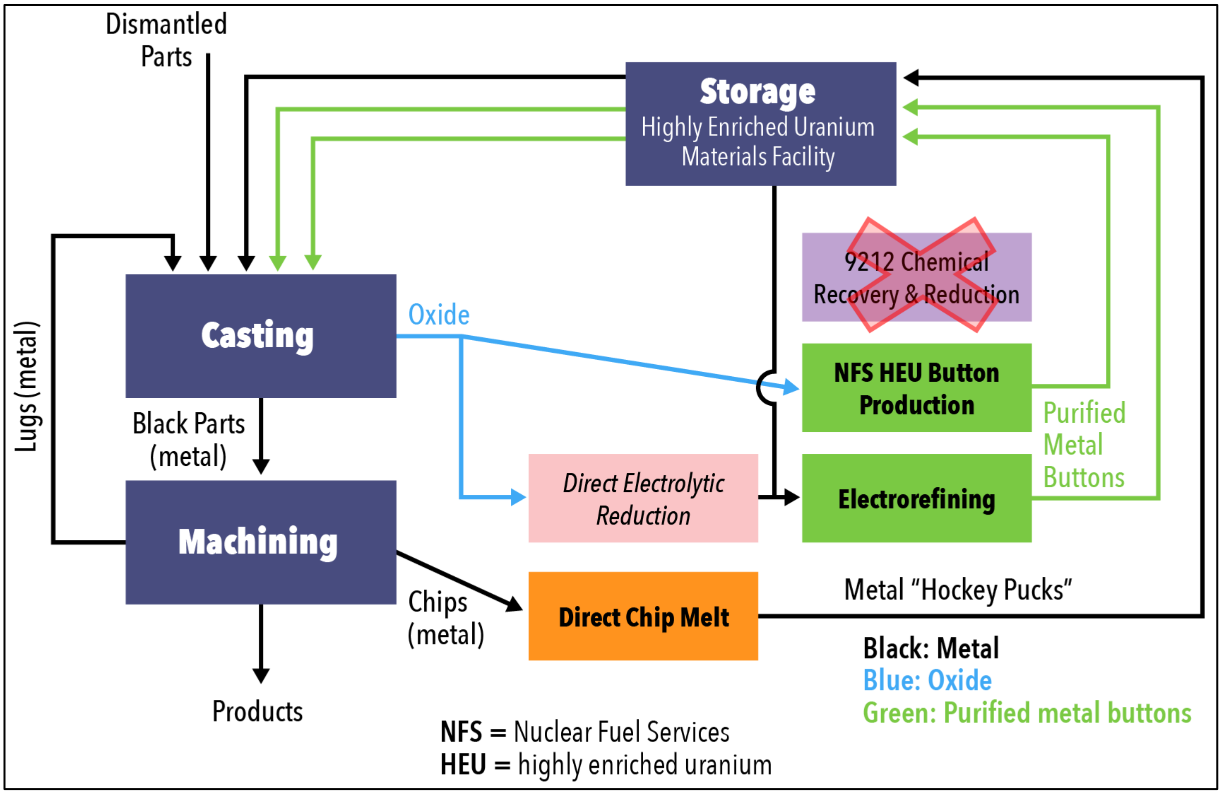


Figure 3–4. Planned highly enriched uranium material flow

While the Uranium Processing Facility is constructed and undergoes startup activities, DOE/NNSA will both relocate capabilities for HEU recovery and purification processing and deploy new technologies that will phase out mission dependency on Building 9212 to meet future mission needs. Ongoing projects include Electrorefining, Calciner, and Direct Chip Melt, which will reduce cost and improve manufacturing processes for nuclear weapon materials. Future projects include Direct Electrolytic Reduction. These capabilities will replace the hazardous HEU processing capabilities, improve safety, and reduce risk. Technology maturation, such as electrorefining and direct electrolytic reduction, is funded and monitored by the Uranium Modernization Program. When new technology is sufficiently mature, the equipment development and deployment is pursued through capital line-item acquisition and major item of equipment processes. This process has generated three major items of equipment acquisitions to enable:

- Electrorefining, which is the electrochemical purification process for HEU metal. This capability, along with the calciner process in Building 9212, will replace the wet chemistry process located in Building 9212.
- The calciner process, which 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 to ensure all material is recovered and facilitate shutdown activities. This process, along with the electrorefining capability, allows for the shutdown of the wet chemistry process in Building 9212.
- Direct chip melt, which is the process by which HEU turnings from machining operations (i.e., chips) are recovered, cleaned, and consolidated in furnaces. This capability will replace the current recovery process where chips are transferred to Building 9212, then cleaned, briquetted, and stored until melted in Building 9212 furnaces.

DOE/NNSA will perform its HEU metal purification using the electrorefining process, expected to achieve CD-4 in 2024. The Uranium Modernization Program is in the process of shutting down the wet chemistry metal purification processes in advance of a fully operational electrorefining capability. Besides high-capacity evaporators, all other wet chemistry processes will shut down once the calciner is operational. The calciner will aid in the cleanout effort of the facility in preparation for eventual shut down and turnover to the DOE Office of Environmental Management for deactivation and decommissioning.

The Y-12 complex will not have an oxide-to-metal conversion capability until the direct electrolytic reduction technology has matured, which is forecasted for the 2030s. A contract is in place to bridge the oxide-conversion capability gap between 2026 and the 2030s. This effort will ensure the ability to meet DoD stockpile requirements during a technology transition.

The Uranium Modernization Program 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. Since an initial extended life investment that concluded in 2015, various investments have been made, or are planned, to improve fire safety, utilities, and ventilation systems in Building 9212. These efforts allow safe and secure operations to continue, including those relocated from Building 9212, in existing facilities through 2040 and beyond.

The Uranium Modernization Program 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.

3.4.2.1.2 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 Strategies	*Future Strategies*
Bringing new processes online and shutting down hazardous processes could interrupt operations.	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 and avoid HEU processing shortfalls.	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 in the shortest possible timeframe to reduce operational risks.	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.

Challenges	Strategies	
	Current Strategies	**Future Strategies**
Growing and retaining SMEs across the nuclear enterprise during key process relocations over an extended period.	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.

HEU = highly enriched uranium
SME = subject matter expert

3.4.2.2 Depleted Uranium Modernization

DU is a byproduct of the HEU enrichment process and has a lower concentration of the fissile isotope uranium-235 and a higher concentration of the fissionable isotope uranium-238 than natural uranium.

Depleted Uranium Accomplishments

- *Y-12 restarted binary alloying production utilizing the onsite Vacuum Induction (VIM) Vacuum Arc Remelt (VAR).*
- *DU Modernization Program began executing the reestablishment of a HPDU conversion capability.*
- *Direct Cast VIM Furnaces brought online to meet W87-1 needs.*

High Purity DU (HPDU) and DU niobium alloy (binary) are required for nuclear component production to maintain and modernize the stockpile through life extension, modification, limited life component (LLC) exchange programs, and future nuclear weapons. HPDU and binary are made into precision components through complex processes that must meet stringent requirements. The DU Modernization Program is responsible for restarting and maintaining lapsed processes to meet imminent weapons delivery mission requirements. These capabilities were suspended in the early 2000s due to the reuse of materials, low demand, and prioritization of other activities. To resume full-rate production, the DU Modernization Program needs to execute HPDU and niobium feedstock procurements before current inventory is exhausted in 2030, restart and maintain alloying and manufacturing capabilities, invest in key new technologies, and execute its bridging strategy to meet enterprise demand.

The Development Vacuum Arc Remelt Furnace at the Testing and Development Facility

The DU Modernization Program is addressing these needs by establishing the capacity to convert depleted uranium hexafluoride (DUF_6) into HPDU, restoring the vacuum arc remelt (VAR) at Y-12 to restart the production of binary alloy ingots, and supporting new manufacturing technologies, such as direct casting and electron beam cold hearth melting. As shown in **Figure 3–5**, direct casting would provide an alternative to the wrought manufacturing process to produce components, which would significantly reduce the risks of current equipment failure, decrease material waste, and improve process efficiency. Furthermore, electron beam cold hearth melting provides three key opportunities in the process of producing a binary ingot: alloying, recycling, and material refinement capabilities.

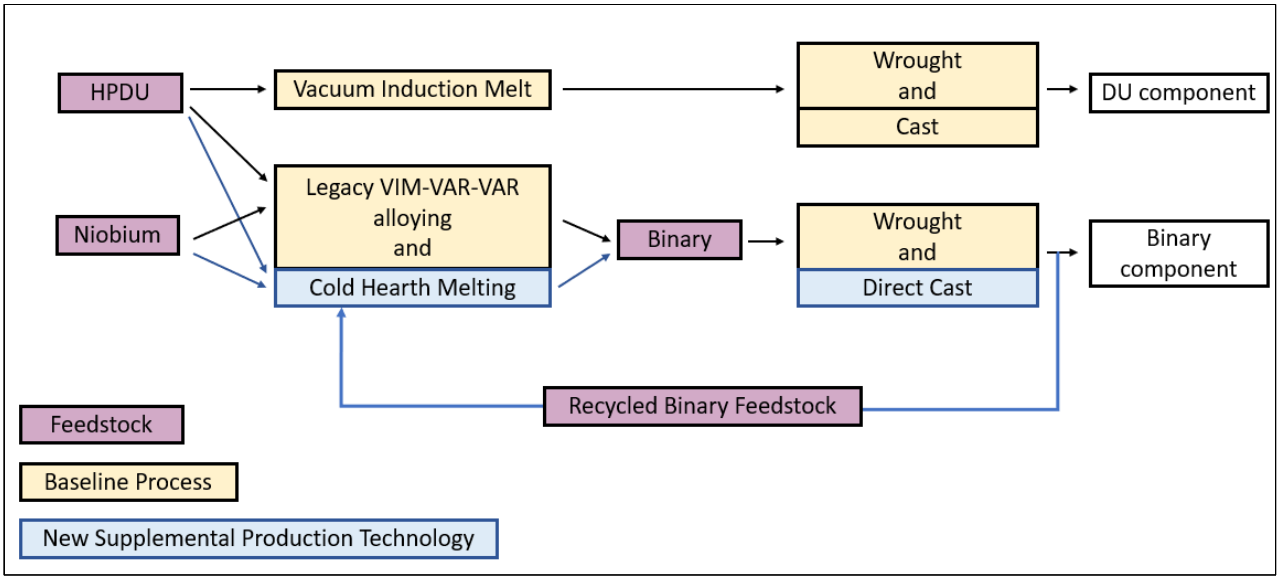


Figure 3–5. Potential production process with new technology insertion

DU Modernization activities include:

- Supplying new HPDU metal feedstock by establishing a DUF_6 to HPDU conversion capability;
- Restarting and maintaining the vacuum induction melt (VIM)-VAR-VAR and component manufacturing processes at Y-12;
- Developing, maturing, and deploying key new technologies for insertion into production to augment existing processes, improve material use efficiency, and reduce reliance on the existing and aging processes;
- Modernizing existing component manufacturing processes to improve reliability, meet capacity and throughput demands, and reduce risk to future LEPs; and
- Executing a bridging strategy to meet weapons deliverables through the Production and Planning Directive and increase component capacity with a mixture of modernized existing capabilities and new technologies.

Electron Beam Cold Hearth Melt

The Multi-Zone Direct Cast Vacuum Induction Melt Furnace

3.4.2.2.1 Status

The DU Modernization Program is currently engaged in many activities to ensure that DOE/NNSA can meet near-term weapons delivery mission requirements. These activities include establishing a reliable supply of HPDU by 2030, executing a bridging strategy, and restarting and modernizing DU alloying and manufacturing capabilities.

The DU Modernization Program's goal is to reestablish a reliable supply of HPDU before the current inventory is exhausted in approximately 2030. To obtain the large quantities required, DOE/NNSA will need to establish a supply chain to convert DUF_6 to HPDU. The program completed an Analysis of Alternatives (AoA) to identify a solution that addresses the long-term need for HPDU by leveraging existing and potential capabilities within the nuclear security enterprise and through qualified vendors. To augment DOE/NNSA's HPDU supply until a long-term capability is established, Y-12 has engaged with a vendor to establish a process to convert recycled DU oxide from Y-12 and Portsmouth, as well as decommissioned DU projectiles from DoD into HPDU.

The DU Modernization Program is also restarting DU alloying capabilities and maintaining existing manufacturing processes. This includes restarting alloying production equipment at Y-12, modernizing component and machining capabilities, training operators, developing procedures, and supporting LANL and LLNL with process qualification activities. The program has also established vendor contracts that provide supplemental production that will allow our production to be flexible and scalable in the future. Collectively, these activities allow for successful manufacturing of binary components. Additionally, the program has developed modernization plans for the facilities that increase their reliability and capacity by determining which equipment to replace and/or update and how to use the available space more efficiently. These plans include schedules for equipment removal and installation, floor plans that demonstrate the optimized machine layout for each building, and waste management plans for the removal of large equipment.

Y-12's current alloying and component manufacturing processes have proven reliable but inefficient in their use of material, leading to unnecessary waste and higher costs. DOE/NNSA is developing new technologies to replace these aging capabilities, which will provide a more efficient and cost-effective means of producing binary components and will allow DOE/NNSA to meet future production demands. The DU Modernization program is accelerating technologies, including direct cast and electron beam cold hearth melting, through technology readiness teams with stakeholders from production, development, design agencies, and technical subject matter experts (SMEs).

Many of DOE/NNSA's Y-12 Manhattan Project-era facilities will be over 80 years old by the mid-2030s and continue to experience age-related failures that present significant risk to mission delivery and personnel safety. Restarting and sustaining DU processing capabilities requires targeted resources to address the risk associated with aging equipment.

3.4.2.2.2 Challenges and Strategies

Table 3–6 provides a high-level summary of DU Modernization challenges and the strategies to address them.

Table 3–6. Summary of Depleted Uranium Modernization challenges and strategies

	Strategies	
Challenges	***Current Strategies***	***Future Strategies***
HPDU metal inventory is insufficient to meet long-term demands.	Procure HPDU from limited commercial entities, recycle DU oxide from Y-12 and Portsmouth, and convert DU projectiles into HPDU. Invest in electron beam cold hearth melting and direct casting to increase material use efficiency and reduce overall HPDU demand. Establish vendor partnerships to supplement production	Stand up a long-term HPDU conversion capability by identifying a solution with the AoA for the DUF_6 to HPDU Project. Bolster the supply chain for HPDU and other uranium fuel cycle products by seeking additional vendor solutions for conversion processes from DUF_6 to HPDU
DOE/NNSA needs to restart, modernize, and maintain lapsed DU alloying capabilities to support future stockpile needs.	Invest in the restart and maintenance of the legacy VIM-VAR-VAR alloying processes. Purchase additional equipment to increase the capacity and improve the reliability of the legacy equipment. Coordinate across production and design agencies to expedite qualification of binary with joint qualification plans.	Deploy electron beam cold hearth melting alloying production technologies to improve efficiency and allow for recycling capabilities. Integrate direct cast technology into production to reduce component blank schedule time, reduce binary material demands and waste due to increased efficiencies and decrease process risk.
Reliance on aging equipment for component manufacturing will limit the ability to meet future stockpile needs.	Execute the DU bridging strategy to reduce bottlenecks, improve space utilization of existing facilities, and increase capacity and reliability of existing processes to fulfill near-term mission requirements. Purchase wrought critical spare parts to sustain the process. Invest in direct casting technology to produce components more efficiently and reliably.	Mature new technologies to improve schedule duration, to improve material efficiencies, and to reduce reliance on aging equipment.
Current DU facilities are experiencing age-related failures and have insufficient floor space to support future stockpile demand.	Identify opportunities to meet capacity within existing space by co-locating key pieces of equipment, improving existing processes, upgrading equipment with modern controllers, and continuously improving upon strategic material models. Recapitalize the aging physical infrastructure, thus reducing risk to produce strategic materials and components. Establish a combination of on- and off-site storage capabilities to store required quantities of HPDU feedstock to meet future mission demand.	Evaluate long-term DU facility options to meet future stockpile demands.
Maintain a trained and qualified workforce to execute the upcoming DU operations.	Develop staffing plan for multi-year training. Transfer knowledge from SMEs near retirement age to new SMEs.	Implement additional strategies to maximize knowledge retention and minimize workforce turnover.

AoA = Analysis of Alternatives
DU = depleted uranium
DUF_6 = depleted uranium hexafluoride
HPDU = high purity depleted uranium
SMEs = subject matter experts
VIM = vacuum induction melt
VAR = vacuum arc remelt

3.4.2.3 Domestic Uranium Enrichment

> ***Domestic Uranium Enrichment Accomplishments***
>
> - *The Demonstration Cascade 2 minor construction project to house the engineering-scale centrifuge cascade testbed at Oak Ridge National Laboratory was completed on schedule and under budget.*
> - *The Domestic Uranium Enrichment program released a request for information for a centrifuge pilot plant deployment study in 2023. Request for Information responses indicated significant industry interest and informed the development of a subsequent request for proposal, on track to be released in 2024.*

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 "less attractive" HEU to produce LEU where needed), which is a finite and currently irreplaceable source.

3.4.2.3.1 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 enriched uranium inventory is finite, the United States will eventually need a new uranium enrichment capability to meet defense requirements specifically for tritium production and naval nuclear propulsion. The Domestic Uranium Enrichment Program is planning to meet these requirements using one or more centrifuge technologies, but first needs to develop and demonstrate candidate centrifuge technologies to better characterize performance, reliability, and lifecycle costs prior to selecting a path forward for a production-scale capability.

3.4.2.3.2 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 Strategies	*Future Strategies*
Enrichment technologies are complex and difficult to develop and deploy. Reestablishment of a domestic enrichment capability requires execution on a tight timeline with little schedule margin for deployment of LEU production to meet tritium need dates in the early 2040s.	DOE/NNSA continuously assesses its inventory to identify unobligated enriched uranium that may provide additional development time or margin to the tritium need date. DOE/NNSA is establishing an acquisition process that supports initiation of facility design and licensing activities for a facility that will support centrifuge production-scale reliability testing in parallel with DUECE technology development to maintain the DUE program's schedule.	Continue developing centrifuge technologies to reduce long-term deployment risks. Execute acquisition strategy to support on time deployment of centrifuge technology.
Establishment of a supply chain for unobligated materials and specialized components required for a domestic uranium enrichment capability. Lack of domestic demand for these components has led to a supply chain void that must be filled.	Evaluate the current state of necessary supply chains for an unobligated domestic uranium enrichment capability, address gaps and engage potential vendors early for high-priority components.	Fund the establishment of a long-term supply chain for unobligated material and components required for a domestic uranium enrichment capability.
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.

DUE = domestic uranium enrichment
LEU = low-enriched uranium

3.4.3 Lithium Management

3.4.3.1 Lithium

Lithium handling, packaging, and processing is a key capability in the nuclear weapon production mission. DOE/NNSA requires specialized, weapon-specific forms of lithium for stockpile sustainment and is the sole source provider for these materials. Y-12 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 Accomplishments

- *The Lithium Homogenization technology, which results in an improved product and enables future material efficiency possibilities, achieved technology readiness level (TRL) 7.*
- *The Lithium Processing Facility reached 100 percent design completion.*
- *Continued years-long work to reduce risk in Beta-2 by installing equipment to eliminate the crystallizer single point of failure and beginning project to reduce building load.*

3.4.3.2 Status

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

DOE/NNSA is actively pursuing alternate, advanced lithium processing technologies and techniques, such as a modernized electrolytic cell, material homogenization techniques, and near net shape pressing

Restored electrolytic cell at Y-12

capability. Technology Readiness Assessments are conducted as needed to assess the strengths and weaknesses of identified technologies.

Aging infrastructure and antiquated equipment present risks to mission delivery that, if realized, will affect the ability to meet stockpile requirements. The 82-year-old facility where lithium is processed, Building 9204-2 (or Beta-2), has severe structural issues due to chemical degradation. The building poses a catastrophic failure risk, as well as safety and environmental concerns. It will be replaced by a future Lithium Processing Facility, which will house modernized lithium processing capabilities. The Lithium Processing Facility previously achieved CD-1, Approve Alternative Selection and Cost Range, and is on track for CD-2/3 approval first quarter of FY 2026. The project is working toward CD-4 in 2033. In the interim, 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- and long-term requirements.

DOE/NNSA will continue to work with stakeholders to develop tailored, long-term staffing plans that anticipate critical skills shortfalls and properly forecast staffing levels based on production requirements. SME growth and sustainment will require SMEs to undergo continued training and development to produce lithium components and resolve technical issues associated with these complex and hazardous 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 Strategies***	***Future Strategies***
Meeting manufacturing deliverables using existing aging and degraded facilities.	Sustain current operations in the legacy lithium facility to meet near-term stockpile needs until a new Lithium Processing Facility is in place. Plan and prioritize recapitalization projects and risk reduction activities to keep facilities and process equipment functional until the Lithium Processing Facility is qualified. Deploy/recapitalize new equipment (production cleaning station glovebox, second wet chemistry line) to increase capacity and reduce single-point failures.	Construct the Lithium Processing Facility. Develop transition plans for relocating people, processes, and tools to the Lithium Processing Facility.
Sustaining the supply of recycled lithium during potential shortages due to disassembly/dismantlement delays	Restart a small-scale purification capability and legacy processing capabilities in the legacy lithium facility to provide additional feedstock material. Monitor and optimize weapons dismantlement schedule to align feedstock with production requirements. Collaborate with DOE/NNSA, DA/PAs to stand up a deuterium gas production method and supply approach.	Develop and prioritize new process technologies and equipment to maximize efficiency and reliability in meeting stockpile needs. Identify, plan, and schedule future weapon system qualifications for direct material manufacturing feed material. Develop, update, and sustain program management tools to optimize the feedstock production schedule.

Challenges	*Strategies*	
	Current Strategies	***Future Strategies***
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.	Mature process improvements (e.g., next-generation electrolytic cell and improved processing methods).
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 to reduce risk. Find adaptive solutions to maintain facilities past their useful lives. Relocate all or part of legacy processing capabilities to structurally sound areas when possible.	Execute future projects including electrical, utility upgrades, and other identified structural life-extending efforts, as identified in the lithium strategy implementation plan. Optimize the purification processes design for the Lithium Processing Facility.
Training and qualifying a sufficiently sized workforce that can support lithium production.	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 in technology summits to develop next generation of SMEs.	Gather and collate knowledge from SMEs through documentation programs targeting critical knowledge areas for new SMEs.

DA/PA = Design Agency/Production Agency
SMEs = subject matter experts

3.4.4 Tritium Management

> ***Tritium Accomplishments***
>
> - *The irradiation of 1,792 TPBARs was completed in Watts Bar Unit, cycle 19 in FY 2024.*
> - *TVA completed eleven shipments of TPBARs to SRS in FY 2023.*
> - *SRS completed six tritium extractions in FY 2023.*

Tritium is a strategic material used for national security purposes. For weapons, tritium 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 its radioactive decay, tritium must be periodically replenished to maintain required inventories. For this reason, weapon components that contain tritium are considered limited life components and must also be replaced on a periodic basis. DOE/NNSA produces tritium by irradiating TPBARs in the Watts Bar Unit 1 and Watts Bar Unit 2 nuclear reactors (WBN 1 and WBN 2) operated by TVA. Reactor fuel used to produce tritium for defense purposes must be free of peaceful use obligations (i.e., unobligated and unencumbered). Thus, WBN 1 and WBN 2 use unencumbered and unobligated LEU fuel when irradiating TPBARs. Once the TPBARs are irradiated, they 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. Besides meeting tritium inventories and sustaining a reliable supply chain, the tritium capability includes R&D for tritium gas processing and production, in addition to science and technology development efforts to improve TPBAR performance, GTS life storage, helium-3 recovery, stockpile surveillance, and other related tritium mission needs. See the Classified Annex for additional information on tritium management.

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. Extraction of tritium from irradiated TPBARs at SRS is ongoing in accordance with the program's multi-year plan.

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

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

Examples of these plan's smaller projects include:

- Completing six maintenance and repair projects for isotopic (deuterium/tritium) separation equipment and supporting infrastructure in 2025;
- Replacing large, obsolete distributed control systems for the gas processing equipment;
- Replacing and refurbishing electronic mass spectrometers to analyze gas associated with processing equipment;
- Installing a protium/tritium separation capability in the Tritium Extraction Facility; and
- Addressing end of life, safety, and space requirements (this includes several minor construction projects).

Some of the scope previously described will require significant processing downtime, particularly maintenance and repair of the deuterium/tritium separation equipment. Completion of the projects in 2025 will be critical to minimize downtime and maintain tritium availability.

The Tritium Finishing Facility line-item project will replace key tritium capabilities housed at the existing 65-year-old manufacturing building that supports GTS finishing, packaging, and surveillance. The overall project is currently paused due to a higher-priority construction project at SRS, but will be completed by December 31, 2036, in accordance with language in the *National Defense Authorization Act for Fiscal Year 2024*. Limited site preparation and design work are continuing through the pause.

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 Strategies	***Future Strategies***
Performing maintenance of a sufficiently flexible tritium supply chain to meet emerging tritium inventory requirements that include the ability to load GTSs on schedule.	Assess supply chain risks and opportunities. Identify investments that provide the best value in maintaining and improving a high level of reliability, flexibility, and resiliency to the program.	Continue to monitor risks and opportunities to identify cost-effective solutions and retain high reliability.
Replacing aging infrastructure associated with current tritium production technologies.	Conduct studies that identify and monitor emerging replacement methods and technologies as risk mitigation for long-term tritium production. Invest in the current technology as long as it remains viable and cost-effective.	Monitor evolving technologies and invest in existing or new technologies as appropriate.
Continuing risk mitigation for aging infrastructure and equipment used in support of stockpile deliverables and future Alts, Mods, and LEPs.	Maintain and recapitalize key tritium capabilities housed in the current 65-year-old HAOM building, along with maintaining the infrastructure via a bridging strategy. Complete maintenance and repair of aged tritium isotopic separation equipment and support systems in HAOM in CY 2025.	Construct the modern TFF to replace HAOM infrastructure critical to stockpile deliverables at SRS. 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 lifecycle.	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 strategies to effectively use existing capabilities while planning for future radiological R&D tritium capabilities need to meet DOE/NNSA mission needs.
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.
Maintaining tritium availability during maintenance and recapitalization periods.	Perform scheduled extractions and unloading to ensure tritium is available prior maintenance and repair outages (i.e., execution of the CY 2025 and CY 2027–2028 partial loading outages to maintain and repair aged isotopic separation equipment).	Perform scheduled extractions and unloading to ensure tritium is available prior to the execution of all future outages.

Alt = alteration
CY = calendar year
GTS = gas transfer system
HAOM = H-Area Old Manufacturing Facility
LEP = life extension program
Mod = modification
TFF = Tritium Finishing Facility
TPBAR = tritium-producing burnable absorber rod

3.4.5 High Explosives and Energetics Management

High Explosives and Energetics (HE&E) development and production, including the associated manufacturing processes and infrastructure, are required to meet the needs of the current and future stockpile. Energetic materials provide instantaneous energy through an exothermic chemical reaction and include specific end products, such as conventional high explosives (CHE), insensitive high explosives (IHE), low explosives (e.g., pyrotechnics and propellants), their respective base explosive ingredients, and various other ingredients required for manufacturing (e.g., precursor materials, polymers, reactants, catalysts, plasticizers, oxidizers, fuels, ballistic modifiers, stabilizers, surfactants, and bonding agents). Energetic materials are integrated into the assemblies or subassemblies into energetic components such as main charges, boosters, actuators, igniters, rocket motors, timers, and detonators. DOE/NNSA uses one of two types of HE produced for the main charge in each nuclear weapon: IHE, 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 CHE, which provides enhanced performance for a lower volume and weight. The type of HE used differs depending on the weapon type and purpose.

> ***High Explosives and Energetics Accomplishments***
>
> - *Executing the Other Transaction Agreement through the Naval Surface Warfare Center, Indian Head Division to construct a TATB (triaminotrinitrobenzene) production facility to manufacture insensitive HE.*
> - *Completed the Enterprise Capabilities Report to provide a comprehensive and independent assessment document capturing the nuclear security enterprise's capabilities for the HE&E mission.*
> - *Completed a joint material and testing framework with LANL and LLNL, and support from Pantex, as part of the Alternate Vendor Strategy for IHE binder material and started towards an alternate vendor qualification.*
> - *Completed facility upgrades at Holston to improve recordings for process parameters, enhanced process controls, increase mechanical operational reliability, and effectively remove environmental constraints for TATB production.*

Across the nuclear security enterprise, DOE/NNSA laboratories and production sites handle energetic material and energetic components as part of the nuclear weapon sustainment and warhead modernization missions.

HE&E development and production depends on the ability to perform HE&E scientific and engineering activities, along with the ability to handle, package, and process SNM (plutonium and uranium) (see Sections 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 energetic materials, energetic components, and WR products. Most of the current facilities were built over 70 years ago, lack the critical infrastructure to meet mission requirements, and have safety and security limitations because infrastructure is failing. New facility construction and existing facility recapitalization across the nuclear security enterprise are needed to improve the capabilities and capacities required for HE&E modernization efforts, mitigate challenges associated with a limited vendor base, and make advancements in energetic manufacturing.

Energetic material processing, production, and manufacturing are currently performed externally by the Holston Army Ammunition Plant (Holston) and internally at Pantex. These capabilities supply energetic material, procure HE from Holston, and process HE safely into precision parts that meet tight specifications. The current stockpile planned warhead modernization programs, LLC exchanges, and future modernization programs will continue to demand HE, energetic materials, and energetic components.

3.4.5.1 Status

The facilities and equipment that support the HE&E mission capabilities are aging and declining in operational condition. These deteriorating conditions pose mission risks and must be maintained through frequent calibrations and rigorous corrective and preventative maintenance.

Recruiting experienced and knowledgeable personnel and conducting extensive safety trainings are imperative to safely operate, care for, and handle energetic and hazardous materials. With an increased workload as well as attrition and 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&E. The High Explosives Science and Engineering (HESE) facility at Pantex will consolidate 15 aging facilities into three new and more efficient facilities to conduct science, technology, engineering, and production activities in weapons assembly/disassembly and HE. The HESE facility should achieve CD-4 in FY 2028. The High Explosives Synthesis, Formulation, and Production (HESFP) facility, also at Pantex, will address explosive and mock formulation operations to support multiple weapon programs, manufacturing technology development for future programs, and support for strategic partners. The HESFP facility should receive CD-4 approval in FY 2035. Finally, the Energetic Materials Characterization project at LANL will provide the capability to perform energetics material characterization, analysis, and testing and will replace obsolete facilities that present risks to workforce safety.

HE&E modernization includes consolidating and modernizing existing facilities critical to meeting the stockpile's energetic material production requirements in a modern environment with enhanced safety and security. DOE/NNSA continues to implement minor construction to mitigate known significant issues with the limited defense industrial base and provide on-site production capabilities for energetic components in the stockpile. DOE/NNSA continues to develop and implement strategies to mitigate supply challenges related to at-risk materials and other ingredients, such as precursor materials (e.g., per- and polyfluoroalkyl substances), which are required for energetic material production and manufacturing.

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 Strategies	***Future Strategies***
Aging facilities and equipment critical for energetic materials.	Coordinate with the Infrastructure and Operations Program and the Programmatic Recapitalization Working Group to improve energetic readiness. Identify and invest in equipment requirements through input from the sites and link them to defined risks and capability gaps. 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- to medium-term refinancing investments where reasonable.	Construct HESFP building, the HESE Facility, and the EMC facility. Develop the High Explosive Component Assembly facility at Pantex to increase the capacity throughput and reliability for all current weapons systems subassembly, weapons surveillance subassembly, and main charge dismantlement activities to meet future demand. Employ creative methods to mitigate obsolescence issues, such as using additive manufacturing to produce parts. Stand up production enclaves, through partnerships between design and production agencies to enable more efficient transfer of new technology.
Depending on a small and shrinking vendor base to supply the explosives, constituent components, other materials, and specialized equipment needed to produce its energetic end products.	When necessary, develop and employ strategies to use in-house capabilities to restore mission schedules at risk. Stabilize existing 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. Enable Naval Surface Warfare Center Indian Head Division to supply HE in the near term and operate as a second source for insensitive HE. Develop and employ an alternate vendor to produce binder pre-cursor materials, and, when possible, maximize the procurement of at-risk precursor and/or constituent components.	Sponsor capital acquisition projects and coordinate efforts among sites and headquarter elements to shepherd projects from business case to beneficial use. Construct HESFP facility at Pantex to add in-house HE manufacturing capabilities and increased capacity to supply HE for WR energetics. Develop an alternate binder option with reduced litigation concerns.

Challenges	*Strategies*	
	Current Strategies	*Future Strategies*
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.	Implement lessons learned from Defense Programs initiatives for energetic materials along lines of effort such as design for manufacturing and requirements and capacity integration. Continue to build on collaboration activities with DoD stakeholders that furthers partnerships with industry to identify and assess supply chain opportunities. Develop the High Explosive Component Assembly facility at Pantex to increase the throughput and reliability for all current weapons systems subassembly, weapons surveillance subassembly, and main charge dismantlement activities to meet future demand.
Ensuring requirements for energetic materials are adequately identified, preserved, and documented.	With the NNSA Energetics Coordinating Committee, document the detailed processes necessary for the synthesis and formulation of energetic materials, creating a repeatable material specification that yields the required engineering and performance requirements. Implement in-situ monitoring, process controls, and data capture within existing and planned manufacturing sites to improve repeatability and inform HE manufacturing modeling.	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 assess manufacturing with computational fluid dynamics, computational chemistry, machine learning, and artificial intelligence. Develop the EMC project to provide sufficient capacity to meet future demand for energetics characterization, analysis, and testing. Develop techniques to reprocess out-of-specification material to meet requirements.
Mitigating 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. Assess HE material reclamation, re-use, and recycling options.	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
EMC = energetic material characterization
LEP = life extension program
WR = War Reserve
HESFP = high explosives synthesis, formulation, and production
Holston = Holston Army Ammunition Plant

3.4.6 Additional Material Needs

Specialized components and materials that are not commercially available must be produced within the nuclear security enterprise or alternative materials must be identified, qualified, and produced. This 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 materials and component manufacturing to support non-nuclear components. See the classified annex for more information on additional material needs.

Challenges	Strategies	
	Current Strategies	***Future Strategies***
Materials are no longer commercially available because of obsolescence or lack of supplier interest	Re-engineer obsolete materials and use microreactors to produce specialty materials in the right quantities and/or identify, qualify, and produce replacement materials	Identify and leverage next generation disruptive technologies

3.5 Weapon Component Production Area

The Weapon Component Production area provides the capabilities needed to support non-nuclear components. Non-nuclear components enable weapon functions such as arming, fuzing, firing, safety, surety, and structural supports. Safety components ensure weapons do not detonate inadvertently or accidentally. Surety components prevent unauthorized use of weapons. Non-nuclear components also include components such as power supplies, neutron generators, cables, and gas transfer systems (GTSs). This area supports production of non-nuclear components and the enabling capabilities for prototyping and materials. It also includes the advanced manufacturing capabilities that use modern technologies to advance DOE/NNSA legacy and existing processes for making and producing weapons components and systems. The capability area involves internal and external manufacturing and maintaining a broad supply base for parts, which includes identifying and verifying trusted suppliers to provide materials and parts within the weapon product realization process.

3.5.1 Non-Nuclear Component Modernization

The Non-Nuclear Capabilities Modernization Program manages projects and executes strategies to modernize, monitor, and ensure DOE/NNSA's non-nuclear capabilities and capacities. The Non-Nuclear Capabilities 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 Component Modernization activities include:

- Procuring equipment to meet non-nuclear component manufacturing capacity requirements;
- Providing equipment and infrastructure for advanced manufacturing capabilities to enable new technology insertion;
- Sustaining DOE/NNSA's capability to produce trusted microelectronics;
- Recapitalizing and conducting equipment maintenance on critical environmental tests and accelerator capabilities that support lifecycle activities for weapon electrical and mechanical systems;
- Procuring equipment that supports the bridging strategy for power sources production capabilities;
- Introducing new processes and technologies that increase efficiency in component manufacturing;

- Procuring equipment for the front-end assurance system for electronic components to reduce the risk of inserting commercial-off-the-shelf parts during weapon modernization programs;
- Mitigating industrial base and supply chain risks for non-nuclear parts by providing supply chain monitoring tools, commodity analysis, and new vendor development support;
- Identifying and monitoring materials used in nuclear weapons that are at risk of obsolescence, discontinuation, scarceness, unavailability, or usability issues;
- Executing planning and Other Project Cost activities to modernize production capabilities for non-nuclear components through line items including the Power Sources Capability, Product Realization Infrastructure for Stockpile Modernization (PRISM), and Microelectronic Components Capability (MC2, formerly the Heterogenous Integration Facility) project; and
- Adding enhanced and advanced manufacturing capabilities at production agencies to manufacture future component designs that are currently outside nuclear security enterprise capabilities.

Non-Nuclear Component Modernization Accomplishments

- *Multi-site: Established the multi-site Electronic Parts Program to ensure commercial electronic parts are utilized reliably, predictably, and repeatably in nuclear deterrence systems*
- *LLNL and KCNSC: Developed and implemented Polymer Enclave fabrication of prototypes*
- *LLNL: Product Realization Infrastructure for Stockpile Modernization (PRISM)—previously known as Next Generation LEP R&D—completed the combined Mission Need Statement and Program Requirements Document*
- *SNL: Advanced Thermal Spray production capability by successfully modifying the facility, installing equipment, and spraying surrogate parts*
- *SNL: Power Source Capability achieved 30 percent design*
- *SNL: Completed four significant projects as part of MESA's Extended Life Program*
- *KCNSC: Strategic Sourcing saved $2.4 million in long-term contracting*
- *KCNSC: KC STEP CE conducted procurements totaling $25 million to support production and development*

Production sites work with the laboratories early in the design phase to provide production perspectives on designs and material selections to enhance component 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.

To deliver future weapon systems, technical advances are necessary across multiple disciplines within the Office of Defense Programs (e.g., weapon components, manufacturing processes, testing, and surveillance), and maturation of those technologies relies on an integrated effort across multiple headquarters offices, several laboratories, plants, and sites within the nuclear security enterprise, and DoD. Technology Realization Teams have been initiated to mature technologies and assess the feasibility of technology advancement. Thermal spray is one example of a technology that was matured and will continue to mature for consideration for future programs of record.

All production sites are facing capacity limitations in production and component development due to increased weapon modernization requirements and scope.

The current KCNSC non-nuclear manufacturing complex was designed based on the programmatic requirements discussed in the 2006 Stockpile Stewardship Plan, including one system in development and one system in production. The number of programs has increased significantly since the 2006 Stockpile Stewardship Plan, as policy has changed over time. This increased workload has caused the site to more than double its workforce 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 needs of the larger workforce. DOE/NNSA has purchased an additional building in February 2023, B23, that it had already partially leased. This will increase the manufacturing space from 275,000 square feet of leased space to 450,000 square feet of owned space. Manufacturing readiness will transpire in phases and will be complete in FY 2028. Additional space needed for long-term manufacturing requirements will be constructed and equipment built out as part of Kansas City Non-Nuclear Component Expansion Transformation phased expansion potentially continuing to FY 2040.

The joint LLNL and KCNSC Polymer Enclave was created to advance direct ink write technology research and production process development with the goal of more rapid product development and optimization of direct ink write manufacturing processes for various weapon programs.

Similarly, SNL is planning to create The Center for Advanced Manufacturing and Innovation. This future, longer-term facility would co-locate researchers and engineers from across the nuclear security enterprise, industry, and academia to rapidly respond to emerging defense programs and global security needs.

All modernization programs and planned nuclear weapon systems require power sources. DOE/NNSA has concluded there is an unacceptable risk to power source development and production due to failing and inadequate facilities and an unreliable supplier base. DOE/NNSA is investing in the development of new power source technologies to expand the options for safe and reliable long-term power sources that can meet evolving system architectures. DOE/NNSA is designing a replacement power sources facility with modern capabilities and sufficient capacity for current and future workloads, which are expected to increase over the next decade.

Similar issues hold true for radiation-hardened microelectronics at SNL's MESA complex. While the full suite of MESA capabilities needs sustainment attention, the most prominent issue for sustained, resilient production of custom warhead strategic radiation-hardened components has been the age and configuration of the silicon fabrication facility (SiFab). SiFab floor space is fully utilized, and there are significant facility challenges for installation of larger and heavier replacement tools. MESA has an ongoing extended life program to sustain its capabilities while plans are developed for equipment sourcing and to provide additional manufacturing space for radiation-hardened microelectronics.

Aging equipment poses reliability and obsolescence issues, resulting in greater operations continuity risks. The Non-Nuclear Capabilities Modernization Program helps mitigate these risks at KCNSC and SNL through projects which replace high risk test, measurement, and production equipment.

The concern with aging capabilities extends to the major environmental test facilities used to qualify and assess non-nuclear components with high reliabilities well beyond those required for commercial products in extreme environments. Most of these facilities, including Saturn and the Annular Core Research Reactor, are decades old and, similar to production facilities, have suffered from technology obsolescence and deferred maintenance. DOE/NNSA has completed studies to prioritize the recapitalization of environmental testing facilities across the enterprise. These facilities must remain operational to ensure that qualification of non-nuclear components does not become a schedule driver for the modernization programs.

DOE/NNSA is becoming increasingly dependent on internal production due to difficulty finding trusted sources for non-nuclear weapon components. This insourcing may require additional facilities, equipment, infrastructure, and personnel for certain product lines. In the long term, capital reinvestment will be crucial to maintaining DOE/NNSA's manufacturing and testing capabilities. 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.

DOE/NNSA is also conducting studies to better understand and anticipate supply chain risks. These studies include multi-tier supplier illumination, targeted risk triage, and actionable mitigation strategies. This includes dozens of studies across multiple commodities and individual suppliers, providing information that has led to the mitigation of supply chain risks. Investing in third party studies on DOE/NNSA's supply chain provides DOE/NNSA the ability to be proactive instead of reactive in the mitigation of risks to the industrial base.

3.5.1.2 Challenges and Strategies

Table 3–11 provides a high-level summary of Non-Nuclear Component Modernization challenges and the strategies to address them.

Table 3–11. Summary of Non-Nuclear Component Modernization challenges and strategies

	Strategies	
Challenges	***Current Strategies***	***Future Strategies***
Manufacturing space was sized for fewer, less-complex weapon systems. Workload projections to produce non-nuclear components for the program of record exceed existing equipment and infrastructure capacity and is insufficient to accommodate mission growth.	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 and KCNSC. Incrementally increase KCNSC production capacity and increasing operational efficiencies in existing production areas through KC STEP. Improve communication and issue resolution using production enclaves, which help to reduce development work and start production sooner.	Continue to sustain and modernize MESA capabilities until replacement facilities or solutions can be supported. KCNExT will add production capacity to support increasing future demand. The facilities will be acquired in a multiyear, phased, lease-purchase approach.
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.	Provide interim relief for some of the critical equipment needs related to key product lines. Investments in multiple Advanced Manufacturing technologies are being made across several DOE/NNSA sites and are currently in use. Production enclaves at design laboratories enable new manufacturing techniques to transition smoothly to production by encouraging early DA/PA interactions.	The Non-Nuclear Capabilities Modernization Program will continue to collaborate with the Research, Development, Test, and Evaluation Program Office to identify and prioritize promising technologies that could be committed to future modernization programs if sufficiently mature and fund them to obtain higher TRL and MRL.[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) and manufacturing readiness level (MRL) are measurement systems to assess maturity levels. TRL assesses the particular technology and utilizes nine levels (TRL 1 is the lowest with the associated scientific research is beginning and TRL 9 is the highest indicating a technology has been proven through successful operation.) MRL assesses the degree to which a component or subsystem is ready to be produced and has nine levels with the lowest being product development and the highest being steady-state production. MRLs represent many attributes of a manufacturing system (e.g., people, manufacturing capability, facilities, conduct of operations, and tooling).

Challenges	*Strategies*	
	Current Strategies	***Future Strategies***
Some material is limited or no longer available due to obsolescence. Quantities remaining from legacy programs are insufficient to meet the demand by weapon programs. Vendors have lost the capability, capacity, or interest to produce more of these materials and in some cases environmental constraints preclude ability to make the products.	Establish a central database for at-risk materials and providing a transparent supply chain network. Materials scientist and engineers are working with commercial suppliers to improve their capabilities, identify new suppliers, or develop internal material production capabilities to increase material availability.	Conduct supply chain analysis and studies to 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 will help 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. Identify and leverage next generation disruptive technologies to re-engineer obsolete materials.
Risks in the available supplier base and the need to produce more classified components is driving additional in-house production capability while continuing to identify and qualify additional suppliers.	Support non-nuclear component material development and identification of replacement materials. Engage in activities to modernize DOE/NNSA's industrial capacity for its implementation. Multiple M&Os have launched efforts to communicate expected intermediate and future demand and assess supplier health based on delivery performance and resiliency, as well as to leverage commercial tools to assess supply chain risks. Across the nuclear security enterprise, M&Os are also improving or developing new classified supplier certification processes.	Engage early with design requirements to research potential new qualified sources. Baseline capabilities at the design agencies to quickly fulfill unexpected needs. Evaluate increased coordination with DoD to leverage their classified supplier base and avenues to streamline reciprocity process across DoD and DOE facility and personnel clearances.

DA/PA = design agency/production agency
KCNExT = Kansas City Non-Nuclear Component Expansion Transformation
KC STEP = Kansas City Short-Term Expansion Plan
M&O = management and operating
MESA = Microsystems Engineering, Science and Applications
MRL = manufacturing readiness levels
TRL = technology readiness levels

3.5.1.3 Capability Based Investments

The Capability Based Investments (CBI) Program manages and executes projects to modernize and sustain equipment, tools, supporting facilities, and infrastructure. CBI addresses enduring, multi-program requirements through discrete, short-duration projects, usually lasting from 1 to 3 years. These capital investments sustain or replace core nuclear and non-nuclear enterprise capabilities for weapons assessment, design, production, and certification. Such projects include recapitalization of high-risk-of-failure test, measurement, and production equipment. The CBI portfolio reduces programmatic risk to missions across the nuclear security enterprise and ensures needed capabilities are available for stockpile stewardship, sustainment, and modernization.

The CBI Program funds projects for total replacement of equipment or tools, including minor building modifications required to install and operate new equipment. CBI funds activities at all eight DOE/NNSA sites and Pacific Northwest National Laboratory, and coordinates closely with production operations, science campaigns, other production modernization offices, and additional stakeholders to reduce programmatic gaps and align funding sources.

DOE/NNSA established the Programmatic Recapitalization Working Group to better understand current and future equipment recapitalization needs across the nuclear security enterprise for all aspects of the nuclear weapons mission. This working group includes a combination of participants from the Office of Defense Programs, as well as full participation from each of the DOE/NNSA sites. The Programmatic Recapitalization Working Group plays a central role in helping programs assess equipment risks across the enterprise and in deconflicting planning and programming for activities to address those risks.

Capability Based Investments Accomplishments

- *SRS: Replaced film radiography with a digital system in tritium reservoir inspection line, streamlining workflow and saving of $18.8 million over the next 8 years*
- *NNSS: Upgraded the flash X-ray power, diagnostics, and imaging for BEEF (Big Explosive Experimental Facility)*
- *LLNL: Relocated the materials test equipment supporting annual assessment and modernization activities from the beryllium-contaminated and seismically unsound building*
- *LANL: Reestablished the capability to fabricate/produce DARHT vessels which support DARHT and PULSE experiments*
- *KCNSC: Upgraded and expanded Precision Cleaning capability to support increasing Safety Mechanism production*
- *KCNSC: Expanded precision machining and GTS manufacturing with $14 million of capital equipment as part of KC STEP*
- *Y-12: Modernized the Computed Tomography capability to improve efficiency and allow for remote operations*
- *SNL: Upgraded the Primary Standard Laboratory High Vacuum Calibration System to support calibration of pressure gage tools*
- *Pantex: Replaced six Vertical Turret Lathes supporting HE mission machining deliverables*

3.5.1.3.1 Status

CBI fulfills equipment capability recapitalization needs that do not fit under any one program. The DOE/NNSA enterprise includes numerous laboratory and production capabilities whose roles are critical to the success of multiple programs but whose outputs make up a relatively small portion of each program's activities. Historically, funding constraints drove prioritization focused on specific, near- and mid-term program of record deliverables. In such cases, the funding needed to address risks to multi-program capabilities was subject to competition. CBI provides a dedicated program office to address those cross-program risks. Through the Programmatic Recapitalization Working Group efforts, DOE/NNSA conducts analyses of programmatic capital equipment to help identify targets of opportunity for investment to reduce mission and performance risk. For example, as equipment ages through and past its life expectancy, it may pose increased risk of performance degradation and/or failure.

Figure 3–6 depicts the useful life status of enterprise programmatic capital equipment as of September 2023. The specific pieces of equipment and capabilities within the Programmatic Recapitalization Working Group data set also help inform CBI decisions.

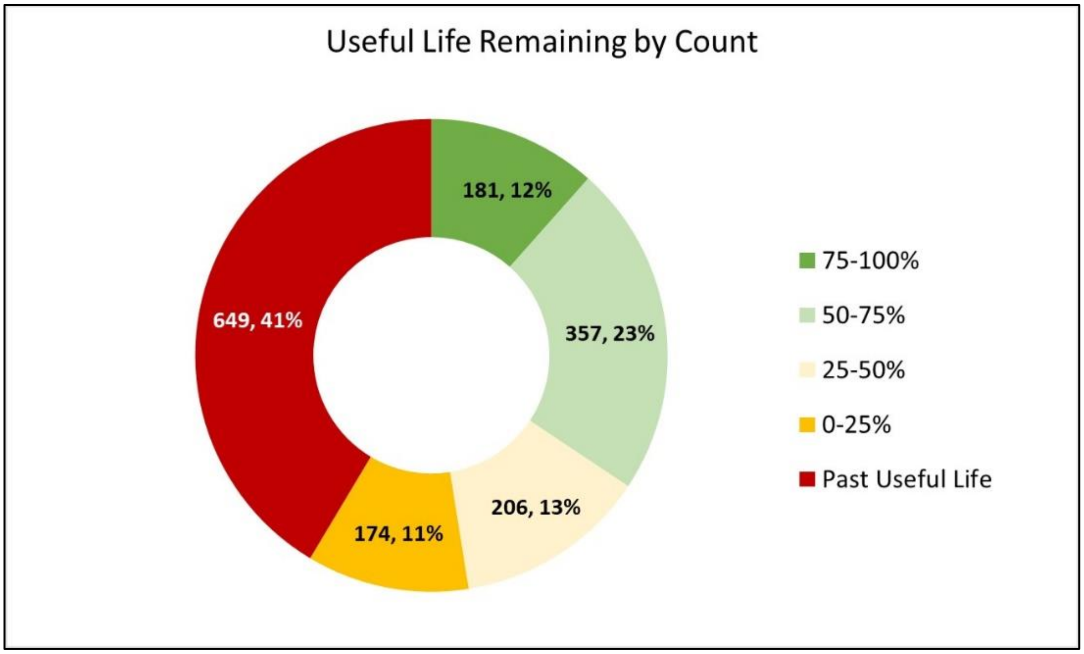


Figure 3–6. Count of equipment by useful life consumed

3.5.1.3.2 Challenges and Strategies

Table 3-12 provides a high-level summary of CBI challenges and the strategies to address them.

Table 3–12. Summary of Capability Based Investments challenges and strategies

Challenges	*Strategies*	
	Current Strategies	*Future Strategies*
Limited ability to forecast equipment failure dates accurately and precisely for a diverse collection of technologies used to enable a wide range of capabilities for developing, testing, and producing weapon systems and subsystems.	Emphasize recapitalization of single points of failure, bottlenecks, and equipment no longer supported by the vendor base. Recapitalize before equipment begins to fail, to the greatest extent possible.	Develop advanced measures of effectiveness for equipment recapitalization planning to effectively capture and analyze data currently obscured by relatively long feedback loops.
Sites have limited internal resources available to execute planned projects, limiting the amount of equipment recapitalization achievable in a single fiscal year.	Coordinate work scope that is challenging yet achievable based on past performance and forecast site capabilities.	Continue to grow capacity of key resources at DOE/NNSA sites, including engineering and craft labor.
Unforeseen equipment failures and emerging risks.	Maintain flexibility to adapt equipment replacement priority list by committing to short-term projects and through frequent updates coordinated with other Federal program offices. Evaluate ways to leverage advanced machine diagnostics for more accurate failure forecasts.	Identify and leverage next generation disruptive technologies that enables predictive equipment maintenance and eliminates failures and downtime.

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 Accomplishments***
>
> *Recent challenges in material supply chain and manufacturing for the current modernization programs highlight the importance of having a robust HE advanced manufacturing technology maturation program. DOE/NNSA's newly operational Facility for the Advanced Manufacturing of Energetics is now able to print large HE components using real stockpile materials. This is a major step forward for HE Additive Manufacturing. This work will serve to demonstrate how this alternate HE Additive Manufacturing path provides a more flexible and responsive nuclear security enterprise.*

DOE/NNSA requires 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 maturation.

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

3.5.2.1 Status

DOE/NNSA must co-invest in process technology along with their product technology innovation to improve responsiveness, reduce cost, and increase product realization agility. Programs associated with the Weapon Component and Material Process Development capability continue to develop and improve multi-system component and manufacturing processes, thus reducing costs and improving schedule execution for the nuclear security enterprise.

Current processes and infrastructure are inadequate 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 for future needs.

Advances in the Weapon Component and Material Process Development capability are 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 increased production demand from multiple concurrent modernization programs. DOE/NNSA is performing AoA studies to seek ways to mitigate potential adverse effects to existing and future programs caused by insufficient facility capacity and emerging production needs.

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.

Weapon Component and System Prototyping Accomplishments

- *SNL: Developed a novel control software for direct ink write to enable rapid prototyping of additively printed polymer parts. Initial prototype-part designs were shared with KCNSC partners to make test builds.*
- *KCNSC: In FY 2023, shipped over 21,000 items of prototype and development hardware to support modernization and sustainment programs. This hardware was used to support production process development along with component- and system-level ground and flight testing to mature and validate design and performance. Prototypes included components using novel materials to reduce system weight and new technologies to improve weapon safety.*

The Weapon Component and System Prototyping capability supports the replacement of sunset technologies and obsolete materials as well as the use of technological advances from industry and academia. This approach provides weapon designers the opportunities to take prudent risks before use in stockpile warheads, facilitates accelerated learning cycles, and integrates multidisciplinary, multi-site teams to support the laboratory and flight tests that provide evidence that the 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 solution pathways to prepare the nuclear stockpile for changing global security environments, such as advanced hardware design for nuclear explosive packages, energetics, microelectronics, mechanisms, GTSs, initiation systems, and neutron generators; and
- 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 lifecycle.

3.5.3.1 Status

Aging facilities and legacy processes are not easily, or economically, modifiable to new technologies. DOE/NNSA requires timely 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 prompt feedback will promote innovation as risks and barriers to participation are lowered.

Advancements in science and technology improve warhead performance and manufacturing. Innovative applications of additive manufacturing and model-based systems engineering have created new approaches for weapon technology prototyping. These new technologies will provide greater performance than is possible with existing technologies and processes as well as options to solve warhead issues that can be implemented more quickly at lower cost.

Prototyping projects such as the Joint Technology Demonstrator or Agile Processes and Technologies have driven partnerships across the complex in areas such as materials science, component organizations, prototype reentry bodies, execution systems integration, and testing scope. These have led to program of record processes (e.g., MECH1 approach to mechanical testing and qualification for the W87-1), a more complete understanding of environments, the ability to better address integration challenges early in development space, and implementation of modeling and simulation tools.

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 allow for more options during component design while reducing component R&D costs. Benefits from advanced manufacturing capabilities also include a reduction in manufacturing footprint, waste, and facility operating costs, an increase in production throughput, and improvement in manufacturing safety.

This capability underpins innovation in future nuclear weapons systems by allowing 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 future production capabilities, including additive manufacturing for metals and polymers, injection molding, internal materials production capabilities, new materials with better properties, and manufacturing simulation capabilities.

Advanced Manufacturing Accomplishments

- *KCNSC: Transformed data, software, and hardware technologies into a fully integrated Smart Factory System in FY 2023. Smart Factory was launched in the GTS production departments with persistent displays, part tracking kiosks, machine connections, and wireless devices, resulting in faster response to production issues, improved priority execution, and improved operational efficiency. The KCNSC Smart Factory team plans to deploy the Smart Factory system to all Stockpile production departments, while developing enhancements and new capabilities to grow KCNSCs capability.*
- *Pantex: Construction of Advanced Fabrication Facility at Pantex forecast completion in FY 2024.*
- *Advanced additive manufacturing techniques for high explosives that will enable formulations that are safer to produce and replace legacy materials that are no longer commercially available.*
- *Integrated in-situ monitoring capabilities with Direct Ink Write printing to accelerate process maturation.*
- *Advanced near net shaping forming technology of lithium component forming to increase material efficiency and stretch the available inventory.*

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 weapon system requirements. This allows the enterprise to field new concepts for the entire lifecycle of a weapon system without 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 such as 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 areas will directly affect the agility and responsiveness of DOE/NNSA's manufacturing infrastructure and continue to develop the required manufacturing capabilities prior to a future weapon program's development engineering phase, thus producing confidence in the schedules and cost estimates for those programs.

Emerging advanced technology will enable a flexible, digital-based enterprise that will use a common set of trusted models and simulations throughout the entire product lifecycle. Benefits include reduced errors and the ability to simulate and predict outcomes for critical manufacturing processes, thereby reducing the iterations needed for manufacturing development; the ability to rapidly incorporate 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. The nuclear security enterprise is realizing several benefits 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 3–13 provides a high-level summary of the Weapon Component Production area challenges and the strategies to address them. See the classified annex for additional information.

Table 3–13. Summary of the Weapon Component Production area challenges and strategies

Challenges	*Strategies*	
	Current Strategies	***Future Strategies***
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 lifecycle of a weapon system.	Federal program managers and M&O managers communicate earlier and more frequently to support collaboration and consensus on necessary activities. Program managers meet regularly to identify opportunities and effect coordination. Regular meetings with M&O managers help to inform and discuss emerging issues and maturation progress.	Create an integrated strategic plan that incorporates cross-program activities.
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.	Mature advanced manufacturing capabilities by using product business cases and partnerships across programs to understand the risk extent for adding a new capability into the stockpile. Engage stakeholders in the technology development cycle early to best understand the full range of risks of inserting a new technology. Capture these risks in a business case and use the R&D phase of a technology to address them and discover additional risks with enough time to explore solutions before stockpile insertion. Increased collaboration between DA/PAs will accelerate development and production for advanced manufactured components for future modernization programs.	Create a risk evaluation framework for early maturation efforts.
Additional infrastructure for detonator component production and inspection, packaging and transportation and warehousing is needed to support planned weapons modernization and sustainment.	Execute small capital projects to provide incremental improvements and facility upgrades to minimize impact to detonator capabilities to aging facilities.	Integrate the detonator production infrastructure investments and NNSA Infrastructure Investment Strategy.

DA/PA = design agency/production agency
M&O = management and operating
R&D = research and development

3.6 Weapon Assembly, Storage, Testing, and Disposition Area

After weapon components are produced, they are assembled into complete warheads and require temporary storage before delivery to DoD. Some of these warheads are removed from the stockpile on a yearly basis for surveillance testing 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, reassembly, and disposition at end of life.

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 subassemblies of components. All these activities require special operations, equipment, facilities, quality control, and special safety and security processes and protocols.

3.6.1.1 Status

The Warhead Assembly Modernization program, which initiates in FY 2025, will modernize the capabilities needed to execute warhead assembly/disassembly operations at Pantex for weapons modernization, surveillance, and dismantlement programs. The program will identify and implement enhancements across all weapon operations at Pantex to increase capability, capacity, and throughput for multiple weapons programs, reducing enterprise risk and ensuring that NNSA is positioned to successfully meet current and future mission demands.

DOE/NNSA maintains extensive infrastructure to assemble, disassemble, stage, and dispose of weapons at a central site. Assembly, disassembly, and short term or non-permanent staging of weapons (nuclear explosives), nuclear weapon components, and non-nuclear weapons components occurs at Pantex. Other sites in the complex, depending on their mission assignments, conduct assembly, disassembly, and staging or storage of nuclear and non-nuclear components. Storage, disassembly, and assembly of components occurs at the production facilities, depending on the mission. With multiple programs in production and development, the storage and staging requirements to accommodate significant quantities of parts at the production agencies, particularly at KCNSC and Pantex, continue to be a challenge. DOE/NNSA is developing and implementing specific actions to address these storage challenges. 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. Additionally, some equipment is becoming obsolete due to unavailable parts and emerging new technology. Sophisticated equipment[6] contributes to the viability of this capability, which depends on this specialized equipment remaining operable. Some new equipment has been installed, but additional equipment replacements are needed to meet mission requirements. As part of the overall strategy, DOE/NNSA is upgrading obsolete items of equipment and the facilities in which the equipment is used to ensure these critical capabilities are maintained.

DOE/NNSA is also investing in modernizing the facilities, equipment, processes, and support processes used specifically for weapon assembly and disassembly activities. These efforts are increasing the

[6] Sophisticated equipment includes 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 mass properties, radiography, laser gas sampling, and computed tomography.

efficiency of operations at the site, resulting in the increased throughput necessary to ensure mission needs are met.

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 evaluations. 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 depends on a broad array of specialized equipment such as system testers that emulate the weapon delivery environment. DOE/NNSA's flexible and dynamic evaluation plan responds to emerging issues and new information, enabling adjustments as conditions change and DOE/NNSA continues to meet key priorities. This planning includes identifying and mitigating issues with equipment.

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 provides evidence for process qualification, weapon certification, reliability, surety, product acceptance, and stockpile evaluation and is 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. In many cases, management and operating (M&O) partners are forced to design testers in-house due to stringent safety and quality requirements. Efforts continue to enhance the common tester architecture; improve trusted, robust test solutions; and develop a system with improved connectivity, interchangeability, and multi-use compatibility with future components and systems. 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 3–14 provides a high-level summary of Weapon Assembly, Storage, Testing, and Disposition area challenges and the strategies to address them.

Table 3–14. Summary of Weapon Assembly, Storage, Testing, and Disposition area challenges and strategies

Challenges	*Strategies*	
	Current Strategies	*Future Strategies*
Numerous capabilities and resources have strained or insufficient capacity to meet sustainment and modernization demands.	Prioritize activities to minimize impacts through cross-complex working groups.	Future strategy has not yet been identified.
Aging testers supporting surveillance are becoming unreliable and unsupportable due to sunset technologies. Replacement equipment, testers, software, and related infrastructure provisions are difficult to acquire to adequately perform testing, component and system surveillance.	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 but reduces required floorspace for surveillance testing.	Refresh and migrate testers to a common platform for components that will be surveilled as those components approach last production unit.
Current aged infrastructure and equipment for operations and operational support is unable to sustain the high rates required for future weapon assembly mission.	Identify and implement modernization opportunities to increase operational efficiencies in weapon assembly and weapon assembly supporting operations.	Construct new weapon assembly/disassembly facilities and new staging capabilities.
Weapon staging capability is significantly degraded and does not support efficient processing. In addition, lack of sufficient fissile material staging capacity and capability requires utilization of operational areas for staging reducing operational capacity.	Identify and implement bridging strategy to maintain weapon and material staging capabilities that ensure safety, security and quality requirements are met.	Execute a modular construction campaign to address weapon and fissile material staging needs to support program of record.

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 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, safely, and securely. The Secure Transportation capability supports DOE/NNSA's goals, including consolidating nuclear material storage and reducing the dangers and environmental risks posed by transporting nuclear cargo. This includes vehicle

Secure Transportation Asset Accomplishments

- *In FY 2023, completed over 150 shipments and deliveries without incident.*
- *Completed Test Article 2 (TA2) Over-the-Road Testing, delivered the Pre-Production Unit Rolling Chassis, and completed the environmental testing for the Mobile Guardian Transporter (MGT) door.*
- *Completed three Federal Agent Candidate Training courses, graduating 42 new Federal Agents.*
- *Executed vehicle sustainment efforts to upgrade and maintained mission vehicles to provide reliable mission support.*

design and fabrication or modification, leading-edge communication systems, and training elite Federal Agents.

Weapons Activities programs receive the highest priority, but the Secure Transportation capability also provides secure transport for other DOE and NNSA programs and offices, such as the DOE/NNSA Office of Counterterrorism and Counterproliferation, the DOE/NNSA Office of Naval Reactors, and the 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 based on changing customer needs and current and future threats. These assets include vehicles (e.g., highly modified trailers, armored tractors, escort vehicles, and support vehicles), aircraft, and a highly trained Federal Agent workforce.

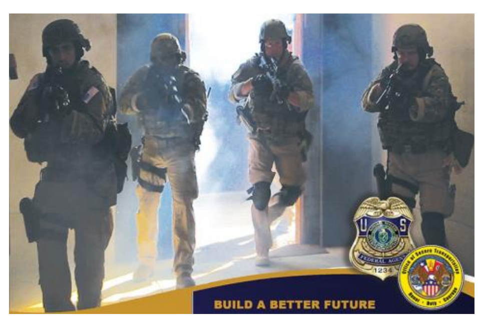
The process of identifying, designing, procuring, and manufacturing vehicles takes multiple years. The Safeguards Transporter (SGT) fleet reached the end of the projected design life cycle in 2018. STA is sustaining this capability by implementing risk-reduction initiatives to extend the life of the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

STA's current armored tractor fleet begins to reach the end of its 12-year service life in FY 2026. To maintain this capability and provide compatibility with the SGT and the MGT, the current armored tractor fleet must be replaced. The next generation armored tractor is being developed under the PHOENIX program with production expected to begin in FY 2027.

Additionally, STA is planning lifecycle replacement for the first 737-400 aircraft in FY 2027 and the second in FY 2032. Once the two 737-400 aircrafts are replaced, STA will own a fleet of three 737-700s. Lifecycle replacement is necessary as older aircraft are more susceptible to fuel leaks, fatigue cracks, and corrosion, and require more inspections. Replacement also mitigates costs and maintenance down-time.

Replacement Aircraft (Boeing 737-700)

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 FA workforce due to the stringent hiring process, Human Reliability Program, security clearances, and turnover. STA continues to execute three Federal Agent Candidate Training courses each year, and in FY 2023 began implementing initiatives to attract, hire, and maintain the FA workforce by increasing starting salary for incoming FAs, offering recruitment and retention bonuses, and creating ladder positions to provide quicker growth to high performing FAs.



Nuclear Material Couriers

3.7.1.2 Challenges and Strategies

Table 3–15 provides a high-level summary of Secure Transportation Asset challenges and the strategies to address them.

Table 3–15. Summary of Secure Transportation Asset challenges and strategies

Challenges	Strategies	
	Current Strategies	Future Strategies
STA is facing continuing hiring and sustainment challenges within the FA workforce. Feedback and analysis have shown that pay is not competitive with other organizations.	Continue to implement initiatives to attract, hire, and maintain FA end strength.	Continue to develop new ideas, evaluate exit interviews to determine reasons for leaving, and monitor the results from current STA hiring initiatives.
The SGT fleet is beyond its design life and sustainment 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.	Evaluate, update, and replace STA assets as required. Incorporate MGT into mission operations as the fleet becomes available.
MGT design and development is facing cost and schedule overruns due to supply chain, staffing shortages, and technical issues.	Complete a rescope, restructure, and replan of the MGT project and schedule to meet delivery of the first production unit as close to FY 2029 as possible.	Monitor and evaluate progress for production of MGTs and their incorporation into STA mission operations.
STA must develop and produce new armored tractors to replace an aging fleet reaching its end of service life and ensure compatibility with both the SGT and MGT. Operating tractors beyond their service life increases risks for mechanical and electrical failures while in mission.	Pending the fielding of new armored tractors, the risks associated with operating tractors beyond their service life will be managed by shortening maintenance cycles and evaluating prognostic technologies.	Develop and produce new armored tractors under the PHOENIX Program.
Aging facilities require significant repair or replacement, to include critical maintenance for mission assets, FA training, and aviation facilities.	Prioritize the most critical projects.	Enhance facilities and execute minor construction projects that will allow for enhanced FA training, aviation infrastructure, and other mission support to ensure 100 percent safe and secure transportation.

FA = Federal Agent
MGT = Mobile Guardian Transporter
PHOENIX = Next Generation Armored Tractor
SGT = Safeguards Transporter
STA = Secure Transportation Asset

3.7.2 Safeguards and Security

The Safeguards and Security capability protects DOE/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. The Safeguards and Security program achieves this capability by ensuring integration among several components including protective forces, physical security systems, information security, personnel security, material control and accountability, and security program operations and planning. See the classified annex for additional information on safeguards and security.

3.7.2.1 Status

The Safeguards and Security capability supports the safety and security of the nuclear security enterprise as the mission becomes more complex and threats continue to evolve:

- DOE/NNSA continues to plan for an unprecedented increase in protective force personnel through FY 2027 in support of known mission growth across the nuclear security enterprise.
- DOE/NNSA's standardization initiative for life-cycle replacement of its aged rifles achieved 100 percent completion during FY 2023.
- 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 2024. The initial installation for counter uncrewed aircraft systems at our Category I sites is nearing completion with an additional plan to continuously evaluate and upgrade components necessary to address this evolving threat.
- DOE/NNSA, in partnership with the National Training Center, completed the contractor Material Control and Accountability Technical Qualification Program Pilot in September 2023. 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. The contractor Material Control and Accountability Technical Qualification Program continues in FY 2024 with four additional sites participating.
- NNSA's Office of Defense Nuclear Security developed the Metallography Case Study Course in August 2023. This course emphasized the crucial role of security and operations in controlling special nuclear material. 18 students from 9 universities participated in the pilot for this class at the University of Tennessee.

DOE/NNSA supports mission growth by prioritizing programs and projects based on prudent risk management. DOE/NNSA continues to implement DOE's Design Basis Threat policy, which requires DOE to assess potential threats to the nuclear weapons complex. The Design Basis Threat policy, updated in 2024, 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 Safeguards and Security 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 3–16 provides a high-level summary of Safeguards and Security challenges and the strategies to address them.

Table 3–16. Summary of Safeguards and Security challenges and strategies

Challenges	*Strategies*	
	Current Strategies	*Future Strategies*
Addressing prolific/rapid advancements in UAS technology.	DOE/NNSA currently employs two full-operational, and one initial operational, CUAS platforms at three of four Category I sites. All four Category I sites will achieve full operational capability in late FY 2024. DOE/NNSA continues to engage with other U.S. Government agencies on emerging UAS threats and methods to counter those technologies.	DNS plans to leverage future technologies and next-generation efforts in CUAS to continue addressing emerging UAS threats.
Modernizing aging security systems and infrastructure, while leveraging new technology.	DOE/NNSA is in the final stages of development and the initial stages of deployment of the new state-of-the-art physical security system Caerus. This modern security system will replace Argus, which has been in use for over 25 years. Caerus is a modernized and upgraded version of an integrated system which has the ability to incorporate commercial off-the-shelf technologies with improved cybersecurity. DOE/NNSA expects to formally test Caerus in FY 2024.	Partner with various organizations to assess and deploy future technologies designed to enhance the overall effectiveness of in-place security measures, aid in the development of enhanced cybersecurity, and incorporate the use of artificial intelligence.
Addressing insider threat.	DOE/NNSA has implemented continuous vetting as part of Trusted Workforce, screening technologies to deter and detect insiders, and insider vulnerability interviews of employees and contractor partners, designed and conducted by the site vulnerability assessment analysts and the Local Insider Threat Working Groups. In addition, steps taken to identify and mitigate insider threats include utilizing the DOE Employee Concerns Program website to report potential insider threats, continuous evaluation conducted by supervisors and cybersecurity personnel, security and law enforcement reporting, and administrative reporting on employees who are members of the Human Reliability Program.	Collaborate with DOE partners to strengthen the current insider threat mitigation techniques, establish a DOE/NNSA-managed Insider Threat Program, and identify opportunities to address the increased insider threat resulting from the advancement of technology and popularity of social media.

CUAS = counter uncrewed aircraft systems
DNS = NNSA Office of Defense Nuclear Security
SIRP = Security Infrastructure Revitalization Program
UAS = uncrewed aircraft system

3.7.3 Information Technology and Cybersecurity

DOE/NNSA accomplishes its strategic goals and objectives in IT and cybersecurity through the delivery of secure, agile, and risk-informed IT and cybersecurity solutions. As the cybersecurity threat landscape constantly evolves, DOE/NNSA strives to respond swiftly and appropriately, adapting IT, operational technology (OT), and cybersecurity defenses to mitigate increasingly sophisticated threats.

DOE/NNSA improves network connectivity and resilience, matures DOE/NNSA's cybersecurity posture, and directs and provides cybersecurity across the nuclear security enterprise and to mission partners. Additionally, DOE/NNSA is implementing a revised IT and cybersecurity strategy that outlines forward-leaning modernization priorities and initiatives. Services are provided through three offices: Cybersecurity, Mission Integration, and IT. These offices work in concert to:

- Increase organizational efficiency and effectiveness;
- Protect classified and unclassified information assets;
- Enhance communication with internal and external partners;
- Provide continuous monitoring and support effective incident response;
- Ensure information is protected from unauthorized access and malicious acts; and
- Comply with statutory requirements governing classified and unclassified data protections and information assurance.

For additional information on IT and cybersecurity, please refer to the classified version of this document.

DOE/NNSA is focusing on the development of integrated IT initiatives to provide effective and responsive technology infrastructure that delivers shared services and common communications platforms to the nuclear security enterprise. Initiatives are prioritized to ensure DOE/NNSA has the technological capabilities required to meet mission critical national security, nuclear nonproliferation, and weapons activity requirements. These priorities will fundamentally transform the IT and cybersecurity environments to provide modern, secure, and agile capabilities, including unified communication, cloud infrastructure, and next-generation collaboration services across the nuclear security enterprise. **Figure 3–7** provides a brief description of these critical priorities.

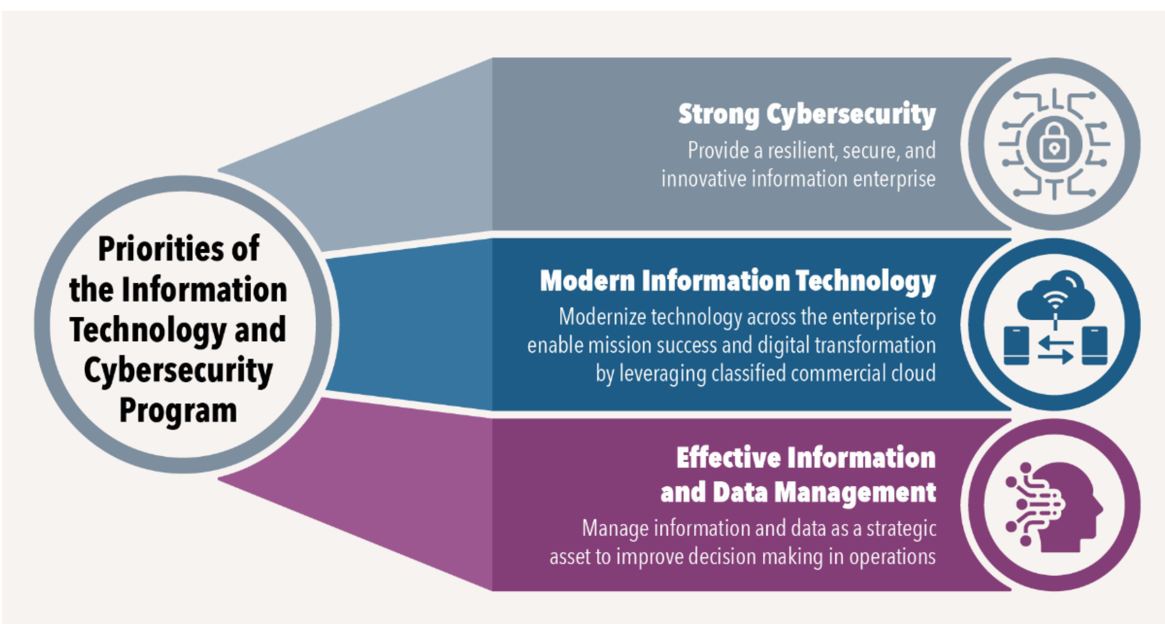


Figure 3–7. Priorities of the Information Technology and Cybersecurity Program

DOE/NNSA's priorities are further divided into goals and objectives, which it is using to guide its implementation efforts.

Strong Cybersecurity

DOE/NNSA ensures effective IT and information management safeguards are established and implemented to support and protect DOE/NNSA's information systems and IT assets. It also directs the implementation and maintenance of cybersecurity assets within the DOE/NNSA classified and unclassified domains. The first goal toward developing strong cybersecurity is to achieve increased efficiency of risk management and information assurance programs. The objectives in achieving this goal include:

- Implementation of an efficient Authorization to Operation process to encourage agile system development and rapid implementation; and
- Expansion of supply chain management collaboration and supply chain risk management to enhance real-time monitoring capabilities and communicate risk and threats.

Strong Cybersecurity Accomplishments

- *Executed a cyber exercise to determine DOE/NNSA's ability to detect and thwart incoming cyber threats.*
- *Enhanced the enterprise security operations center that provides 24/7/365 cybersecurity services to DOE/NNSA networking enclaves.*
- *Continued the maturation of cybersecurity capabilities while leveraging investments in cybersecurity tools such as endpoint detection and response and other Zero Trust Architecture enablers.*

The second goal, modernization of the cybersecurity architecture to enable zero trust principles, comprises the following objectives:

- Establishment of a new center of excellence that coalesces around enterprise requirements and continues to develop existing centers of excellence;
- Engagement with SMEs across the nuclear security enterprise to address policy and technology gaps in the ability to combat threats to the OT environment;
- Performance of a cybersecurity enterprise capability portfolio gap analysis; and
- Mitigation of artificial intelligence and quantum threats while leveraging the capabilities of the technology.

The third goal for this priority is to improve incident detection and response through automation, testing, and training. To accomplish this, DOE/NNSA will:

- Expand 24/7 cybersecurity functions and operations for all security operations centers to ensure robust monitoring of DOE/NNSA's technologies;
- Establish a crisis action team to rapidly respond to incidents; and
- Improve collaboration between security operations centers and emergency operation center to enhance collaboration, intelligence sharing, and real-time incident management efforts.

Modern Information Technology

DOE/NNSA delivers IT that aligns organizational strategies and business outcomes with enabling technologies to deliver DOE/NNSA's missions. The mission of the DOE/NNSA is to provide modernized, reliable, and secure IT services and resources to achieve DOE/NNSA missions. These efforts align to support and enable the DOE/NNSA workforce in achieving mission success in both classified and unclassified environments. To do this, DOE/NNSA will develop common IT ecosystems across the enterprise to strengthen interoperability and data fidelity. It will also modernize conferencing environments across all classification levels for better real-time information sharing capabilities.

> ***Modern Information Technology Accomplishments***
>
> - *Deployed new classified cloud technologies across the nuclear security enterprise.*
> - *Evolved unified communications capabilities to enhance information sharing between other government agencies and DOE/NNSA, facilitated expanded partnerships, and modernized the execution of DOE/NNSA's mission.*
> - *Supported field office IT services provisioned by M&O partners and oversaw the M&O partners' unclassified IT programs.*

The second goal in support of this priority is to improve mission support applications and automate processes. The objectives include maximizing cloud hosting options and leveraging automation to support business processes and improve the user experience.

Effective Information Data Management

DOE/NNSA plays a pivotal role in ensuring effective information and data management. Through the application of policy and technical assessments, the enterprise ensures that service delivery remains responsive to the dynamic needs of DOE/NNSA's mission programs. DOE/NNSA's goal is to establish department-wide and NNSA-specific strategies and policies to manage information and data. These will include:

- Implementing data management and governance practices to mature data value;
- Promoting a culture of data sharing, collaboration, and continuous improvement that spans all levels of the enterprise;
- Developing a connected ecosystem of security-informed and scalable data infrastructure solutions; and
- Cultivating a culture of experimentation and innovation, including forward-leaning exploration of emerging technologies and modern development practices.

> ***Effective Information Data Management Accomplishments***
>
> - *Improved data sharing processes and protocols while streamlining efforts for collaboration by establishing the nuclear security enterprise Data Council.*
> - *Piloted a platform to support cross-site collaboration on large data sets, including use cases for artificial intelligence and machine learning.*
> - *Designed a platform and robust data pipelines to enable machine learning user cases on cyber data.*
> - *Bolstered IT cybersecurity professionals' employment opportunities and professional experiences across the nuclear security enterprise through development programs such as the Cyber Specialist Advance Hire Program and the Cyber Specialist Rotation Program.*

DOE/NNSA also has a goal to build an adaptive and resilient IT and cybersecurity workforce. This effort includes:

- Developing and promoting workforce strategies and programs to attract, develop, and retain IT and cybersecurity professionals both among the Federal workforce and at DOE/NNSA's M&O laboratories, plants, and sites;

- Optimizing financial resource allocation by planning, tracking, and executing an IT and cybersecurity budget based upon zero-baseline budgeting; and
- Executing an acquisition management program that tracks current contract implementation and proactively plans for executing option years, renewing contracts, or initiating new procurements that meet lead-time requirements to ensure service continuity.

3.7.3.1 Status

DOE/NNSA continues to manage IT and cybersecurity programs designed to reduce risks, improve collaboration, and enhance IT and cybersecurity solutions. While these efforts are managed as projects, they are not managed under the same acquisition policies as the line-item construction or minor construction projects.

Enterprise Digital Transformation

DOE/NNSA invests in innovation to enable its mission and business needs and is supporting digital transformation and digital engineering through focused investment in:

- Enhanced unclassified and classified infrastructure and focused improvement, upgrades, and advancements;
- Artificial intelligence and machine learning capabilities; and
- IT and application modernization.

DOE/NNSA continues to implement an enterprise transformation initiative that will deliver a modern, reliable, comprehensive, and secure computing environment that supports the enterprise and aligns with current and future IT service delivery models. With the managed services model, DOE/NNSA's networks will benefit from industry best practices and improve ongoing security updates, network monitoring, and threat sharing and broadcasts. It will incorporate timely and relevant security configurations, fine-tuned settings for performance from a security perspective, and dynamic configurations to meet evolving business environments.

DOE/NNSA continues to invest in the modernization and resiliency of IT with an emphasis on addressing risks related to hardware and software assurance, OT assurance, and supply chain management.

The current and future anticipated mission requirements. Due to the increased demand for advanced technology to protect information, agility and risk management is critical to respond to cybersecurity threats and technology requirements. DOE/NNSA anticipates the continued growth of cybersecurity capabilities and activities, which will be used in identifying, protecting, detecting, responding, and recovering against cyber threats.

The current state of the infrastructure. DOE/NNSA secures unclassified and classified systems, meeting nuclear security enterprise standards. These networks are constantly evaluated and upgraded to meet the constantly changing landscape.

The current state of the workforce. In today's rapidly evolving digital landscape, the need for a skilled IT and cybersecurity workforce has become increasingly critical. Recruiting and retaining top talent continues to be a challenge due to competition for IT and cybersecurity resources. DOE/NNSA continues to partner across the nuclear security enterprise to expand the workforce through development programs for M&Os and analyzing job requirements to meet evolving mission needs. By doing so, DOE/NNSA will continue to be a competitive employer that can recruit, develop, and retain top IT and cybersecurity talent.

Technologies deployed to address cybersecurity threats. DOE/NNSA's IT and cybersecurity programs maintain management, operations, and technical security safeguards throughout the nuclear security enterprise for adequate protection of information assets. The security tools listed in **Table 3–17** provide the first lines of defense against known adversaries and emerging threats.

Table 3–17. Technologies deployed or to be deployed to address Information Technology and Cybersecurity threats

Cybersecurity Framework Core Function	*Technology*
Identify	Enterprise governance, risk, and compliance
	COE sensor platform for cybersecurity intelligence
	Vulnerabilities asset management
	Supply chain management center solution
Protect	Multifactor authentication identity and access control management solution
	Encryption
	Firewalls
	Intrusion prevention system
Detect	Network monitoring
	Configuration management
Respond	Incident response
	Enterprise forensics
Recover	The nuclear security enterprise maintains overlapping cybersecurity technology capabilities that ensure defense-in-depth and continuity of operations at alternate locations.

COE = Center of Excellence

Chapter 4
Infrastructure and Operations

Infrastructure modernization and expansion 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, engineering, and production activities at DOE/NNSA's laboratories, plants, and sites. To meet these demands, DOE/NNSA, with congressional support, has made significant progress in modernizing its infrastructure, eliminating excess facilities, and improving management practices. However, DOE/NNSA has experienced significant delays to several projects, resulting in increased costs that have required reprioritization of planned investments, including large line-item projects. The proposed project timelines in this chapter are estimates and subject to change.

This chapter provides a broad view of infrastructure and operations across the nuclear security enterprise and explains how DOE/NNSA conducts infrastructure planning and management to capture infrastructure activities 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, "Weapons Activities Capabilities that Support the Nuclear Security Enterprise." Infrastructure is an essential element of each capability area, as shown in Figure 3–2 and mentioned in the capability sections of each key capital project in Section 4.2.2.

Infrastructure and Operations Major Accomplishments

- *Nine projects are scheduled to be completed in fiscal year (FY) 2024 based on the Standardized Acquisition and Recapitalization (STAR) Initiative, which uses a standard design to reduce costs and accelerate construction of small office and light laboratory facilities across the nuclear security complex.*
- *Completed construction of the new Emergency Operations Center building at Sandia National Laboratories (SNL), in addition to three recapitalization projects focused on site utilities.*
- *Completed acquisition of Building 23 at the Kansas City National Security Complex (KCNSC), in addition to the build out of three additional programmatic expansion areas.*
- *Completed many projects across the nuclear security enterprise, including the Lawrence Livermore National Laboratory (LLNL) New Non-Destructive Testing Evaluation Building 310, the Nevada National Security Sites (NNSS) New Site Operations Center, the Los Alamos National Laboratory (LANL) New High Explosives Shipping and Receiving Transfer Facility, the Pantex Plant (Pantex) West Interconnect Replacement, and the Y-12 Security Complex (Y-12) Building 9204-02 Switchgear 810 Replacement.*
- *Completed the upgrade of the Radiological Laboratory Utility Office Building at LANL to a Hazard Category 3 facility to support plutonium operations.*

Figure 4–1 illustrates the size, age, and scope of DOE/NNSA's nuclear security enterprise infrastructure that drive the challenges and strategies discussed in this chapter. Comprehensive enterprise asset management requires continuous, multi-level planning across the entire spectrum of asset types, resulting in balanced enterprise investment decision making across the entire asset management lifecycle, as shown in **Figure 4–2**. Planning initiates an asset's lifecycle, followed by acquisition through new construction, lease, or purchase. Most 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.

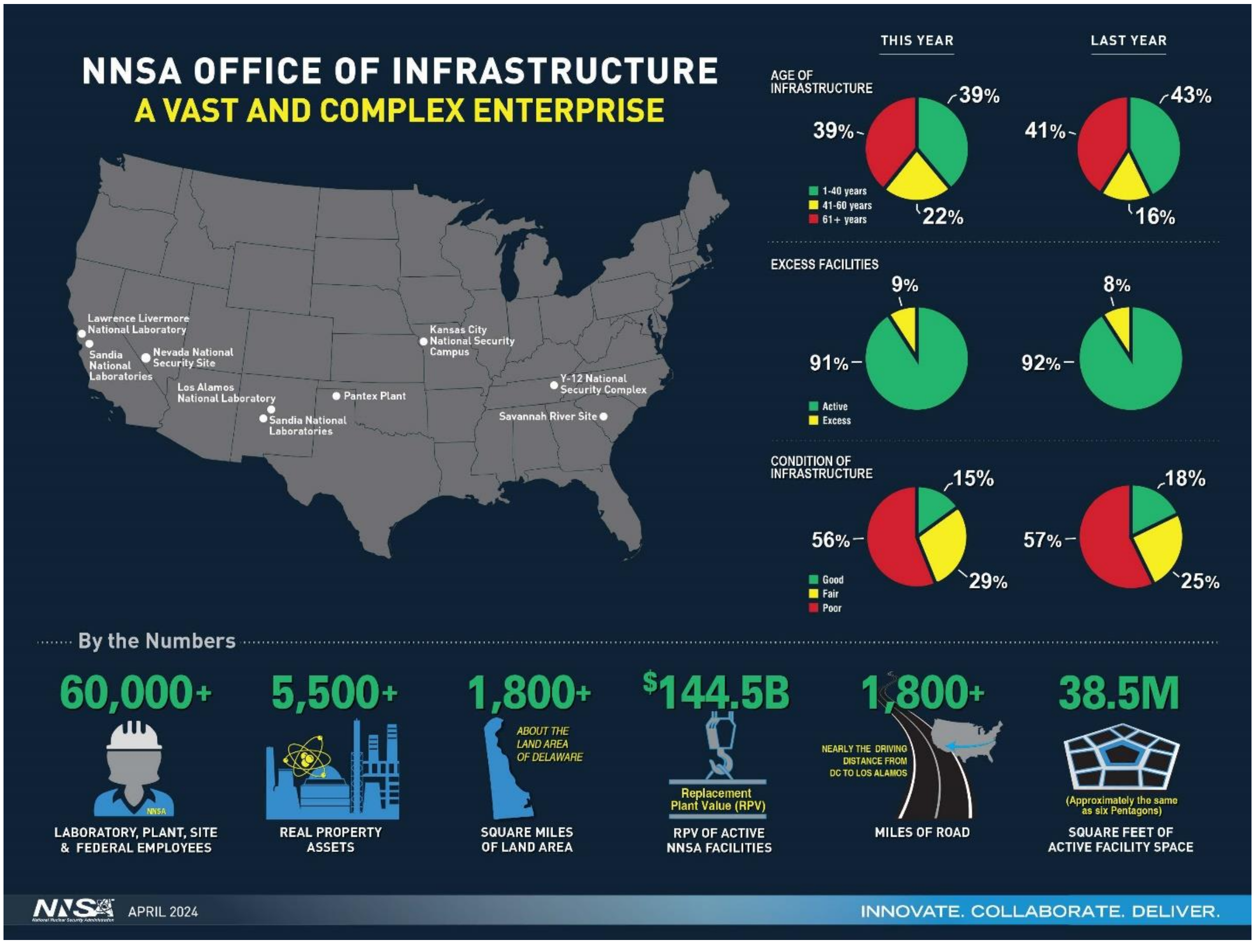


Figure 4–1. DOE/NNSA infrastructure size and scope

The asset management lifecycle model shown in Figure 4–2 illustrates the different types of investments across various funding sources. Sections 4.1 through 4.5 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, forecasts facility replacement schedules, plans for new and replacement acquisitions, and anticipates disposition needs and excess facilities' costs for disposition in a timely manner.

Sections 4.2, 4.3, and 4.4 describe acquisition strategies as well as modernization, recapitalization, and sustainment activities for existing facilities that support capabilities needed to sustain the stockpile. Section 4.2 discusses plans for programmatic construction by capability area and the actions being taken to sustain, recreate, and improve the capabilities detailed in Chapter 3. Section 4.3 provides information about recapitalization projects. Section 4.5 addresses the disposition of excess facilities. Sections 4.2 through 4.5 also discuss a wide range of programs, processes, and funding types, reflecting the complexity of aligning investment needs to funding sources.

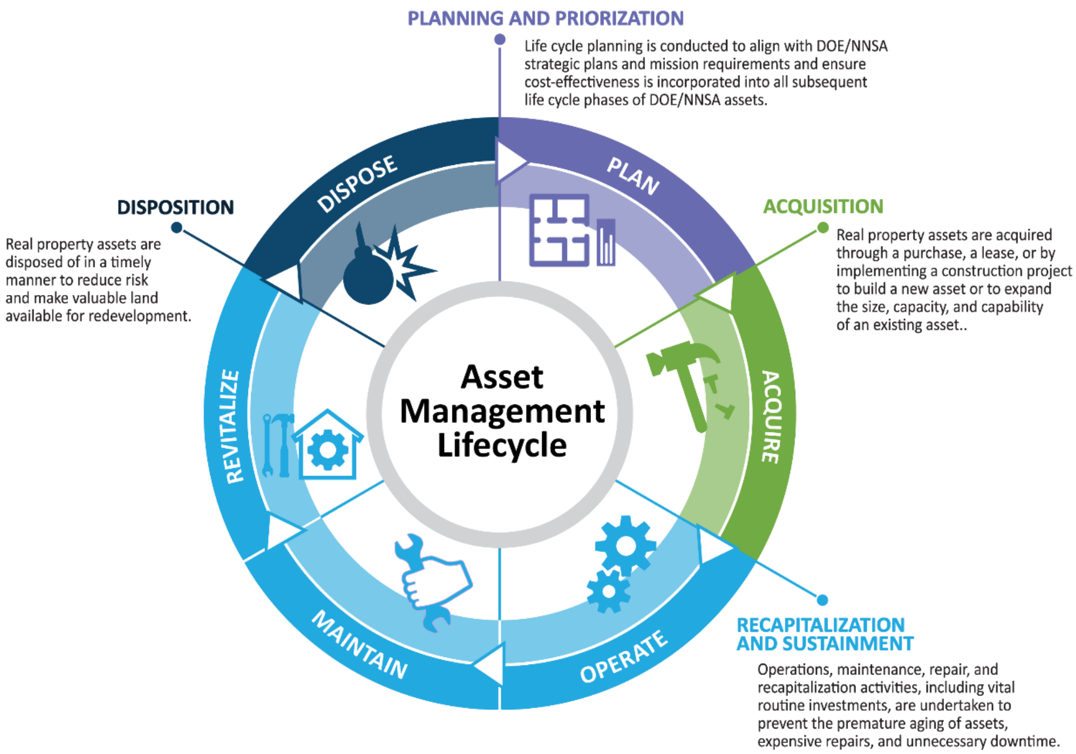


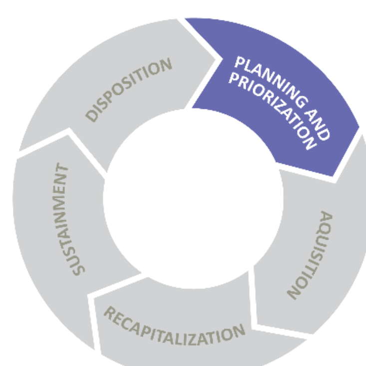
Figure 4–2. Asset management lifecycle

Facility acquisition occurs through line-item projects, minor construction, purchase, or leasing. Operating, maintaining, and revitalizing existing facilities is funded through minor construction, recapitalization, maintenance, and operations. Disposition occurs through demolition, sale, transfer, or lease termination. The funding strategy to support any given type of project can vary greatly based on 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. Additional details on these investments are discussed throughout this chapter as well as in the *FY 2025 Stockpile Stewardship and Management Plan* classified annex.

4.1 Planning and Prioritization

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. Capital investment planning involves identifying emerging needs in the weapons programs as well as science and technology investments to support those programs. Operational and capital investment planning must work in tandem to achieve the desired balance and cost-effectiveness. The combination of operational and capital investment planning leads to the development of a strategic investment plan.



The asset management lifecycle, shown in Figure 4–2, is the basis for all investment planning within DOE/NNSA. This framework can be applied to a single facility or to numerous facilities and describes how the DOE/NNSA infrastructure program operates. Each element of the framework must be considered to allocate resources appropriately and optimize the nuclear security enterprise's ability to accomplish the mission. While the framework is straightforward, the processes used to achieve a prioritized balance across multiple facilities of varying age, condition, and importance to the capabilities they support is not. In the DOE/NNSA environment, decision making is complicated by multiple funding mechanisms, budgets, changing guidance, and time-sensitive requirements.

DOE/NNSA has recently worked to better understand the nuclear security enterprise's long-term, strategic investment needs. DOE/NNSA uses data-driven, risk-informed tools to pinpoint when and where infrastructure investments are needed. This planning captures issues such as the development of new infrastructure or the resiliency of existing infrastructure to ensure continued operations. Asset management software provides accessible data for maintenance and sustainment-needs planning. These tools reduce mission risk by improving decision making, increasing buying power, and accelerating delivery. Direct mission needs are integrated and aligned with routine infrastructure sustainment and renewal processes to create a comprehensive plan for long-term investments. Bottom-up planning across the nuclear security enterprise is completed through area planning, described in Section 4.1.1, and site-focused deep dive reviews. These processes are also aligned with industry standards.

4.1.1 Area Planning

Area planning connects DOE/NNSA's strategic vision for the nuclear security enterprise with planned infrastructure investments. Area plans provide information on the lifecycle management strategies of co-located or functionally similar facilities, buildings, and other structures at each site. They are also 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 aligns the planning process with DOE/NNSA mission needs. Area plans are regularly updated to reflect the latest developments and priorities.

DOE/NNSA and its management and operating (M&O) partners develop area plans that align mission capabilities with associated assets across the nuclear security enterprise. These area plans showcase important elements of each capability's long-term infrastructure needs and span direct mission and mission enabling capabilities. Area plans include numerous types of mission enabling infrastructure, such as flagship experimental facilities, weapon component production facilities, utilities, and emergency services. When incorporated into site development plans, area plans provide a holistic roadmap for modernizing DOE/NNSA infrastructure. Area plans are developed assuming an unconstrained budget; therefore, they require annual adjustments to reflect changing budgetary environments.

> ***Savannah River Site (SRS) Transition***
>
> *As the SRS mission requirements for DOE/NNSA increase and the DOE Office of Environmental Management progresses toward a defined end state of the site's clean-up mission, the primary authority, accountability, and site stewardship responsibility for SRS is planned to transition from the DOE Office of Environmental Management to DOE/NNSA by 2025. In September 2023, DOE/NNSA signed the SRS Landlord Transition Plan, which represents a joint agreement between the DOE Office of Environmental Management and DOE/NNSA to accomplish a seamless SRS transition. The transition plan transfers four major responsibilities from DOE Office of Environmental Management to NNSA: the M&O contract, including landlord and essential site services; the Protective Force contract; the K Area Complex; and environmental permits/agreements.*
>
> *DOE/NNSA's FY 2025 budget request assumes execution of the transition plan, with primary site management and funding responsibilities beginning in FY 2025.*

4.1.2 Integrated Infrastructure Portfolio-Level Planning Initiative

DOE/NNSA has a significant backlog of infrastructure needs. To address this backlog, DOE/NNSA requires a large, prioritized, and balanced enterprise-wide plan of infrastructure investments that are designed to expand and modernize capabilities, increase capacities, improve facility conditions, and attract and retain a world-class workforce. The plan must be agile, to respond to emerging and evolving needs and opportunities, and time-phased, to accelerate value delivery. To address this planning need, DOE/NNSA established the Integrated Infrastructure Planning (IIP) Team in 2022. The IIP Team is a cross-functional body of staff from DOE/NNSA headquarters, and all DOE/NNSA laboratories, plants, and sites. The IIP Team is taking initial steps to identify the highest mission risk areas and balance investments across the DOE/NNSA infrastructure portfolio. These steps include:

- Developing a visual representation of DOE/NNSA's infrastructure plan to understand ongoing and future DOE/NNSA projects;
- Providing guidance and instructions to allow early planning and preparation for the next fiscal year budget cycle;
- Promoting group discussions to prioritize and integrate infrastructure investment decision making across DOE/NNSA;
- Identifying developments required to support a multitude of planned infrastructure investments that are collocated within a campus area (a physical location where multiple adjacent facilities support the same capability), thus driving efficiencies and reducing aggregate costs;
- Using a standardized and repeatable process to develop measurable and achievable prioritization and project readiness criteria; and
- Standardizing and improving data management systems and processes for use across the nuclear security enterprise.

The IIP Team drives the application of DOE/NNSA's priorities and facilitates risk-based decisions. Improved and open communication across DOE/NNSA's laboratories, plants, sites, partners, vendors, and workforce is essential to achieving mission goals. Other focuses include improving agility, identifying and rapidly solving issues, effective decision making, and maintaining pace with mission needs. Planning, prioritization, and integration of a wide variety of projects is key to the success of the IIP Team initiative.

A more integrated prioritization of infrastructure needs will better utilize budget and project delivery resources across science, production, mission enabling infrastructure, and other mission areas historically treated as stovepipes.

4.1.2.1 Weapons Activities Line-Item Planning Integration

The Weapons Activities line-item planning integration process establishes procedures to consolidate line-item data collection, synchronize infrastructure planning across Weapons Activities programs, and support the IIP Team. The integrated planning process, conducted in collaboration with the DOE/NNSA laboratories, plants, and sites, identifies and prioritizes 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, as well as the Future Years Nuclear Security Program programming and budgeting process as projects reach appropriate milestones.

Programmatic infrastructure investments are linked to the mission-specific capabilities that are applicable to Weapons Activities, such as plutonium modernization. They address investment needs for direct programmatic infrastructure and include facilities and equipment that enable the nuclear security enterprise to carry out weapons-related production and research, testing, and sustainment activities to meet DOE/NNSA's national security missions. In contrast, mission enabling infrastructure provides support for programmatic activities, including general purpose office buildings and 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.

DOE/NNSA Capital Construction Categories

Line-item *– A construction project with a total estimated cost greater than the minor construction threshold, resulting in the project requiring its own line-specific authorization and appropriation by Congress.*

Minor Construction *– Any plant project not specifically authorized by law with an approved total estimated cost that does not exceed the minor construction threshold (currently $34 million).*

Institutional Minor Construction *– 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.*

The program offices' comprehensive review of project proposals ensures all current and proposed line-item construction projects (detailed in Sections 4.2.2–4.2.3) represent necessary investments to support the program of record. The cost estimation process for proposals within capital acquisition is further described in Chapter 5, "Budget and Fiscal Estimates," Section 5.9.2.

4.1.3 Critical Decision Acquisition Milestone Process

DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets Change 7*, outlines a series of staged approvals that are referred to as Critical Decisions (CDs) and applies to line-item projects and major item of equipment (MIE)[1] projects greater than $50 million. Each CD stage requires specific deliverables prior to and during the process 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*, constitute the Initiation Phase. The IIP Team is working to standardize planning activities prior to CD-0 across DOE/NNSA. The Definition Phase ranges from CD-0 approval through approval of CD-1, *Approve Alternative Selection and Cost Range*. These activities are prerequisites for the Execution Phase, which includes approval of CD-2, *Approve Performance Baseline*, approval of CD-3, *Approve Start of Construction*, and activities prior to CD-4*, Approve Start of Operations or Project Completion*.[2] DOE/NNSA typically combines CD-2 and CD-3; the preparations for a CD-2/3 submittal package include all the activities necessary for both CD-2 and CD-3 approval. The beginning of CD-4 marks the transition to the Closeout Phase. CD-4 approval is based on readiness to operate and maintain the system, facility, or capability. Transition and turnover do not necessarily terminate all project activities; in some cases, they mark the point at which the operations organizations assume responsibility for operating and maintaining the new facility. DOE/NNSA Supplemental Directive 413.3-7, *Project*

[1] An MIE is 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 a 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.

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

Management for Non-nuclear, Non-complex Capital Asset Acquisition, provides further guidance on this process and greatly streamlines the requirements for non-nuclear, non-complex projects under $100 million.

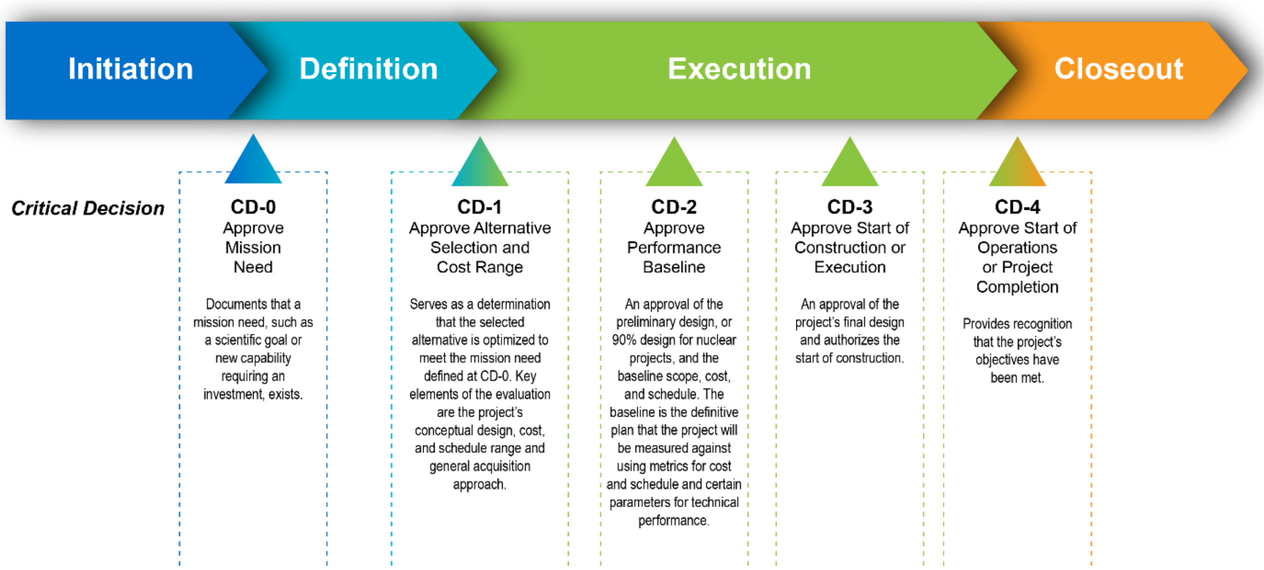
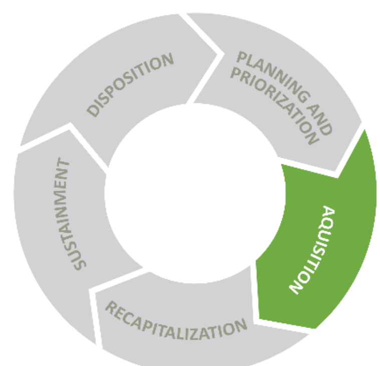


Figure 4–3. Critical Decision process

4.2 Acquisition



DOE/NNSA has more than 5,500 facilities across the nuclear security enterprise with a combined average age of 48 years. Many of the largest and most complex facilities will require line-item construction projects or campus-type approaches to accomplish modernization or replacement. Because aging facilities pose an increased risk to mission execution, and large-scale construction projects require significant coordination and funding over multiple years, DOE/NNSA continues to evaluate construction project proposals as a part of the overall 25-year plan for Weapons Activities. This plan identifies the long-term funding levels necessary to replace infrastructure that has aged out or will age out in the next 25 years, permitting informed decision making.

4.2.1 Streamlining Acquisition Practices

DOE/NNSA is improving its acquisition process and has established several initiatives to streamline design and acquisition. These initiatives aim to optimize processes for accelerating infrastructure delivery while decreasing cost and schedule impacts to improve execution capacity and value delivery.

4.2.1.1 Enhanced Minor Construction and Commercial Practices

In 2019, NNSA established the Enhanced Minor Construction and Commercial Standards (EMC^2) pilot to streamline non-complex, non-nuclear construction projects up to $50 million using successful minor construction program management and commercial construction practices. The EMC^2 pilot also conveys DOE 10 Code of Federal Regulation 851 safety requirements using the Occupational Safety and Health Administration construction safety practices (OSHA 3886) already familiar to commercial contractors.

This pilot has enabled DOE/NNSA to reduce acquisition timelines by up to 18 months and achieve cost savings of up to 30 percent. Recently completed projects using the pilot include the Emergency Operations Centers at LLNL, SNL, and Y-12, and the Y-12 Fire Station (see Section 4.2.3).

In September 2023, DOE/NNSA incorporated lessons learned from the EMC^2 pilot into DOE/NNSA policy through the publication of Supplemental Directive 413.3-7. This work is part of DOE/NNSA's multi-year effort to better align project risk with oversight.

Looking ahead, DOE/NNSA is evaluating the expansion of its streamlined approaches beyond the $100 million threshold, reflecting a commitment to continuous improvement and efficiency in construction initiatives while adhering to best practices and achieving optimal project outcomes.

4.2.1.2 Standardized Acquisition and Recapitalization

The goal of the Standardized Acquisition and Recapitalization (STAR) initiative is to simplify the design and delivery of commercial-like buildings, such as small offices and light laboratories, while meeting DOE standards, including the Guiding Principles for Sustainable Federal Buildings. It has two elements:

- Design Library: STAR created a library of concept-level designs that were submitted by DOE/NNSA sites and are available for any site to use or reference. By the end of 2023, there were 21 designs in the library and 14 STAR projects underway. Additional STAR designs, including standardized parking garages, multi-story office buildings, and laboratories, have been introduced at LLNL, and seven STAR construction projects have been completed at the site. The reuse of successful designs and construction approaches has streamlined execution and created cost predictability in a highly volatile construction market.
- Design Criteria: LANL, SNL, and NNSS are leading the development of unified design standards by creating a standard design process for office buildings that can be used by all sites. By the end of 2023, the sites delivered 100 percent Issued for Construction designs for three buildings, each with construction estimates under $30 million. This initiative has expanded to include a conceptual design for a $50 million office building. The criteria and processes of the remaining five sites will be reviewed and incorporated into the current model to create an enterprise-wide standard.

> ***Management and Performance***
>
> *DOE/NNSA is committed to encouraging competition and increasing the base of qualified contractors by simplifying major acquisition processes. DOE/NNSA will continue to focus on delivering timely, best-value acquisition solutions by using a tailored approach to contract structures and incentives that are appropriate for the special missions and risks at each site. DOE/NNSA continues to:*
>
> - *Lead improvements in contract and project management practices;*
> - *Provide clear lines of authority and accountability; and*
> - *Improve cost and schedule performance.*

In addition to the EMC^2 and STAR initiatives, 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** shows the historical average age growth of DOE/NNSA facilities and planned reduction in average age after completing the projects described throughout this chapter. The average age calculation shows the impact that the construction of ongoing line-item projects and proposals has on the average age of DOE/NNSA facilities.

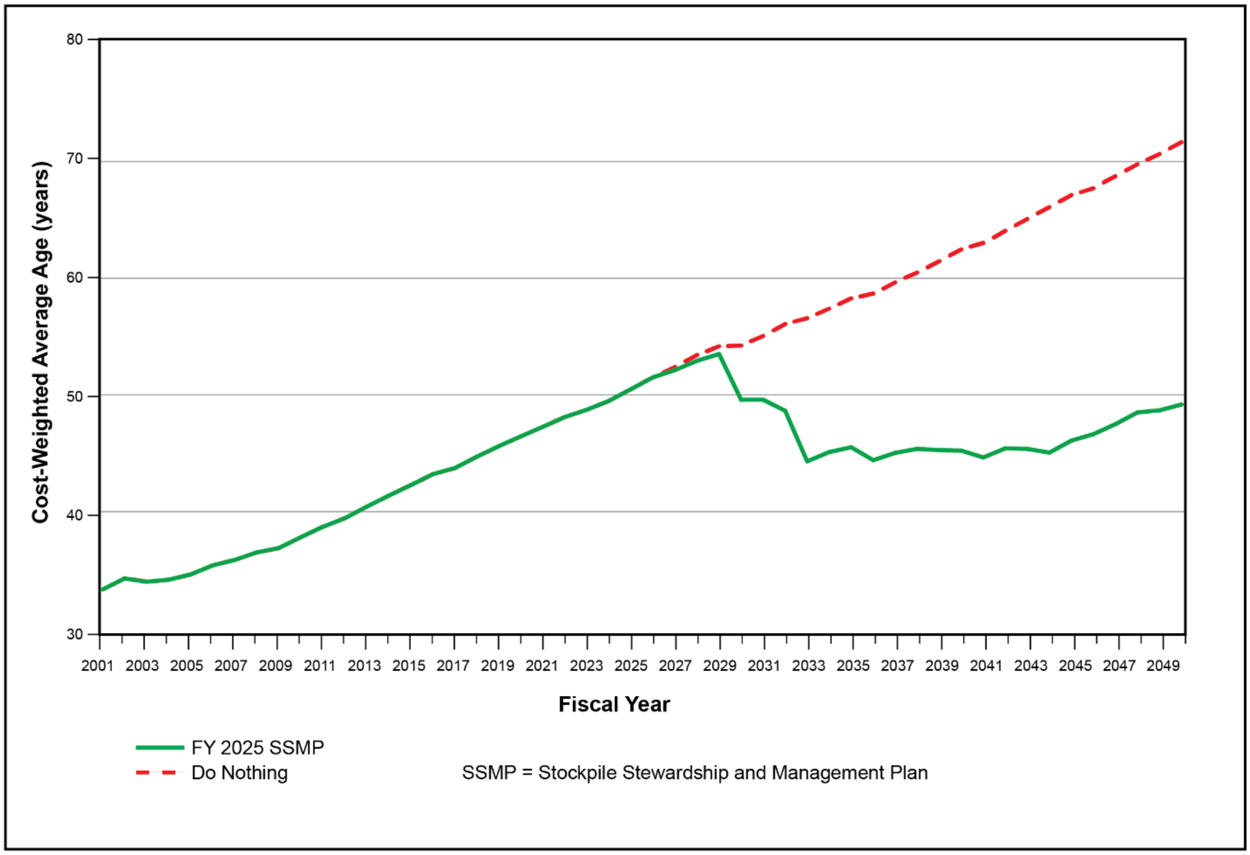


Figure 4–4. Historical and projected average age of DOE/NNSA facilities

The following sections discuss current and planned line-items and MIEs for the nuclear security enterprise. Programmatic line-items and MIEs are presented in Section 4.4.2 by Weapons Activities capability area, followed by mission enabling line-items in Section 4.2.3. Section 4.2.4 details other recent acquisition efforts undertaken by DOE/NNSA.

4.2.2 Programmatic Construction

Programmatic construction projects are categorized according to the Weapons Activities capability areas, which are detailed in Chapter 3. Sections 4.2.2.1–4.2.2.7 describe current and proposed line-item projects within each capability area, including their projected schedules and cost ranges. The projected schedules and cost ranges represent one potential planning scenario and may change in future Stockpile Stewardship and Management Plans as stockpile and enterprise requirements are refined and alternatives are formally assessed.

Project proposals (pre-CD-0) capture potential mission gaps and emerging requirements across the nuclear security enterprise but have not formally achieved approval of their mission need (per the CD process) or developed an Analysis of Alternatives (AoA) to determine the best way to meet the need. Scope descriptions associated with projects in this phase are illustrative; decisions on scope and location are made once DOE/NNSA completes a project's AoA and the project achieves CD-1. Locations for pre-CD-0 proposals are not specified unless the illustrative scope assumes modernization of an existing facility, but all scope and location decisions will be made through the project management process. Additionally, pre-CD-0 project proposals with low fidelity cost and schedule estimates that do not have an ongoing or upcoming planning study are only listed with descriptions and are not shown in the cost and schedule figures.

4.2.2.1 Weapon Science and Engineering

Line-item and MIE projects in the Weapon Science and Engineering area support the physical sciences and engineering disciplines that comprise the theoretical and experimental capabilities needed to assess the current nuclear stockpile and design as well as certify future stockpile weapons. Planning estimates and schedule dates for projects in this area are listed in **Figure 4–5**, which also includes project proposals in this area that have an ongoing or upcoming pre-CD-0 planning study.

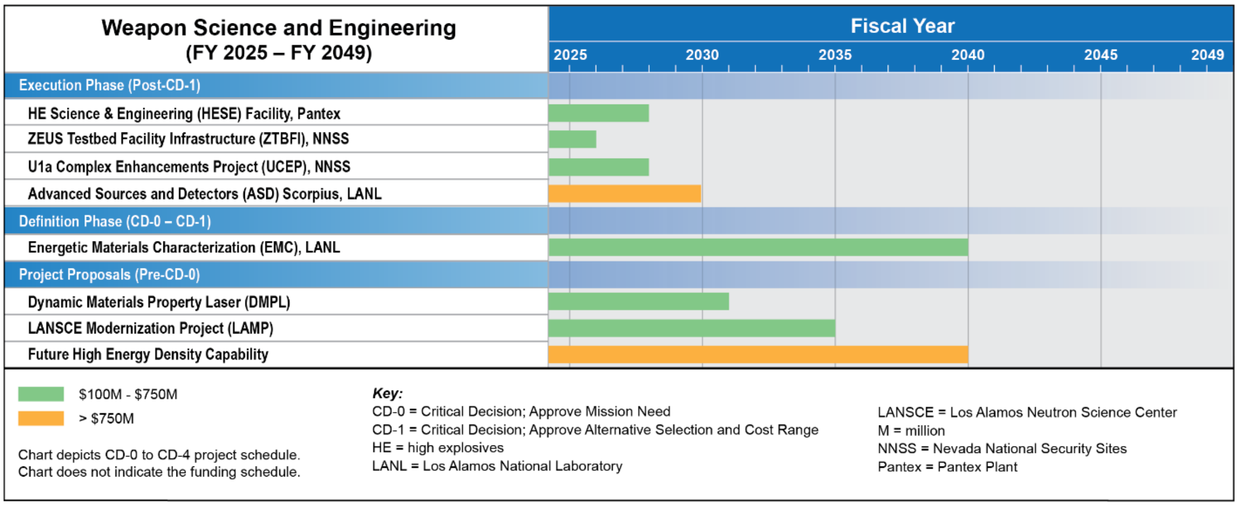


Figure 4–5. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Science and Engineering

DOE/NNSA is executing four 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 qualify and surveille high explosives (HE), provide a technology development laboratory, and provide office space for technical staff. It will replace 15 World War II-era facilities at Pantex, support the HE Center of Excellence for Manufacturing mission for DOE/NNSA, and help sustain high-quality scientific staff. The facilities to be replaced are an average of 68 years old. The HESE facility will be approximately 73,000 square feet. The HESE facility project design is complete and received CD-2/3 approval in April 2022. The main works contract for the facility was awarded and construction began in May 2022.
- The **Z-Pinch Experimental Underground System (ZEUS) Testbed Facilities Improvement Project** at NNSS includes the design, construction, and commissioning of the ZEUS Testbed and systems to support dense plasma focus diagnostics. The area will be used for neutron diagnosed subcritical experiments.
- The **U1a Complex Enhancements Project (UCEP)** comprises two subprojects, UCEP10 and UCEP20, at NNSS. These subprojects will provide infrastructure modifications to house and field multipulse radiography and include structures, systems, and components necessary for deploying the Enhanced Capabilities for Subcritical Experiment ASD project's pulsed X-ray radiography equipment. UCEP10 achieved CD-4 in June 2022 and UCEP20 achieved CD-2/3 in June 2022. The

U1a Complex at NNSS is now known as the Principal Underground Laboratory for Subcritical Experimentation (PULSE), but the project is listed in the FY 2025 budget request under the UCEP name.

- The **Advanced Sources and Detectors (ASD) Scorpius** project is an MIE that will fill the pulsed X-radiography capability gap through development of a multi-pulse linear induction electron accelerator. The project's scope includes design, technical maturation, fabrication, testing, installation, commissioning, and readiness execution at PULSE at NNSS. The project director role for ASD is from LANL. The ASD project received CD-2/3 approval in November 2022.

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** supports HE research and development (R&D) activities at LANL, including safety and performance assessments, component qualification and surveillance, evaluation of material responses to all aspects of the stockpile-to-target sequence, resolution of significant finding investigations (SFIs) involving energetic materials, provision of technical data for annual weapon assessments, and development of new and replacement materials. The project will consolidate operations into collocated, modern facilities and allow 18 legacy structures dating from the 1950s to move toward disposition. The current DOE/NNSA plan has paused CD-1 for this project until FY 2030. To mitigate programmatic impacts, DOE/NNSA, in conjunction with LANL, is evaluating alternative solutions that consider risks to missions, life-extending commitments for legacy HE infrastructure capability, current funding options, and priorities for investments and construction resources.

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. These project proposals are a part of the planning process (pre-CD-0) and 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 AoA and achieves CD-1.

- The **Mesoscale Science** capability is the future of DOE/NNSA's predictive models that are used in the assessment of the U.S. nuclear stockpile. The qualification of materials for future weapons systems will increasingly be reliant on experimental data interrogating physics and chemistry at the mesoscale (1–100 micrometers). Therefore, the assessment of the future stockpile, maintenance of the current stockpile, and qualification of new materials and manufacturing processes will seek to understand the behavior of materials at the mesoscale in weapons-relevant environments, particularly under the thermal, thermodynamic (including shock), and radiation environments encountered in nuclear weapons. DOE/NNSA is pursuing a two-site strategy, which would leverage multi-billion-dollar investments from the DOE's Office of Science, to address this mesoscale science gap:

  (1) The **Dynamic Materials Properties Laser (DMPL)** would be a high energy (5 kilojoule), long pulse laser capability MIE in partnership with the DOE's Office of Science/Fusion Energy Sciences to complement the Matter in Extreme Conditions – Upgrade line-item project at the Linac Coherent Light Source.

  (2) The **Defense Materials Science Sector (DMSS)** would be a dynamic experiments hutch in addition to a materials science and qualification hutch using enhanced X-ray properties from the Advanced Photon Source – Upgrade project.

- The **Los Alamos Neutron Science Center (LANSCE) Modernization Project (LAMP)** would replace technologically obsolete and high-risk accelerator systems with modern, sustainable technologies to ensure enduring and robust capabilities for dynamic multi-frame proton radiography, neutron scattering on defense-relevant materials, neutron radiography of components and subsystems, and nuclear physics of defense-relevant isotopes. LAMP would address the LANSCE accelerator's end-of-life system failures and technology obsolescence by modernizing major accelerator systems to optimize beam quality and performance. This modernization would improve reliability, maintainability, efficiency, sustainability, and performance, while ensuring the ability to increase scheduled beam time to LANSCE science stations to meet increased demand. The LANSCE facility's unique capabilities enable DOE/NNSA to resolve SFIs, assess the stockpile, evaluate and qualify components for the future stockpile, assess foreign systems, analyze historic and current experiments, and improve computational models. The facility would also continue to function as a user facility for scientific studies.
- The **Future High Energy Density Capability** project would address major gaps in the ability to use high-energy X-ray and neutron sources to test the performance of nuclear weapon circuit boards and other large components in hostile threat environments. There are gaps in the energy and power capacity required to access the full range of high energy density (HED) conditions relevant to the nuclear explosive package; the proposed facility would help close these mission gaps while ensuring the safety and effectiveness of the nuclear stockpile by addressing the shortcomings and limitations of the aging Z Pulsed Power Facility.
- The **Enhanced Fusion Yield Capability at the National Ignition Facility (NIF) Project** would upgrade the NIF laser at LLNL, which is currently operating at its highest sustained levels of energy 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 upgrade paths are being assessed within the limitations of the current facility. DOE/NNSA is exploring other infrastructure solutions in addition to a line-item to address this need.
- The **Radiological Science Capability Project** would consolidate and relocate the aging radiological facilities that support 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 **Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility Modernization Project** would be a series of activities at LANL to extend DARHT's reliability and resilience, increase the quality and quantity of DARHT data, and enable hydrodynamic measurements in complex environments. These upgrades would ensure continued delivery of foundational hydrodynamic test capabilities in support of current and future national security missions, such as stockpile stewardship and global security.
- The **Building 851 Next Generation Cinematographic Moderate Energy Radiography Capability Project** would upgrade the LLNL 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 **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 at LLNL. The project would use the existing Contained Firing Facility and 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.

4.2.2.2 Weapon Simulation and Computing

Line-item projects in the Weapon Simulation and Computing area enable high performance computing (HPC) and the development of the weapons codes, models, and data analytics used to design and assess the behavior of nuclear weapons systems and components. **Figure 4–6** shows the planning estimate and schedule dates for the project proposal in this area that has an ongoing or upcoming pre-CD-0 planning study.

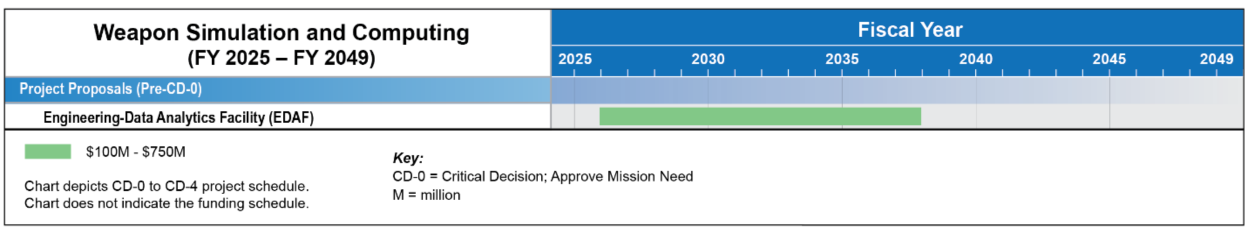


Figure 4–6. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Simulation and Computing

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

- The **Engineering-Data Analytics Facility Project** would construct a new HPC facility to 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.

4.2.2.3 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 meet all military requirements and endure all predicted environments. Planning estimates and schedule dates for projects in this area are listed in **Figure 4–7**, which also includes project proposals in this area that have an ongoing or upcoming pre-CD-0 planning study.

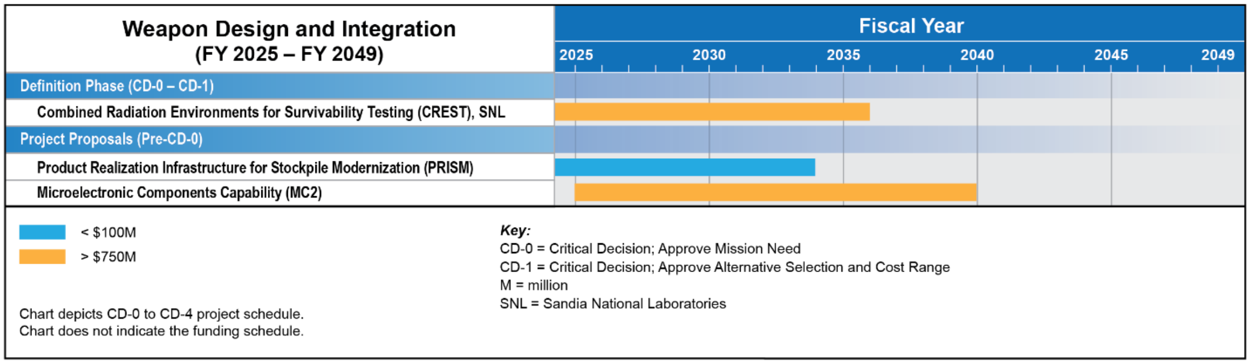


Figure 4–7. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Design and Integration

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 (ACRR) at SNL 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. 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 designed to meet current and future stockpile modernization needs.

In addition to the project in the Definition Phase, DOE/NNSA is considering several programmatic line-item proposals in the Weapon Design and Integration area. These project proposals are in the planning process (pre-CD-0) and 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 AoA and achieves CD-1.

- The **Product Realization Infrastructure for Stockpile Modernization (PRISM) Facility**, formerly the Next Generation Life Extension Program (LEP) Research and Development Component Fabrication Facility, would be a joint design agency/production agency-owned collaborative space and testbed to assess, develop, tailor, and transition new manufacturing technologies and designs to accelerate the development and production of non-nuclear components for future modernization programs. This project intends to use streamlined line-item acquisition procedures under the DOE Order 413.3 Supplemental Directive.

- The **Microelectronic Components Capability (MC2) Project**, formerly the Heterogenous Integration Facility, would provide modern and agile clean room space to support microelectronic design and production at the Microsystems Engineering, Science, and Applications (MESA) complex at SNL. A new facility is needed due to the MESA complex's age and space limitations, the rapid evolution of microelectronics fabrication technologies, and the potential need to continuously produce trusted and strategic radiation-hardened microelectronics while simultaneously installing new fabrication and production capabilities. The proposed facility would provide state-of-the-art cleanroom space, integrate a variety of microelectronic technologies, and accommodate the evolving tool-size platforms that are not possible in the current MESA complex.

- The **Full Replacement of Saturn and High-Energy Radiation Megavolt Electron Sources (HERMES) Project** would involve the construction of a facility to replace the current capabilities of both Saturn and HERMES. The project would include modified, upgraded, and enhanced accelerators; new buildings for high bay laboratory space, data collection, analysis laboratory space, and light electrical laboratory space; and support, storage, office, administrative, and conferencing space.
- The **Gas Transfer Systems (GTS) and Surety Laboratory** would enable DOE/NNSA to meet GTS and Surety enduring mission needs for future systems, such as the W93. The current GTS facility at LANL is over 60 years old and has been modified to temporarily shore up capabilities to meet past and current mission work. The future laboratory would provide a modern structure with lower maintenance requirements that can meet the expanded future demands of the weapons program, as well as work areas and equipment with an efficient layout and current state-of-the-art technology required to meet future testing needs.

4.2.2.4 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. Planning estimates and schedule dates for projects in this area are listed in **Figure 4–8**, which also includes project proposals in this area that have an ongoing or upcoming pre-CD-0 planning study.

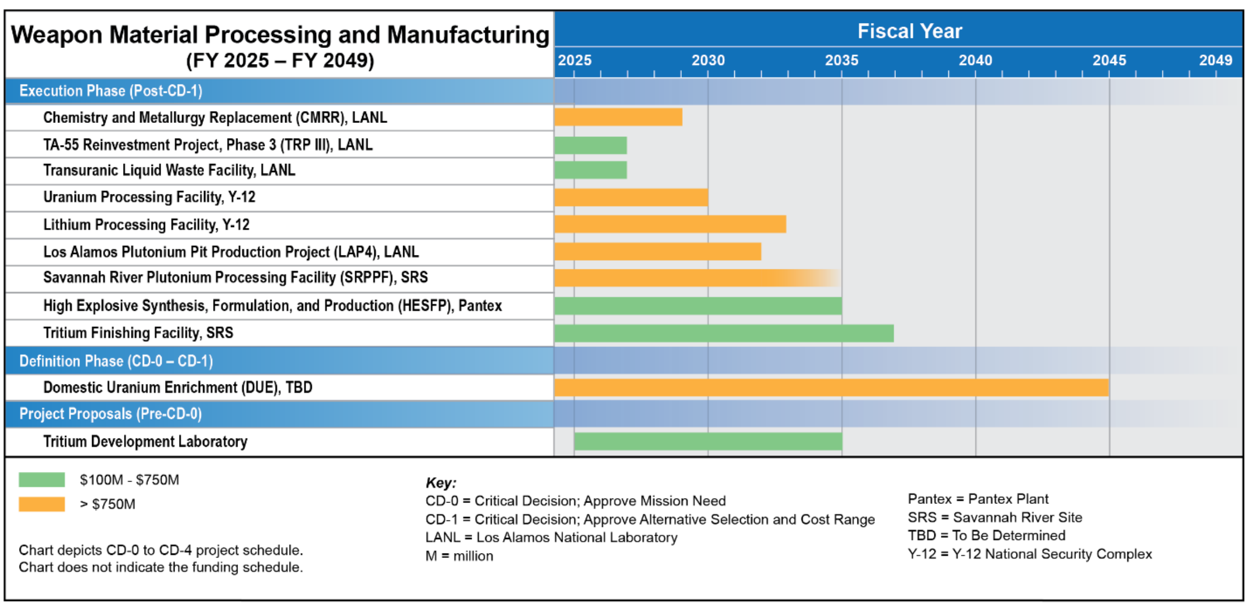
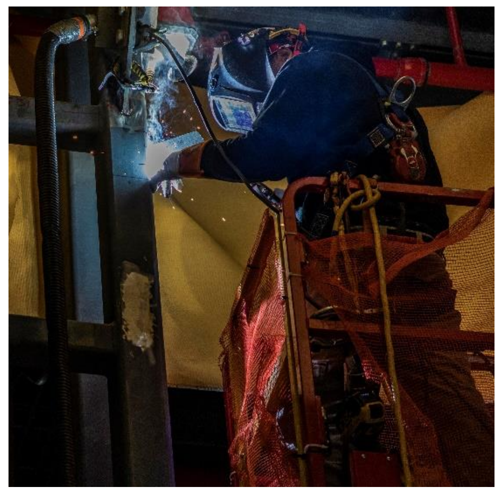


Figure 4–8. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Material Processing and Manufacturing

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

- The **Uranium Processing Facility (UPF) 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's enriched uranium processing capabilities currently located in Building 9212, which is an original Manhattan Project-era facility that is degraded, poorly configured to meet today's strategic needs, and poses multiple risks to meeting the mission.



Equipment installation in the Main Process Building (left) and a worker in the Salvage and Accountability Building (right) at the Y-12 Uranium Processing Facility in 2023

- The **Transuranic Liquid Waste (TLW) Facility** will support transuranic liquid waste treatment, which is a key support capability for DOE/NNSA operations at PF-4 at LANL. The current Radioactive Liquid Waste Treatment Facility is past its useful life and does not meet current codes and requirements. The TLW 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)** will support 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 **Lithium Processing Facility (LPF) Project** will construct a new facility to replace the current lithium facility at Y-12. At more than 80 years old, the current 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 was selected at Y-12, and the former Biology Building was demolished to make room for this project. Lithium process design is 60 percent complete and facility design and site civil exploratory boring activities have commenced. The East End Electrical Substation will also be constructed to meet increasing power demands associated with LPF.

- The **Los Alamos Plutonium Pit Production Project (LAP4)** will support plutonium pit production at LANL. LAP4 will replace aging and outdated equipment with pit manufacturing equipment in PF-4 at LANL to increase throughput. LAP4 achieved CD-2/3 for the Decontamination and Decommissioning subproject in the first quarter of FY 2022 and the 30 Base Equipment Installation subproject in the second quarter of FY 2023.
- The **Savannah River Plutonium Processing Facility (SRPPF)** will support plutonium pit production at SRS by repurposing the former Mixed Oxide Fuel Fabrication Facility into a safe, secure, compliant, and efficient pit production facility. The former Mixed Oxide Fuel Fabrication Facility is a Security Category I/Hazard Category II[3] 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 pits per year as close to 2030 as possible at SRS. Other minor construction and recapitalization projects outside of line-item scope will be necessary at SRS to support plutonium pit production at SRPPF.
- The **High Explosives Synthesis, Formulation, and Production (HESFP) Facility** at Pantex will establish an HE production capability within the nuclear security enterprise to address DOE/NNSA production requirements. This project will consolidate limited legacy facilities and provide the required capability and capacity to address explosive and mock formulation operations to support multiple weapon programs, technology development for future programs, and strategic partners. CD-1 was approved in February 2021, and CD-2/3 100 percent design is complete. DOE/NNSA strategically paused the HESFP project to prioritize projects that provide greater support to delivery of warheads on the schedule needed by the military and is re-evaluating its approach to the project.
- The **Tritium Finishing Facility (TFF) Project** at SRS will construct two new Process Buildings and relocate reservoir-related and other capabilities from the current 65-year-old facility to newer, centralized facilities. This will significantly increase facility reliability specific to natural phenomena hazards, addressing Defense Nuclear Facilities Safety Board concerns. While 30 percent design completion was authorized for the overall project, the need to prioritize staffing for SRPPF at SRS led DOE/NNSA to strategically pause the TFF project. DOE/NNSA is re-evaluating its approach to this project.

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 for defense missions.

In addition to projects in the Definition and Execution Phases, DOE/NNSA is considering several programmatic line-item proposals in the Weapon Material Processing and Manufacturing area. These project proposals are in the planning process (pre-CD-0) and should not be considered part of the program

[3] Security Category I facilities are designed to contain certain quantities of strategic special nuclear materials and require the most rigorous levels 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.

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 AoA and achieves CD-1.

- The **Tritium Development Laboratory** would reestablish the radiological R&D capability required for maturation and de-risking of new tritium and GTS processing technologies to meet mission requirements, address obsolescence, increase efficiency, and maintain core competencies. A DOE/NNSA study is underway to assess current capabilities across DOE to establish whether a Tritium Development Laboratory is needed.
- The **Depleted Uranium Complex**, formerly the Depleted Uranium (DU) Manufacturing Complex, would consolidate several processes required to meet the DU mission and replace capabilities currently located in other buildings at Y-12. DU production facilities that support canned subassembly production at Y-12 were constructed in the 1940s and 1950s. These facilities perform production work for DU and general manufacturing; they are vital to canned subassembly production. However, they are oversized for today's mission, do not meet current codes and standards, are costly to operate, have many operating issues, and have exceeded their life expectancies. These facilities must be upgraded or replaced to ensure continued mission availability and reduce annual operating costs.
- The **Integrated Technology for Advanced Manufacturing (ITAM) Campus Project** would create modern infrastructure with capabilities for development of advanced assembly system technologies (e.g., robotics and automation, welding, inspection) to accelerate deployment. The ITAM Campus would collocate several capabilities, including manufacturing, assembly, computing, characterization, and inspection expertise, in an open, collaborative space with the ability to elevate to secure, when needed.
- The **Analytical Chemistry Lab (ACL) Project** would construct a stand-alone laboratory in the protected area to replace the current 9995 Hazard Category II laboratory in Building 9995 at Y-12. This would ensure the capability is viable to support all future enriched uranium mission requirements. The 9995 laboratory performs compositional analysis of a broad range of samples in support of various programs, including weapons material production, waste management, environmental remediation, and health and safety. Building 9995 supports special nuclear material (SNM) and non-SNM production. All production-related work will eventually cease if the appropriate analytical- and infrastructure-related capabilities fail to perform as planned. Additional planned construction will replace other material sampling currently performed in Building 9995.
- The **High Explosive Component Assembly Facility Project** would support weapons assembly, disassembly, and stockpile surveillance. The facility would be required to fabricate parts for current weapon rebuilt units, future nuclear weapon assembly and rebuilds, and joint test assemblies. The existing component assembly facilities at Pantex support all current weapons systems subassembly, weapons surveillance subassembly, and main charge dismantlement activities under the production, surveillance, and dismantlement Production Control Document schedule. Facility capacity must support the assembly and disassembly rates projected for future workloads.
- The **Applied Technologies Laboratory** would provide a small, modernized facility designed with more efficient HVAC and laboratory controls to support development operations associated with uranium and lithium missions. The current, aging facility's development operations include essential technology solutions and advancements that enable Y-12 to provide material to

production, develop and demonstrate new uranium and lithium technologies, and provide weapons quality assurance.

- The **Enriched Uranium Manufacturing Center** would implement the second phase of the Uranium Strategy to replace enriched uranium capabilities in the Building 9215 Complex at Y-12. The line-item would include machining, chip cleaning, dimensional inspection, and analytical services, including parts storage and quality evaluation.

4.2.2.5 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. Planning estimates and schedule dates for the project in this area are listed in **Figure 4–9**.

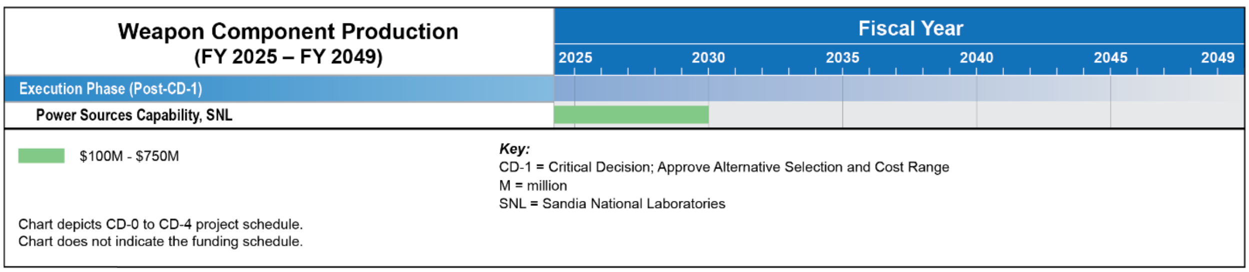


Figure 4–9. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Component Production

The Weapon Component Production area has one line-item project in the Execution Phase that is past 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—very few commercial suppliers are viable for this work. The current facility at SNL 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 Execution Phase, DOE/NNSA is considering two programmatic line-item proposals in the Weapon Component Production area. These project proposals are in the planning process (pre-CD-0) and 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 each project completes an AoA and achieves CD-1.

- The **Neutron Generator Enterprise Consolidation (NGE+) Project** would optimize manufacturing by consolidating existing facilities for neutron generator operations that are currently conducted in several buildings across multiple sites. Additionally, modernizing aging infrastructure and providing flexible-use space is needed to accommodate agile responses to advancing requirements and technology; develop material and personnel flows; improve efficiency; consolidate processes; and reduce redundancies, waste, and risks to mission work.

- A project that addresses the need for **Manufacturing Sciences for Nuclear Explosive Package Components** would construct new facilities to maintain and enhance capabilities for materials and manufacturing process development for nuclear explosive package applications (excluding plutonium, HE, and polymers/soft materials) that the Sigma Complex currently fulfills at LANL. Co-located buildings are envisioned to support uranium foundry operations, the deformation process, welding/joining/additive manufacturing, an electrochemistry facility capable of radiological and beryllium operations, and a beryllium fabrication capability with appropriate ventilation scaled to support the projected size of future mission need.

4.2.2.6 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. Planning estimates and schedule dates for ongoing and proposed projects in this area are listed in **Figure 4–10**, which also includes project proposals in this area that have an ongoing or upcoming pre-CD-0 planning study.

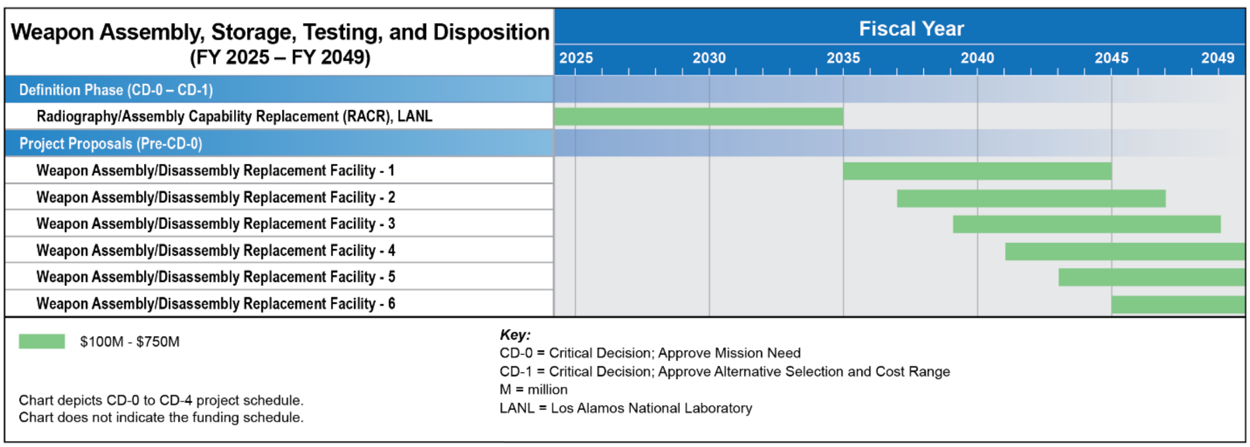


Figure 4–10. 25-year programmatic line-item schedule for ongoing and proposed projects related to Weapon Assembly, Storage, Testing, and Disposition

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 and thus is not included in Figure 4–10. The project would seek to address the mission need for secure, sustainable capabilities to enable nuclear weapon and nuclear component staging. DOE/NNSA is analyzing scope requirements and corresponding cost estimates to meet the mission need. The team reviewing the project will also consider multiple minimum viable projects capable of progressive build in a campus arrangement to provide the best value. Necessary actions to extend the use of Zone 4 have been identified, including maintaining the current staging facilities, security, and other key infrastructure.

- The **Radiography/Assembly Capability Replacement (RACR) Project** received CD-0 approval in October 2022; however, after CD-0 approval, an integrated project team investigated alternative strategies to meet program requirements via a minimum viable product approach in lieu of a single line-item investment. DOE/NNSA is still analyzing how to move forward to meet the mission need, with the goal of consolidating existing assembly and radiography operations currently conducted in a multitude of facilities at LANL dating to the 1950s and spread throughout the campus.

DOE/NNSA is considering three programmatic line-item proposals in the Weapon Assembly, Storage, Testing, and Disposition area. These project proposals are in the planning process (pre-CD-0) and 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 AoA and achieves CD-1.

- The phased **Weapon Assembly/Disassembly Replacement Facility Projects** would ensure that Pantex maintains the capability to support all ongoing and future weapon programs for DOE/NNSA. Pantex bays and cells are the only facilities in the Nation authorized for the full assembly and disassembly of nuclear weapons. These weapon assembly and disassembly operations are conducted in 60 bay and cell facilities, as well as in special purpose satellite facilities. The facilities are an average of 47 years old, with many facility systems using outdated technology and nearing the end of their useful life. The proposed weapon assembly/disassembly replacement facilities will focus on increasing throughput and efficiencies, lowering operating costs, and reducing the number of Technical Safety Requirements controls.
- The **Consolidated Environmental Test Facility Project** would upgrade, modernize, and consolidate environmental testing capabilities in support of stockpile modernization programs and limited life components associated with enduring the stockpile.
- The **Assembly and Disassembly Center Project** would complete the third and final phase for the Enriched Uranium Strategy. The new facility would support Y-12's enriched uranium processing capabilities: product certification, quality evaluation and surveillance, assembly of components, dismantlement and disassembly of components, radiography, and dimensional inspection.

4.2.2.7 Transportation and Security

Line-item projects in the Transportation and Security area support protection of all aspects 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**, which also includes project proposals in this area that have an ongoing or upcoming pre-CD-0 planning study.

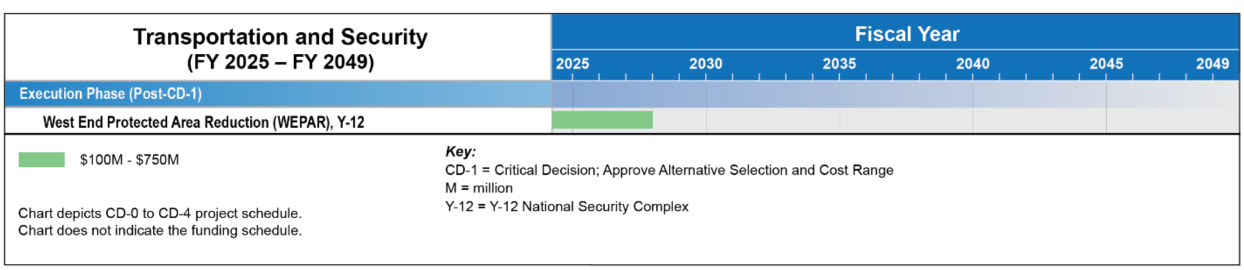


Figure 4–11. 25-year programmatic line-item schedule for ongoing and proposed projects related to Transportation and Security

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. A new Perimeter Intrusion Detection and Assessment System will protect the sensitive facilities remaining within the now reduced perimeter, reducing security and operating costs. DOE Office of Environmental Management cleanup activities for facilities previously encompassed by the larger protected area may also 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.

4.2.3 Mission Enabling Construction

Mission enabling infrastructure line-items provide site-wide utilities, office and laboratory space, and other services that support the nuclear deterrence mission. Two mission enabling line-item projects were recently completed:

- The SNL Emergency Operations Center, which houses emergency management staff offices and the 24/7 Emergency Management Communications Center. The communications center features dedicated spaces for incident management and coordination, as well as multi-purpose training rooms. The new facility is equipped with improved tools and enhanced capabilities to collect, analyze, and share incident information with internal and external emergency response organizations. The Emergency Operations Center began full operations in early 2024.

Sandia Emergency Operations Center

- The 138 kilovolt (kV) Power Transmission System Replacement Project, which held a ribbon-cutting ceremony in March 2024, designed and constructed a new 138 kV power transmission system to replace and upgrade 26 miles of the degraded, 55-year-old existing system in the mission corridor at NNSS. Along with upgrading the collocated fiber optic lines, the project provides the site with reliable power and communications to mission critical facilities.

Crews working on the 138 kV Power Transmission System Replacement Project at NNSS

Planning estimates and schedule dates for mission enabling line-items are listed in **Figure 4–12**, which also includes project proposals that have an ongoing or upcoming pre-CD-0 planning study. These projects are crucial to meeting daily operational needs across the nuclear security enterprise.

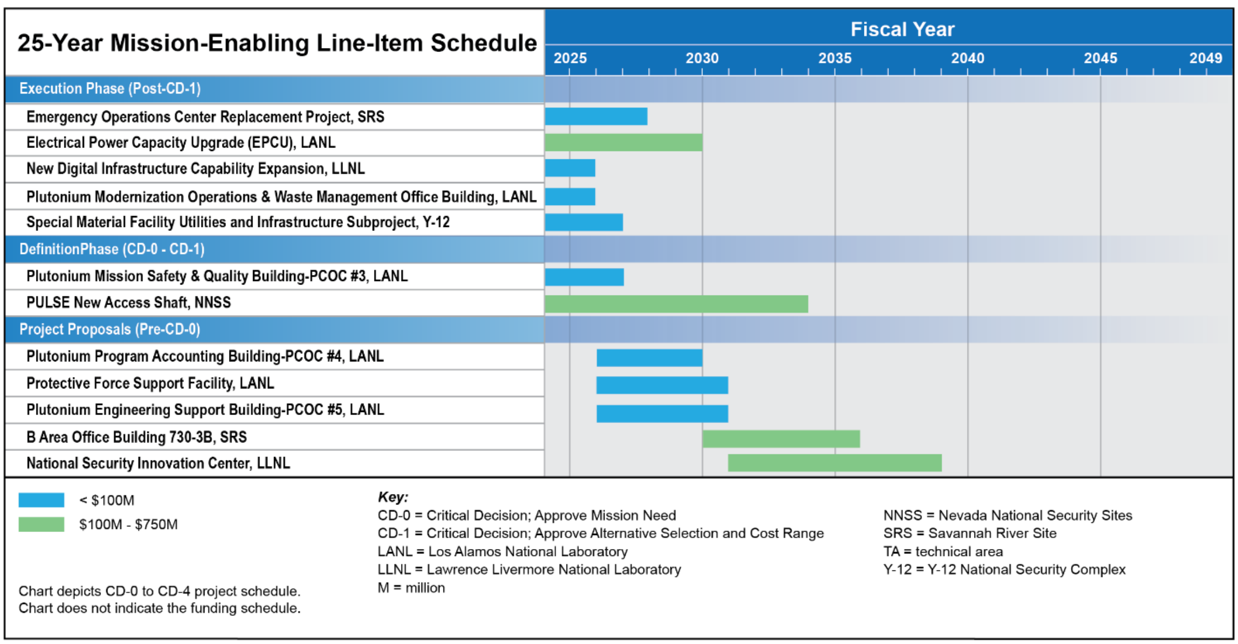


Figure 4–12. 25-year mission enabling line-item schedule

The following mission enabling projects listed are in the Execution Phase of the CD process:

- The **Emergency Operations Center Replacement Project** at SRS is a new 31,000-square-foot facility that will provide emergency and non-emergency communications 24/7/365, and will manage all site emergencies once formally activated. This project replaces the existing Emergency Operations Center, which is located in the basement of a building that is past its design life and experiencing utility failures. This project is funded by the DOE Office of Environmental Management and will be managed by DOE/NNSA to align with the transition of SRS to DOE/NNSA. The project achieved CD-0 in January 2017 and CD-1 in June 2020, and is being executed using the Supplemental Directive 413.3-7 streamlined approach.

- The **Electrical Power Capacity Upgrade (EPCU)** at LANL will address projected increases in electrical demand to reliably support multiple program activities performed at the site. Power demand for all programs is expected to exceed the system's existing transmission and distribution capacity. This electrical upgrade will support critical Weapons Activities requirements for stockpile modernization programs, SFIs, ongoing stockpile stewardship programs, and other work, as well as add redundancy to power supply at LANL.
- The **Digital Infrastructure Capability Expansion (DICE) 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 **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 **Plutonium Modernization Operations & Waste Management Office Building** is currently in the execution phase. In addition, this complex encompasses the TA-46 Protective Force Facility, the Plutonium Production Building, the Plutonium Mission Safety & Quality Building, the Plutonium Program Accounting Building, the Protective Force Support Facility, and the Plutonium Engineering Support Building.
- The **Special Materials Facility Utilities and Infrastructure Subproject** will provide infrastructure and utility upgrades at Y-12. This repurposed facility is necessary to support special materials processing and production for future mission requirements. The facility has received funding and approval for execution under an EMC^2-like acquisition approach. Project design commenced in FY 2022.

The following mission enabling projects listed are in the Definition Phase of the CD process:

- The **Plutonium Mission Safety & Quality Building** is a component of the Plutonium Modernization Operations Complex at LANL.
- The **PULSE New Access Shaft Project** at NNSS would provide expanded access to the PULSE underground to support the increased operations of multiple testbeds resulting from the ongoing expansion of the science-based Stockpile Stewardship Program.

There are multiple proposals for new mission enabling projects planned over the next 10 to 25 years. These project proposals are in the planning process (pre-CD-0) and 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 AoA and achieves CD-1.

- The **Plutonium Program Accounting Building**, the **Protective Force Support Facility,** and the **Plutonium Engineering Support Building** are components of the Plutonium Modernization Operations Complex at LANL that are anticipated pre-CD-0 projects.
- SRS is planning to increase staffing to meet an increase in production needs. The **B Area Office Building 730-3B** will provide additional office space to house pit production administrative staff while F Area facilities are constructed.
- The **National Security Innovation Center** at LLNL would move staff out of dispersed, end-of-life Weapons Program office buildings into a more centralized location and would enable optimized use of space. Stockpile modernization efforts and future stockpile stewardship missions require

multidisciplinary teams of scientists and engineers to develop, innovate, and apply sophisticated modeling and simulation tools to conduct high-fidelity experiments. The multidisciplinary team approach requires collocated weapons program staff equipped with quality classified workstations with modern information technology infrastructure.

- Pantex's current maintenance facilities are dispersed, inefficient, and nearing the end of their operational life expectancies. The **Production Maintenance Facility** would replace multiple facilities, consolidate maintenance processes, and provide a more efficient location to support production operations and facilities. The new facility, as well as the Tooling Replacement Facility, would be located together in a campus to provide consolidated tooling and tooling-related maintenance processes.
- Pantex tooling operations are required to support the weapons assembly/disassembly and SNM mission, including tooling receipt, quality inspection, and storage. Pantex's tooling operations are currently housed in an antiquated, inadequate facility that is in poor condition; the proposed **Tooling Replacement Facility** would address this gap.
- The **Component Staging and Packaging Facility (Building 12-064)** at Pantex is currently used for nuclear and non-nuclear operations including nuclear component staging, packaging operations, and container activities. Due to structural concerns with Building 12-064, no nuclear explosive operations are allowed. The replacement of this building will ensure a modern, right-sized facility that will meet the required capability and capacity to support future nuclear workload and mission requirements. This out-year lifecycle replacement project will relocate packaging and container operations into a modern, right-sized facility.
- LLNL's Environment, Safety and Health (ES&H) analytical laboratory services directly support the health and safety of radiation workers as well as the compliance with regulatory requirements to enable mission critical functions. The buildings in which the laboratories currently reside are beyond their expected life, are aging, and are brittle. The **New ES&H Analytical Laboratory Facility** will relieve strain on the operational structure and increase resiliency and responsiveness in the long term.
- The Y-12 Waste and Transportation Management mission is to manage the full lifecycle of all waste generated at the site. The **New Waste Management Complex** aims to consolidate capabilities required to support future Y-12 needs. The current facilities range in age from 30 to 50 years old and are not appropriately sized for future mission needs. The complex will provide a centralized, efficient location for Waste Management and Sustainability and Stewardship activities in a smaller overall footprint.
- The **Analytic Gas Laboratory** at Pantex will 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 nonproliferation missions at Pantex.

4.2.4 Other Acquisition Efforts

DOE/NNSA is also executing multiple acquisitions through various purchase and leasing tools and expanding the use of DOE/NNSA acquisition authorities.

4.2.4.1 Real Estate and Leased Facilities

Leases are an important real estate strategy to address short-term needs. DOE/NNSA is streamlining its process to better use leasing as a tool for addressing temporary mission needs while ensuring long-term needs are addressed in the most cost-effective manner. Leases provide the flexibility needed to deal with surges in mission work, but can be more costly than construction and ownership if not well structured or used as an enduring solution.

DOE/NNSA is implementing a range of innovative tools and processes related to leasing strategies. The lease scoring system rolled out in early 2019 is driving better decision making by offering an objective metric for evaluating a lease's risk and comparing it within DOE/NNSA's broader leasing portfolio. This system helps improve the terms and conditions in leases, minimize tenant improvements, and ensure exit strategies are in place for new leases. Lease scoring is also normalizing the solicitation for space to encourage better rates, while site visits improve usage and ensure the lessor is delivering per the lease.

DOE/NNSA is also developing guidance to support unique contracts that include real estate elements. The guidance will help DOE/NNSA determine Real Estate Contracting Officer involvement and oversight to mitigate risk. The hybrid guidance will improve future contract execution and provide additional transparency to all stakeholders.

4.2.4.2 Direct Purchases

DOE/NNSA continues to expand the use of acquisition authority through purchase across the enterprise.

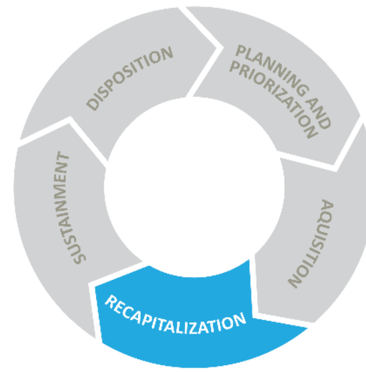
- **Kansas City Non-Nuclear Component Expansion Transformation (KCNExT)** is a multi-year, multi-phase lease-purchase project to increase capacity and capability of both office and manufacturing space to meet requirements. KCNSC facilities are charged with manufacturing and sourcing more than 85 percent of the non-nuclear components in the nation's weapon systems. The current KCNSC Botts campus was sized to support workload projections based on one weapon modernization program in production and one weapon modernization program in development. KCNSC is now supporting three weapon modernization programs and three weapon modernization programs in development.

  As a result, KCNExT will be a series of independent projects to accommodate expected long-term growth. KCNExT will provide flexibility to expand, reconfigure, and/or consolidate operations conducted across the Kansas City metropolitan area facilities. Using the existing authority to purchase real property, DOE/NNSA plans to negotiate a series of lease-purchase agreements with the current landowner to construct portions of the property to meet expanding requirements. In addition to acquiring and operating the KCNExT campus, KCNSC will consolidate operations and employees from other leased facilities in the Kansas City metropolitan area to KCNExT, terminating leases at those locations.

- As part of the Kansas City Short-term Expansion Program (KC STEP), **Building 23** is a recent acquisition conducted in 2023 that provides an additional 450,000 square feet of warehouse space within a mile of the current campus for KCNSC East. The infrastructure upgrades to this facility allow for the relocation of specific manufacturing capabilities to KCNSC East. This will establish new capabilities at KCNSC East as well as expand and rearrange other manufacturing capabilities remaining at the Botts Road main campus. While planning efforts continue for the KCNExT as a long-term facility expansion strategy, KC STEP provides near-term increased factory capacity to support the B61-12 LEP and W88 Alteration 370, as well as partially filling needs for the W80-4 and W87-1 programs.

NNSA continues to evaluate the best approach to gaining new infrastructure to meet the mission needs in a timely and cost-effective manner. In some instances, direct purchase is in the best interest of the U.S. Government. Developed in 2021, 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 provides necessary assurance to the owner and required time for DOE/NNSA to perform the due diligence for any Federally funded purchase.

4.3 Recapitalization



Through recapitalization, DOE/NNSA, in partnership with M&O contractors, modernizes and sustains assets to enable mission success and readiness; ensures operational safety and security; safeguards the workforce, public, and environment; and meets nuclear security mission needs.

In addition to major acquisition and line-item construction, DOE/NNSA uses minor construction and recapitalization to sustain major facilities and replace smaller capital assets. These projects are an effective method to increase DOE/NNSA's mission performance and reduce operating costs because they can be completed much faster than line-item construction projects and are frequently more cost effective due to less stringent reporting and oversight. Minor construction and recapitalization enable DOE/NNSA to be responsive to emerging infrastructure issues and changing stockpile requirements.

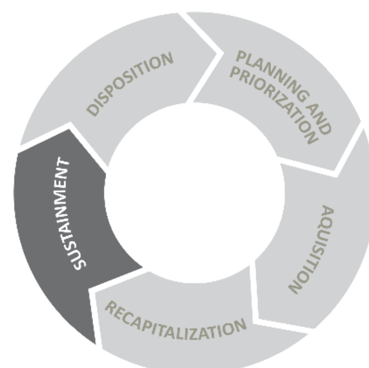
Modernizing the nuclear security enterprise is accomplished through formal recapitalization programs planned and funded at the DOE/NNSA level, site-directed investments, and other funding mechanisms. These investments improve the condition, reliability, efficiency, and capability of infrastructure to meet mission requirements. Programs plan and execute replacement, installation, upgrades, and minor construction projects to revitalize existing facilities or construct new facilities and additions. In some applications, a campus approach to addressing larger requirements can be applied by executing a series of projects over multiple funding years.

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

- Pantex – Bay and Cell Safety System Replacement Portfolio (all cell HPFL scope)
- Pantex – West Electrical Interconnect Replacement
- Pantex – Building 12-104A Blast Door Interlock Programmable Logic Controller Replacement
- LLNL – New Building 321G Manufacturing Building (Site Directed Investments)
- LLNL – New Building 310 Nondestructive Evaluation Building
- LLNL – New Building 144 Stockpile Office Building (STAR)
- LLNL – New Building 226 Vapor Deposition Process Lab/Joining Facility (STAR)
- LLNL – New Building 449 Design Certification Office Building (STAR)
- LLNL – Building 321A Radiological & Materials Characterization Facility Revitalization
- LLNL – New Building 265 Environmental, Safety and Health Building (STAR, Site Directed Investments)
- LANL – TA-16-260 HE Pressing Facility Bays 1 & 2 Renovation (Recapitalization)
- LANL – TA-08 HE Shipping and Receiving Facility (Recapitalization)
- LANL – LANSCE Fire Suppression Portfolio (Recapitalization)

- LANL – LANSCE Industrial Controls (Recapitalization)
- LANL – PF-4 Controls Systems Component Replacement (Recapitalization)
- SNL – Building 858N (MESA SiFab Bulk Chemical Distribution System Upgrade)
- SNL – NM/KAFB Redundant Gas Line Replacement
- SNL – 14” Water Line Replacement (H Street)
- SNL – Weapon Engineering Science and Technology Laboratory
- NNSS – PULSE New Sewage Lagoon
- NNSS – New Nevada Site Operations Center Building 23-461KC – Building 23 Tool Room & Model Shop Machining Operations Area Expansion Buildout
- Y-12 – Fire Water Lateral Replacement Portfolio
- Y-12 – Nuclear Facility Criticality Accident Alarm System Replacement
- Y-12 – Building 9204-02E Transformers 814 and 815 Replacement
- Y-12 – Building 9215 Switchgear and Transformer 253 Replacement

4.4 Sustainment



DOE/NNSA, in partnership with M&O contractors, maintains and operates existing infrastructure to enable mission success and readiness; ensure operational safety and security; safeguard the workforce, public and environment; and meet mission needs more efficiently and cost-effectively.

Sustainment activities include operations, maintenance, and repair activities to ensure the condition of real property assets is sufficient for them to perform their designated purposes and to mitigate risks. In some instances, the nature of core mission areas leads to direct programmatic sustainment funding for certain missions. These efforts support the recurring daily work needed to sustain and operate plants, properties, assets, systems, roads, and equipment in conditions suitable for their designated purposes. Effective sustainment planning, including the maintenance of a detailed backlog of required work, provides a valuable metric of the overall health of a site’s facilities and infrastructure. Sustainment plans also guide the determination of maintenance strategies (e.g., predictive, preventive, or corrective) and provide facility condition models based on maintenance funding levels and other external drivers. These models offer leaders a prediction of the extent to which infrastructure will support mission attainment in coming years.

As the workload increases for stockpile sustainment and modernization, demand is expected to increase on facilities supporting mission work across the nuclear security enterprise. Line-item projects are experiencing delays, and planned infrastructure may also experience delays to their projected schedules. As the delivery of these projects are delayed, the enterprise will continue to rely on aging infrastructure; therefore, the sustainment of these facilities must be a priority, and maintenance and recapitalization needs must factor into risk mitigation activities and investments.

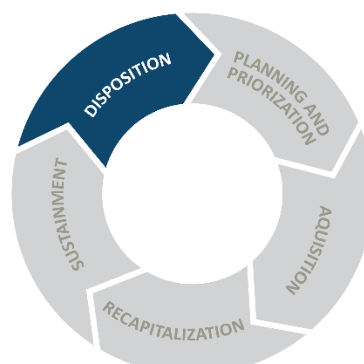
External Impacts on Operations and Maintenance

DOE/NNSA is working to address the legacy impacts of the Coronavirus Disease 2019 (COVID-19) pandemic and other geopolitical events that led to disruptions in the established vendor base, industry supply chains, and labor markets. The extended lead times for components and the scarcity of qualified labor have raised concerns about potential delays in infrastructure delivery, increased supply costs, and the need to maintain current infrastructure during the construction phase. DOE/NNSA is diligently working to mitigate risks posed by these issues.

DOE/NNSA is leveraging its purchasing power by expanding strategic procurements and updating subcontracting requirements. It is expanding its partnership with the Supply Chain Management Center to create new contracting vehicles for construction services that may be leveraged by any site. The use of the Defense Priority Allocation System for defense-related acquisitions has also helped shorten delivery times by mandating higher priority with vendors. In August 2023, DOE/NNSA raised the dollar thresholds on its subcontracting packages for faster procurements that are better in line with today's costs. Now only subcontracting packages over $100 million require Federal consent; those between $30 million and $100 million require notification, but not consent.

DOE/NNSA uses strategic procurements to achieve cost and time savings on significant building systems and construction services. Building on the success of two asset management programs that use supply chain management strategies for the repair and replacement of building system (the Roof Asset Management Program and the Cooling and Heating Asset Management Program), DOE/NNSA utilizes contracting vehicles that directly support infrastructure projects.

4.5 Disposition



DOE/NNSA infrastructure that is no longer needed must be dispositioned to minimize risks to workers, the public, the environment, and the mission. Dispositioning infrastructure also reduces the cost burden of maintaining excess facilities in a safe and secure state. Approximately 8.7 percent of assets located on DOE/NNSA's sites are designated as excess. This number represents over 300 excess assets with 3.7 million gross square feet. The need for new construction space often drives the need for disposition investments. Other high priority dispositions include stabilizing degraded facilities, characterizing hazards and conditions, removing hazardous and flammable materials, and placing facilities in the lowest acceptable risk condition possible until they can be dispositioned. DOE/NNSA's area plans outline the details of how DOE/NNSA plans to address excess facilities.

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

- Demolition of two higher-risk process contaminated facilities – NNSA's Ice House (Building 41-0004) at LANL and the DOE Office of Environmental Management Criticality Laboratory (Building 9213) at Y-12;
- Advanced planning and field work performed in support of the utility reroute scope associated with DOE-Office of Environmental Management disposition activities in preparation for the demolition of the large process contaminated excess facilities at Y-12;
- Demolition of Building 251 (Heavy Elements Facility) at LLNL;

- Removal of Building 862 (Standby Power Plant) and 9970 at SNL;
- Demolition of 11 process and industrial contaminated facilities at NNSS; and
- Federal transfer of eight buildings at the old Albuquerque Complex, which reduces the scope of the complex's demolition.

The longer an unused facility is left standing before demolition, the more it deteriorates, and the more difficult it is to maintain in a safe shutdown condition. Aging facilities can pose risks to human health, the environment, and the mission. During the next 10 years, 550 additional assets with 3.7 million gross square feet are planned to become excess on DOE/NNSA sites. Process contaminated assets may require DOE Office of Environmental Management expertise to demolish. 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.

Chapter 5
Budget and Fiscal Estimates

The Fiscal Year (FY) 2025 President's Budget for Weapons Activities prioritizes implementation of the *National Defense Strategy* and the *Nuclear Posture Review* by modernizing the Nation's nuclear deterrent. It supports a safe, secure, reliable, and effective nuclear stockpile and a resilient and responsive nuclear security enterprise. The capabilities that enable the Department of Energy's National Nuclear Security Administration (DOE/NNSA) to design, manufacture, certify, transport, maintain, and assess the stockpile per the program of record, are described in Chapter 3, "Weapons Activities Capabilities that Support the Nuclear Security Enterprise," and outlined in Appendix B, "Weapons Activities Capabilities." Throughout this chapter, the FY 2025 President's Budget Request is compared to the FY 2024 enacted appropriation, so explanations of change will not exactly match the Congressional Justifications that DOE/NNSA submitted in support of the President's Budget Request.[1] The FY 2025 President's Budget provides an increase of 3.9 percent for Weapons Activities above the FY 2024 enacted appropriation.[2] DOE/NNSA coordinates closely with Department of Defense (DoD) to synchronize DOE/NNSA's warhead deliveries with the modernization of DoD delivery platforms, which is particularly important since all legs of the nuclear triad (land, sea, and air) are being modernized.

The first part of this chapter displays budgetary information for the FY 2025 budget request based on the program of record described in Chapter 2, "Stockpile Management" and the capabilities described in Chapter 3, "Weapons Activities Capabilities that Support the Nuclear Security Enterprise." Sections 5.4–5.8 compare the FY 2025 budget request to the FY 2024 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 and funding levels.

Section 5.9 describes the basis of cost projections for selected programs beyond FY 2025. The cost-estimating techniques supporting the budget request are consistent with Government Accountability Office best practices, and the estimates have been updated with current requirements for each weapon system. The chapter concludes with an overview of the 25-year resource requirements for 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.

- The Planning phase evaluates the range of work required 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

[1] The Congressional Justifications provide explanations of change between the FY 2023 enacted appropriation and the FY 2025 request based on the timing of document preparations and the passage of the FY 2024 appropriations bill.
[2] FY 2025 levels include the reallocation of $173 million in funding from Defense Environmental Cleanup to Weapons Activities and Federal Salaries & Expenses to support the transition of oversight of the Savannah River Site (SRS) to NNSA.

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 and management and operating (M&O) partners to ensure they reflect a complete set of requirements. This phase drives the development of a range of strategies, alternatives, and plans designed to accomplish timely execution of key mission priorities and enable DOE/NNSA to achieve its mission. DOE/NNSA also coordinates with DoD through the Nuclear Weapons Council on long-term planning, specifically with the Requirements Planning Document that covers 25 years of stockpile management. Intended to align weapon system modernization plans with delivery systems and platform schedules, the document acts as a strategic document that DOE/NNSA utilizes to inform future investment, scheduling, and resources.

- The Programming phase is the decision-making process that aligns available program resources with priorities, resulting in a balanced, integrated, executable Future Years Nuclear Security Program (FYNSP) that DOE proposes 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 describe the 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, then ensures DOE/NNSA spends those resources in accordance with the law. Budget Execution is the phase in which appropriated resources are distributed and controlled to achieve their approved purpose. After Congress passes and the President signs authorization and appropriation bills, the apportionment process makes funds available to DOE for obligation and expenditure. Appropriation legislation and the 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 the identified performance measures at multiple levels within DOE/NNSA, including evaluation of the performance of the M&O partners.

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

5.2 Portfolio Management

DOE/NNSA is implementing process improvements during the Planning and Programming phases to clearly identify the program elements of strategically important, cross-program portfolios; this process improvement facilitates better planning integration across DOE/NNSA. Leveraging business system improvements allows decision makers to better understand the interconnections between multiple portfolio elements and the implications of changing timelines or funding levels for one program or project on the whole portfolio.

The Integrated Infrastructure Planning Team is taking the initial steps to identify highest mission risk areas and balance investments across the infrastructure portfolio, as described in Chapter 4, "Infrastructure and Operations," Section 4.1.2. Section 4.3 describes how, in some instances, potential solutions to infrastructure requirements include a "campus" approach, which ensures quicker delivery of capability to the nuclear security enterprise rather than waiting for the completion of a single large project. The Institute for Defense Analyses, a Federally Funded Research and Development Center, recently completed a study for DOE/NNSA evaluating the use of portfolios for pooling construction contingency funds, defining several options for portfolio groupings and modeling the overall risk in each portfolio structure. Their recommendations are under consideration.

5.3 Fiscal Year 2025 Future Years Nuclear Security Program

The FY 2025 FYNSP budget request supports the current stockpile, warhead modernization and acquisition activities, recapitalization and modernization programs for infrastructure, and reestablishment of necessary production capabilities. It supports research and development (R&D) efforts, implementation of enhanced experimental and computational capabilities, and the Federal and M&O workforces who carry out this work. Of note, programmatic line-items are funded under the programs they support, while mission-enabling construction is funded through Infrastructure and Operations.

Table 5–1 displays the FY 2024 enacted budget, and the program budget requests for Weapons Activities for FY 2025 to FY 2029. Sections 5.4–5.8 describe the FY 2025 budget request in more detail.

Table 5–1. Overview of Future Years Nuclear Security Program budget request for Weapons Activities in fiscal years 2024–2029[a]

Activity	*Fiscal Year (dollars in millions)*					
	2024 Enacted	*2025 Request*	*2026 Request*	*2027 Request*	*2028 Request*	*2029 Request*
Stockpile Management	5,329.2	5,140.7	5,235.8	5,535.5	5,582.0	5,613.0
Production Modernization	5,865.9	5,877.7	6,290.5	6,618.5	6,955.6	6,918.7
Stockpile Research, Technology, and Engineering	3,280.4	3,174.2	3,219.8	3,221.1	3,180.6	3,310.9
Academic Programs and Community Support	122.0	128.2	121.9	121.9	121.9	121.9
Infrastructure and Operations	2,584.8	3,299.9	3,449.9	3,391.5	3,528.1	3,812.2
Secure Transportation Asset	357.1	371.4	412.2	457.6	461.7	465.0
Defense Nuclear Security	1,038.4	1,180.0	1,150.7	1,202.7	1,254.1	1,280.0
Information Technology and Cybersecurity	578.4	646.0	704.9	748.5	752.1	798.3
Legacy Contractor Pensions and Settlement Payments	65.5	30.6	64.2	40.9	39.4	39.7
Adjustments	(113.6)	0.0	0.0	0.0	0.0	0.0
Weapons Activities Total	**19,108.0**	**19,848.6**	**20,649.9**	**21,338.1**	**21,875.4**	**22,359.6**

[a] Totals may not add because of rounding.

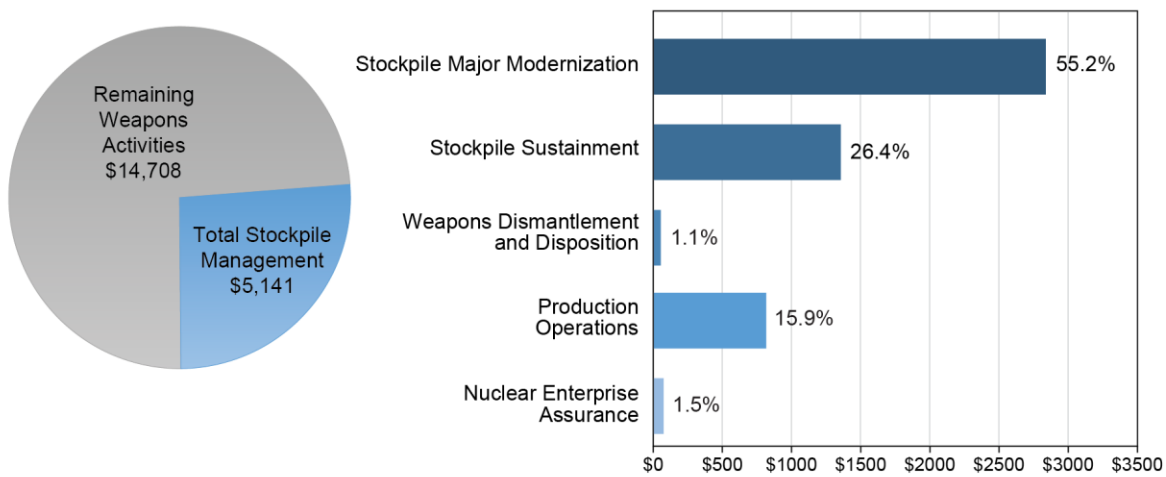
5.4 Stockpile Management

Stockpile Management encompasses five major subprograms that directly support the Nation's nuclear weapons stockpile: Stockpile Major Modernization, Stockpile Sustainment, Weapons Dismantlement and Disposition, Production Operations, and Nuclear Enterprise Assurance (NEA). Additional information about the Stockpile Management program can be found in Chapter 2, "Stockpile Management," and in the classified annex to the *Fiscal Year 2025 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (FY 2025 SSMP).

5.4.1 Budget

The budget request for Stockpile Management decreased 3.5 percent from the FY 2024 enacted budget and is illustrated in **Figure 5–1**.

Stockpile Management Funding Request for FY 2025
(Dollars in Millions)



Fiscal Year ($M)

	2024 Enacted	2025	2026	2027	2028	2029
Stockpile Major Modernization	3,219.2	2,838.8	2,814.1	3,008.4	2,997.3	2,969.5
Stockpile Sustainment	1,276.6	1,356.3	1,422.3	1,473.4	1,504.3	1,535.9
Weapons Dismantlement and Disposition	56.0	54.1	61.5	68.9	70.3	71.8
Production Operations	710.8	816.6	857.2	897.7	916.6	935.8
Nuclear Enterprise Assurance	66.6	75.0	80.7	87.1	93.5	99.9
Total Stockpile Management	5,329.2	5,140.7	5,235.8	5,535.5	5,582.0	5,613.0

Note: Numbers may not add due to rounding

Figure 5–1. Fiscal year 2025 President's Budget Request for Stockpile Management

5.4.2 Fiscal Year 2025 Budget Request Compared to Fiscal Year 2024 Enacted Budget

5.4.2.1 Stockpile Major Modernization

Stockpile Major Modernization updates the Nation's nuclear stockpile by replacing aging or obsolete components to ensure continued service life and enhancing security and safety features. Stockpile Major Modernization includes the B61 Life Extension Program (LEP), the B61-13 program, the W88 Alteration (Alt) 370 Program, the W80-4 LEP, the W87-1 Modification (Mod) Program, and the W93 Program. A dedicated line-item for the Sea Launched Cruise Missile-Nuclear (SLCM-N) is not included in the FY 2025 request, as the budget formulation process was near final when the *National Defense Authorization Act for Fiscal Year 2024* (FY 2024 NDAA) was signed into law; however, per Section 1640 of the FY 2024 NDAA, DOE/NNSA is coordinating with DoD to meet congressional direction and establish a program of record for SLCM-N.

The budget request for Stockpile Major Modernization decreased, representing an alignment of B61-12 LEP plans for the last production unit, the completion of component production for the W88 Alt 370, and a decrease for SLCM-N since no funding is requested.

5.4.2.2 Stockpile Sustainment

Stockpile Sustainment directly executes maintenance, limited life component exchanges, 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 slightly to support:

- A ramp-up in planned activities associated with the B61-12 transition to Stockpile Sustainment;
- A ramp-up in production readiness activities for the W76-1/2 Mk4B Shape Stable Nose Tip update to existing aeroshells in support of a first production unit in FY 2026;
- Product Realization Integrated Digital Enterprise (PRIDE) software development and deployment; and
- Integrated Surety Architecture activities.

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.

The decreased budget request for Weapons Dismantlement and Disposition reflects reduced levels for legacy component disposition and characterization.

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 covers sustainment of labor required for weapon systems capabilities that enable individual weapon production and are not specific to one material stream.

The budget request for Production Operations increased to support expanded engineering and quality assurance processes responsive to increased non-nuclear component production requirements and programmatic equipment maintenance.

5.4.2.5 Nuclear Enterprise Assurance

NEA, a subprogram first funded in the FY 2023 budget request, actively manages subversion risks to nuclear weapons and associated design, production, and testing capabilities. NEA enables the secure use of digital technologies in the modernization of weapons, facilities, and engineering capabilities by preventing, detecting, and mitigating the consequences of potential subversion.

The budget request for NEA increased, reflecting the coordination, integration, planning, and development of Operational Technologies and Nuclear Weapons Information Technology. These two strategies are mutually supportive and will be leveraged to create a comprehensive strategy per the FY 2024 NDAA, Section 3222.

5.4.3 Key Milestones

DOE/NNSA plans include the following key Stockpile Management milestones in **Figure 5–2**[3] to sustain and modernize the stockpile. There is one change from last year's plan: The 2030s/2040s notional stockpile modernization effort, *Delivery of the Future Air-based Warhead*, is removed due to revised planning by the Nuclear Weapons Council.

There were no milestones from the *Fiscal Year 2024 Stockpile Stewardship and Management Plan* (FY 2024 SSMP) anticipated to be completed in FY 2024.

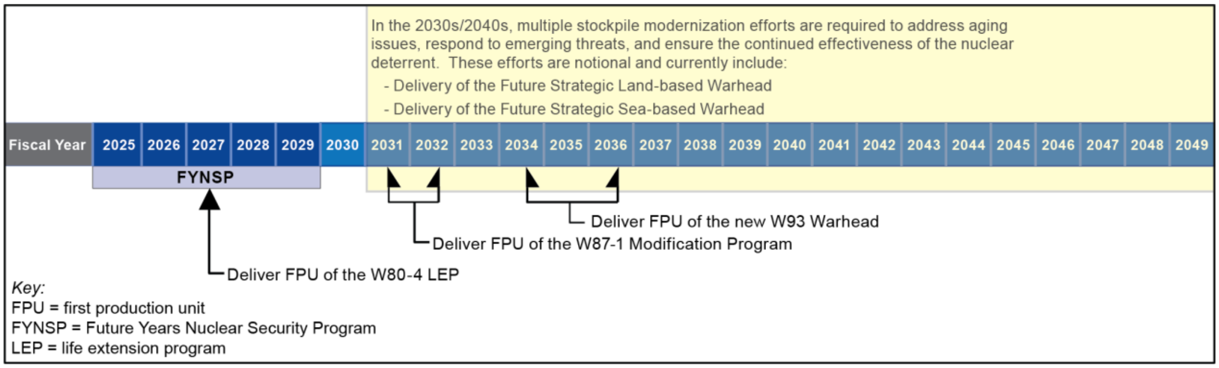


Figure 5–2. Key milestones for Stockpile Management

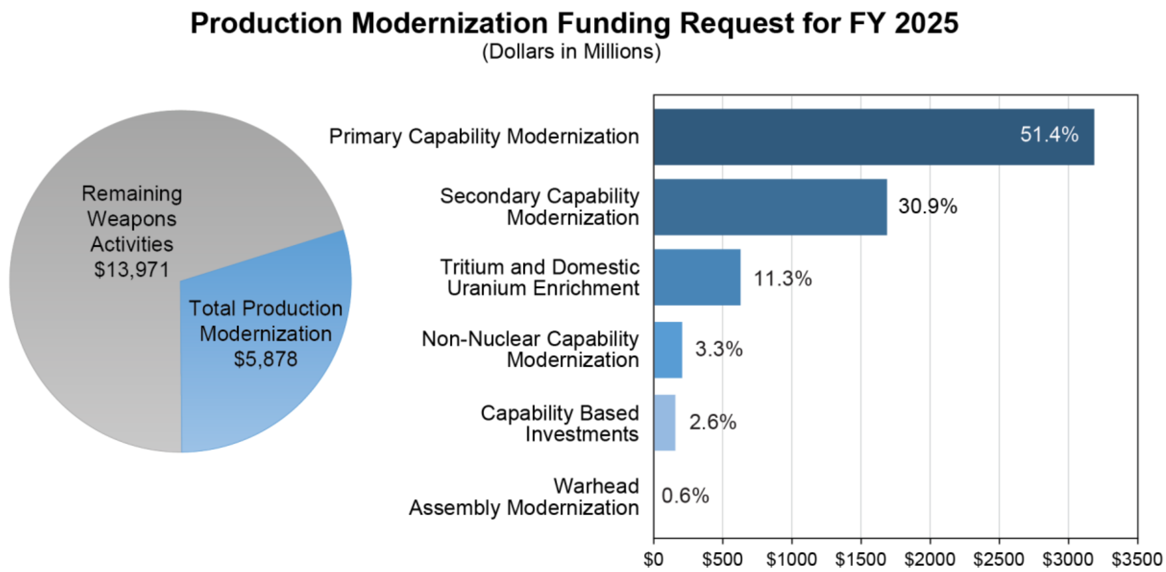
5.5 Production Modernization

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 six major subprograms: Primary Capability Modernization, Secondary Capability Modernization, Tritium and Domestic Uranium Enrichment (DUE), Non-Nuclear Capability Modernization, Capability Based Investments (CBI), and Warhead Assembly Modernization. Additional information is located in the classified annex to the FY 2025 SSMP.

5.5.1 Budget

The budget request for Production Modernization increased 0.2 percent from the FY 2024 enacted budget and is illustrated in **Figure 5–3**.

[3] These key milestones do not reflect 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 FY; meeting Surveillance Program requirements as approved via the surveillance governance model; and updating system reliability estimates and issuing a Weapons Reliability Report.



Fiscal Year ($M)

	2024 Enacted	2025	2026	2027	2028	2029
Primary Capability Modernization	3,188.9	3,022.1	3,704.9	4,138.5	4,387.6	4,430.4
Secondary Capability Modernization	1,687.7	1,815.4	1,503.1	1,312.8	1,327.0	1,172.9
Tritium and Domestic Uranium Enrichment	628.0	661.7	637.9	670.1	778.1	879.4
Non-Nuclear Capability Modernization	204.9	191.3	238.8	280.7	184.1	155.2
Capability Based Investments	156.5	153.2	146.5	161.4	162.5	163.7
Warhead Assembly Modernization	0.0	34.0	59.3	55.0	116.3	117.1
Total Production Modernization	5,865.9	5,877.7	6,290.5	6,618.5	6,955.6	6,918.7

Note: Numbers may not add due to rounding

Figure 5–3. Fiscal year 2025 President's Budget Request for Production Modernization

5.5.2 Fiscal Year 2025 Budget Request Compared to Fiscal Year 2024 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 comprises Plutonium Modernization and High Explosives and Energetics (HE&E) Modernization. The Plutonium program includes five line-item construction projects: Los Alamos Plutonium Pit Production Project (LAP4), Technical Area (TA)-55 Reinvestment Project Phase 3, Transuranic Liquid Waste Facility, Chemistry and Metallurgy Research Replacement project, and the Savannah River Plutonium Processing Facility (SRPPF). The HE&E program includes the High Explosives (HE) Synthesis, Formulation, and Production project and the HE Science and Engineering Facility.

The budget request for the Primary Capability Modernization program decreased due to:

- Using carryover to execute construction on LAP4, Transuranic Liquid Waste Facility, Chemistry and Metallurgy Research Replacement project; and
- Ramping down construction for HE Science and Engineering Facility.

These decreases are offset by increases in other areas of the program:

- Los Alamos Pit Production funding, which increased to support equipment purchases; installation activities; and the hiring, training, qualification, and retention of additional staff to support the war reserve pit production ramp-up;
- SRPPF funding increase for maturing design of the main process building and subprojects, early procurements of long-lead equipment items, and ongoing glovebox fabricator support; and
- HE&E increased due to supply chain needs and amplified responsibilities for the W93.

5.5.2.2 Secondary Capability Modernization

Secondary Capability Modernization restores and increases manufacturing capabilities for the secondary stage of nuclear weapons. This modernization includes ensuring the availability of strategic materials and other sub-component streams, as well as modernizing the facilities and operations required to process these materials, fabricate them into parts, and assemble the final components. Secondary Capability Modernization's subprograms are Enriched Uranium Modernization, including the Uranium Processing Facility; Depleted Uranium Modernization; Lithium Modernization, including the Lithium Processing Facility; Advanced Materials and Capabilities Modernization (formerly Special Materials); and Mission Delivery Modernization (formerly Secondary Stage Capability Modernization).

The budget request for Secondary Capability Modernization increased to support:

- Mitigating emerging risk areas at the Y-12 National Security Complex (Y-12) to meet future mission demand;
- Reducing risk in depleted uranium and lithium operations and supporting depleted uranium operations beyond the 2030s;
- Funding new, necessary capabilities to produce other future weapon system components; and
- Preparing a Lithium Processing Facility (LPF) site, long-lead procurements, and adding the East End Substation to the LPF project.

5.5.2.3 Tritium and Domestic Uranium Enrichment

Tritium and DUE consists of two parts: Tritium Sustainment and Modernization, which produces, recovers, and recycles tritium to support national security requirements, and includes the Tritium Finishing Facility (TFF); and the DUE Program, which establishes a reliable supply of enriched uranium to support national security needs.

The budget request for Tritium and DUE increased to support:

- Labor and material purchases for DUE centrifuge development;
- Initiation of design activities for the DUE Pilot Plant; and
- Investments to increase confidence in the overall tritium supply chain, including repair of critical isotopic separation equipment, increasing inventories to reduce just-in-time manufacturing risks, executing production assurance initiatives, and continuing to fund science and technology initiatives.

These increases are partially offset by the use of carryover for TFF.

5.5.2.4 Non-Nuclear Capabilities Modernization

Non-Nuclear Capabilities Modernization consolidates management and oversight, and prioritization of strategic investments to modernize the extensive suite of infrastructure and equipment required to support the non-nuclear component lifecycle. This program modernizes the capabilities and technologies needed for design, qualification, production, and surveillance of non-nuclear components for all weapon systems. It also includes the Power Sources Capability line-item construction project.

The budget request for this program decreased, reflecting the planned sequencing of equipment procurements for Kansas City National Security Campus (KCNSC) expansion efforts. This decrease is partially offset by increased support to Power Sources Capability, which modernizes power sources R&D, development, and production at SNL.

5.5.2.5 Capability Based Investments

The CBI program executes projects for equipment, tools, and facility modifications that are directly related to enduring mission deliverables and reducing programmatic risks across the nuclear security enterprise. CBI addresses enduring, multi-program weapon activity capabilities through discrete, short-duration projects. CBI activities primarily involve 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 did not change significantly.

5.5.2.6 Warhead Assembly Modernization

Warhead Assembly Modernization, a new subprogram proposed to begin in FY 2025, modernizes the capabilities needed to execute warhead assembly/disassembly operations for weapon modernization, surveillance, and dismantlement programs.

5.5.3 Key Milestones

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 presented in **Figure 5–4**. There were several changes to last year's plan:

- The FY 2024 milestone, *Achieve operational capability for the Light Initiated High Explosives (LIHE) at SNL (NM),* is delayed to 2025 due to Light Initiated High Explosives Annex construction work delays and readiness timeline from construction completion to operational.
- The FY 2025 milestone, *Obtain Critical Decision (CD)-2/3 for SRPPF*, is delayed to FY 2026 based on the most recent Design Performance Baseline-Baseline Change Proposal, which shifts the risk-informed date to 2026.
- The FY 2031 milestone, *Obtain CD-4 for LAP4*, is shifted to FY 2032 due to the alignment of scope between the 30 Base and 30 Reliable and challenges with executing work within an operating nuclear facility.
- The FY 2034 milestone, *Obtain CD-4 for Energetic Materials Characterization*, is shifted to FY 2037 to account for pausing the project due to capacity constraints at the site.

The FY 2024 milestone, *Produce first War Reserve production lot of PBX-9502*, is complete.

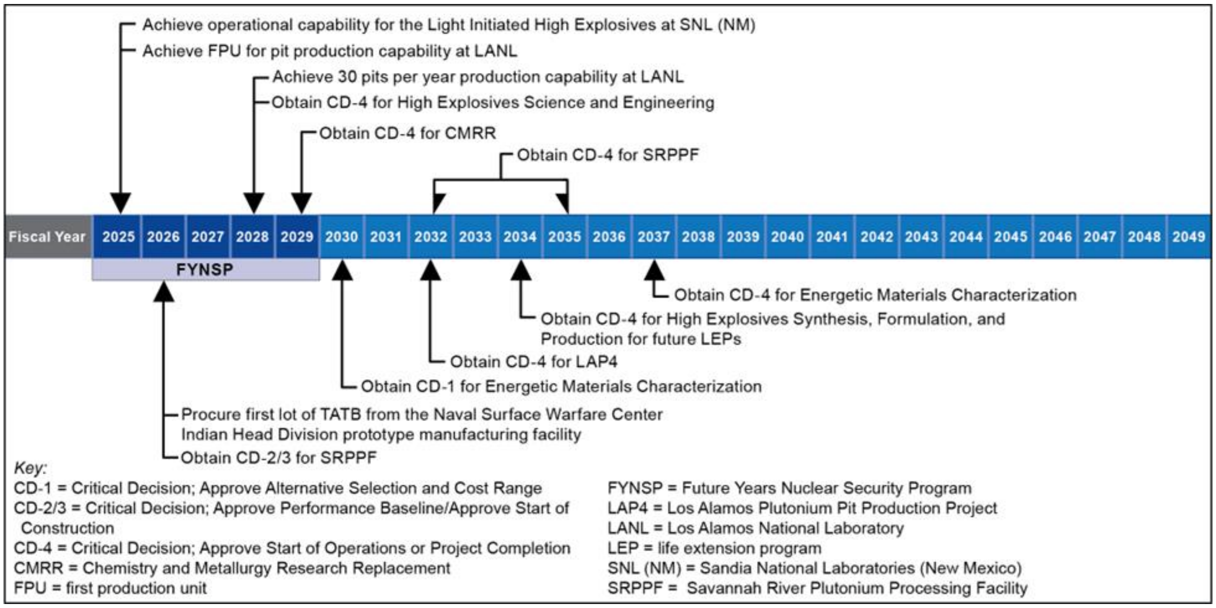


Figure 5–4. Key milestones for Primary Capability Modernization

5.5.3.2 Secondary Capability Modernization

Key milestones for Secondary Capability Modernization are illustrated in **Figure 5–5**. There were several changes to last year's plan:

- The FY 2024 milestone, *Produce a qualified binary ingot by restarting lapsed manufacturing processes*, is delayed to FY 2025 due numerous equipment and infrastructure challenges in the Vacuum Induction Melt Vacuum Arc Remelt restart effort. Y-12 addressed these challenges and identified mitigations to support Process Prove In to meet the near-term program of record needs. The FY 2025 date supports long-term program of record needs.
- The FY 2024 milestone, *Obtain CD-4 for Y-12 plant electrorefiner*, is delayed with an updated completion date pending Baseline Change Proposal approval.
- The FY 2029 milestone, *Obtain CD-4 for Uranium Processing Facility*, is shifted to FY 2030 due to contractor performance and congressionally directed workforce reductions. The project is undergoing an External Independent Review and Independent Cost Review, which will inform a baseline change request.
- The FY 2031 milestone, *Obtain CD-4 for Lithium Processing Facility*, is shifted to FY 2033 due to the addition of the East End Substation subproject, as well as cost and schedule estimates that have increased beyond the high-end of the CD-1 range. DOE/NNSA is performing a project review to validate costs and identify opportunities for savings, including alternative acquisition strategies.
- The FY 2026 milestone, *Obtain CD-4 for Y-12 Calciner project*, is delayed with an updated completion date pending Baseline Change Proposal approval.

Three new milestones were added:

- *Reestablish feedstock supply of binary* in FY 2026;
- *Establishment of Capability at Nuclear Fuel Services* in FY 2026; and
- *Obtain CD-4 for Y-12 Enriched Uranium Chip Processing* in FY 2034.

The FY 2024 milestone, *Achieve Technical Readiness Level 7 for Direct Cast*, is complete.

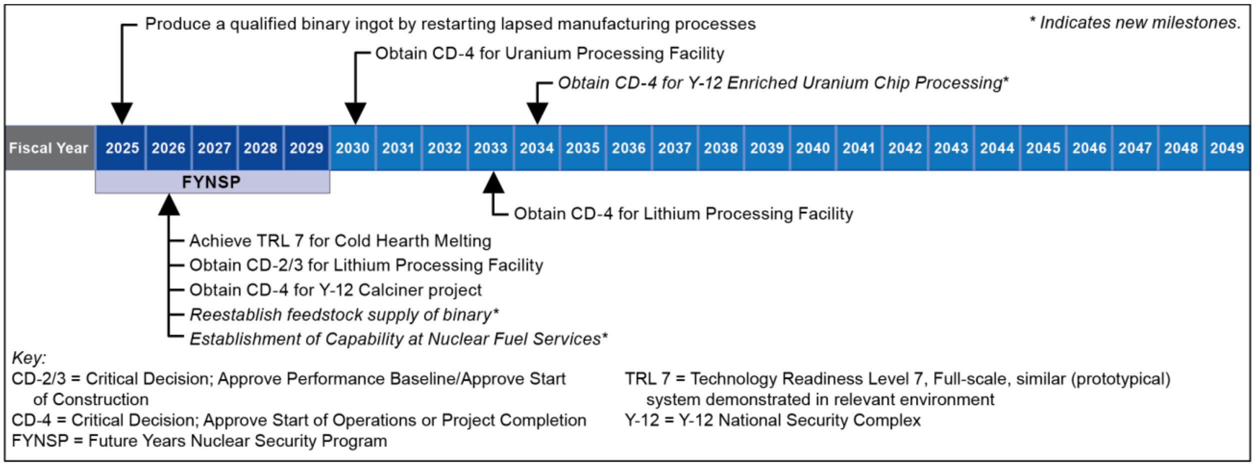


Figure 5–5. Key milestones for Secondary Capability Modernization[4]

5.5.3.3 Tritium and Domestic Uranium Enrichment

Key milestones for Tritium and DUE are shown in **Figure 5–6**. Major changes from last year's plan related to Tritium and DUE include:

- The FY 2025 milestone, *Implement use of new tritium-producing burnable absorber rod (TPBAR) Transport Cask for four-fold increase in capacity*, is delayed to FY 2026 because a change in vendor for the cask lengthens the time for licensing and implementation.
- The FY 2025 milestone, *Reliably produce a total of 2,800 grams of tritium using two Tennessee Valley Authority reactors over their 18-month cycles*, is moved to FY 2027 due to higher priority scope within Production Modernization.
- The range *Obtain CD-4 for TFF* is condensed to FY 2037 since the project is paused through FY 2028 due to prioritization of SRPPF at the Savannah River Site (SRS).

The FY 2024 milestone, *Complete facility modifications to prepare for future demonstration of the Oak Ridge National Laboratory small centrifuge*, is complete.

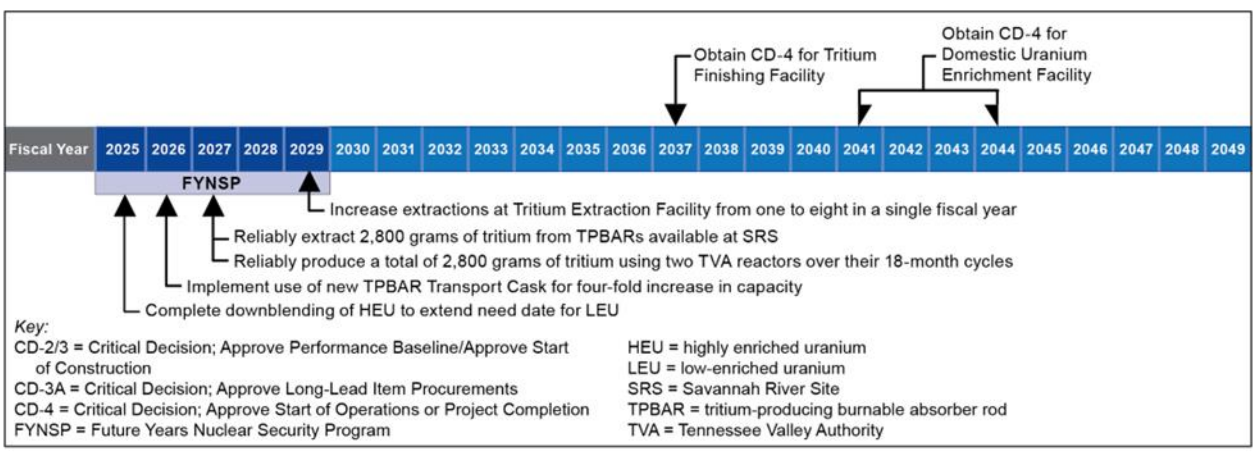


Figure 5–6. Key milestones for Tritium Modernization and Domestic Uranium Enrichment

[4] The FY 2026 milestone, *Obtain CD-4 for Y-12 Calciner project*, is delayed with an updated completion date pending Baseline Change Proposal approval.

5.5.3.4 Non-Nuclear Capability Modernization

Key milestones for Non-Nuclear Capability Modernization are displayed in **Figure 5–7**. There is one new milestone in FY 2025, *Complete Saturn Phase 1 Refurbishment*, and one new milestone spanning 2025 through 2042, *Complete Kansas City Non-Nuclear Expansion Transformation (KCNExT).* The FY 2028 milestone, *Complete KCNSC Short-term Expansion Plan, including all of Building 23,* is delayed to FY 2030 to balance other mission priorities. Two milestones from the FY 2024 SSMP are anticipated to be completed in FY 2024:

- *Complete SNL's Agile Facility final fitout and transition to operations*
- *Upgrade Annular Core Research Reactor Simulator*

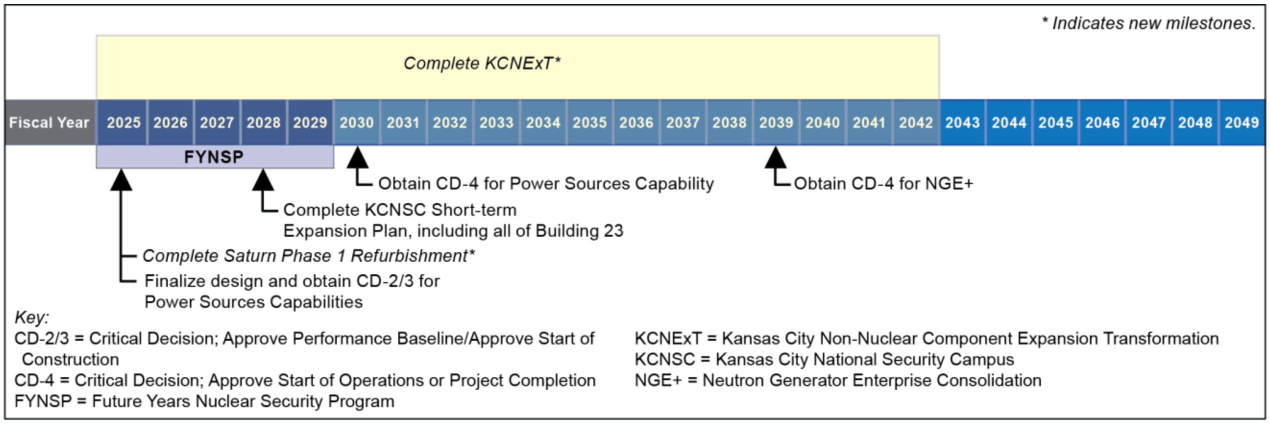


Figure 5–7. Key milestones for Non-Nuclear Capability Modernization

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.

5.5.3.6 Warhead Assembly

As a new subprogram under development, Warhead Assembly has not yet established milestones, but will include milestones in future versions of the SSMP.

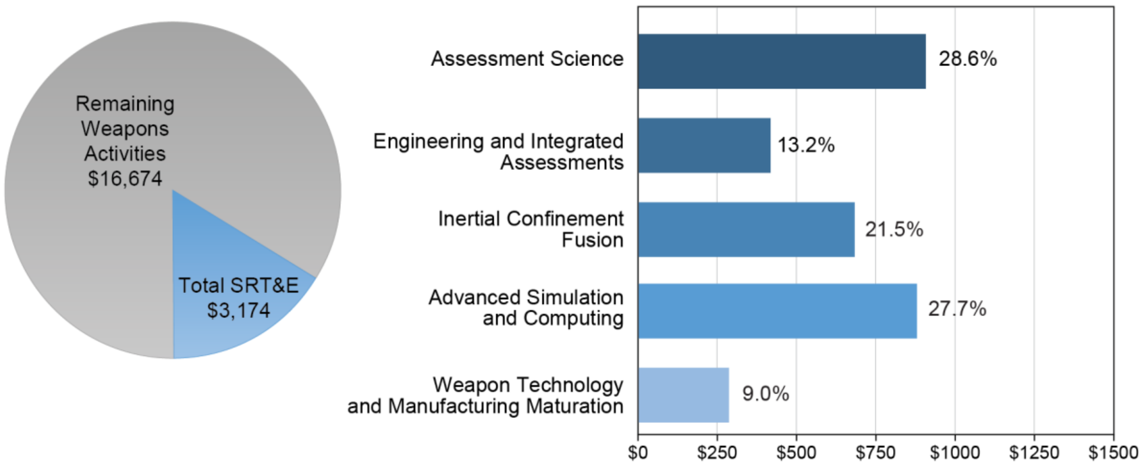
5.6 Stockpile Research, Technology, and Engineering

Stockpile Research, Technology, and Engineering (SRT&E) program provides the knowledge and expertise needed to maintain confidence in the nuclear stockpile without additional underground nuclear explosive testing. SRT&E encompasses five major subprograms: Assessment Science, Engineering and Integrated Assessments, Inertial Confinement Fusion (ICF), Advanced Simulation and Computing (ASC), and Weapon Technology and Manufacturing Maturation.

5.6.1 Budget

The budget request for SRT&E decreased 3.2 percent from the FY 2024 enacted budget and is illustrated in **Figure 5–8**.

Stockpile Research, Technology, and Engineering Funding Request for FY 2025
(Dollars in Millions)



Fiscal Year ($M)

	2024 Enacted	2025	2026	2027	2028	2029
Assessment Science	1,043.1	907.3	947.5	864.2	779.6	794.7
Engineering and Integrated Assessments	409.5	418.0	419.7	480.5	519.7	588.8
Inertial Confinement Fusion	690.0	682.8	681.9	704.9	705.2	705.5
Advanced Simulation and Computing	830.0	879.5	879.3	879.9	861.3	891.0
Weapon Technology and Manufacturing Maturation	307.7	286.5	291.4	291.7	314.9	331.0
Total SRT&E	3,280.4	3,174.2	3,219.8	3,221.1	3,180.6	3,310.9

Note: Numbers may not add due to rounding

Figure 5–8. Fiscal year 2025 President's Budget Request for Stockpile Research, Technology, and Engineering

5.6.2 Fiscal Year 2025 Budget Request Compared to Fiscal Year 2024 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 underground nuclear explosive testing. The program comprises six subprograms: Primary Assessment Technologies, Dynamic Materials Properties, Advanced Diagnostics, Secondary Assessment Technologies, Enhanced Capabilities for Subcritical Experiments (ECSE), and Hydrodynamic and Subcritical Experiment Execution Support. The Los Alamos Neutron Science Center Modernization Project (LAMP), Principal Underground Laboratory for Subcritical Experimentation (PULSE) (previously named the U1a Complex Enhancements Project), and Z-pinch Experimental Underground System Testbed Facilities Improvement line-item construction projects are also contained within this program.

The budget request for Assessment Science decreased, reflecting reduced funding for PULSE and ECSE Advanced Source and Detectors consistent with project profiles, as well as prioritization of R&D for designs and key materials that support options for the future stockpile. This decrease is partially offset by increases that support:

- Design, assembly, and analysis of multiple subcritical experiments;

- Highest priority acceleration opportunities for samples and experiments for the Plutonium/Pit Aging Plan; and
- Experimental diagnostics and hardware at current experimental sites at LANL, LLNL, and Nevada National Security Sites (NNSS).

5.6.2.2 Engineering and Integrated Assessments

Engineering and Integrated Assessments is responsible for developing the foundational technologies and enterprise capabilities underpinning warhead environmental survivability, increasing the responsiveness of the enterprise, and supporting new integrated system concepts. These technologies and capabilities are matured and developed from a system-agnostic perspective until a warhead's response to the stockpile-to-target sequence is understood, ensuring a responsive nuclear deterrent through collaborative partnerships, proactive integration, and assessments. This program includes seven subprograms: Archiving and Support, Delivery Environments, Weapons Survivability, Studies and Assessments, Aging and Lifetimes, Stockpile Responsiveness, and Advanced Certification and Qualification. The Combined Radiation Environments for Survivability Testing line-item project also resides within this program.

The increased budget request for Engineering and Integrated Assessments supports the Nuclear Weapons Council-directed Phase 1, *Concept Assessment*, on non-ballistic reentry vehicles and hard and deeply buried targets to explore opportunities to fill deterrence gaps and meet future threats with modern U.S. nuclear capabilities. The current funding profile for the Nuclear Weapons Council-directed Phase 1 Studies has required the Nuclear Weapons Council to prioritize the Phase 1 Studies. The increase is partially offset by realignment of work scope and funding for Capabilities for Nuclear Intelligence from Archiving and Support to Advanced Simulation and Computing.

5.6.2.3 Inertial Confinement Fusion

ICF provides high energy density (HED) science capabilities 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 advance the R&D capabilities necessary to meet those needs for the deterrent of the future. The program includes three subprograms: HED and Ignition Science for Stockpile Applications, ICF Diagnostics and Instrumentation, and Facility Operations.

The budget request for ICF decreased slightly while maintaining support for critical diagnostic R&D and for National Ignition Facility, Omega, and Z pulsed power facility sustainment activities.

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 and management requirements. ASC supplies 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: Integrated Codes, Physics and Engineering Models, Verification and Validation, Computational Systems and Software Environment, Facility Operations and User Support, and Capabilities for Nuclear Intelligence.

The increase in the budget request for ASC supports:

- Transfer of the Capabilities for Nuclear Intelligence portfolio from other SRT&E programs;
- Multiple Phase 1 activities and assessments of future systems;
- Assessment of specific applications where artificial intelligence/machine learning has potential to achieve significant advancements;

- Development and deployment of new workflow and analysis capabilities; and
- Development of predictive models, experimental collaborations, and integrated Verification and Validation/Uncertainty Quantification processes.

5.6.2.5 Weapon Technology and Manufacturing Maturation

Weapons Technology and Manufacturing Maturation develops agile, affordable, assured, and responsive technologies and capabilities for nuclear stockpile sustainment and modernization. It comprises three subprograms: Surety Technologies, Weapon Technology Development, and Advanced Manufacturing Development.

The budget request for Weapons Technology and Manufacturing Maturation decreased, reflecting the prioritization of urgently needed, non-surety technology component development over non-weapon specific surety development for future applications. This decrease is partially offset by increases for establishing demonstrator programs to drive component integration and rapidly advance technology readiness levels, and by development of novel and innovative weapons components, capabilities, and architectures.

5.6.3 Key Milestones

DOE/NNSA and the national security laboratories, plants, and sites use the Stewardship Capability Delivery Schedule to guide experimental and simulation capability development. It also helps 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**. There are no major changes from last year's plan.

Five milestones from the FY 2024 SSMP are anticipated to be completed in FY 2024:

- *Evaluate and implement re-entry concepts/environments using technology maturation demonstrators for future stockpile applications*
- *Extend nuclear environment test capabilities at the Z pulsed power facility, Hermes, Saturn, and National Ignition Facility*
- *Develop a Platform for Use of multi-megajoules Fusion Yield Experiments*
- *Accept Advanced Technology System-4/El Capitan exascale computing platform*
- *Design and demonstrate a light weight, modular weapon system architecture*

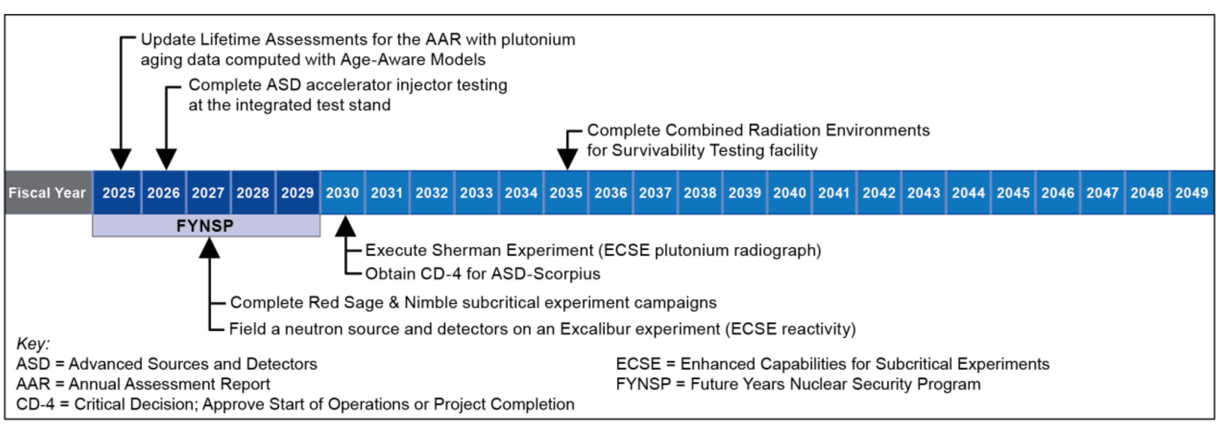


Figure 5–9. Key milestones for Stockpile Research, Technology, and Engineering

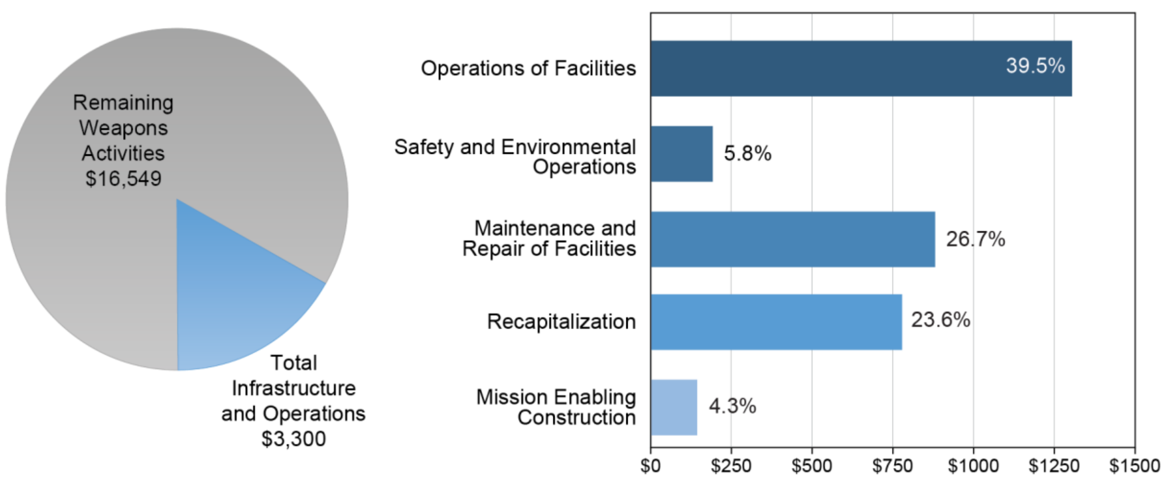
5.7 Infrastructure and Operations

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 Operations of Facilities, Safety and Environmental Operations, Maintenance and Repair of Facilities, Recapitalization, and Line-Item Construction. 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 27.7 percent from the FY 2024 enacted budget and is illustrated in **Figure 5–10**.

Infrastructure and Operations Funding Request for FY 2025
(Dollars in Millions)



	Fiscal Year ($M)					
	2024 Enacted	2025	2026	2027	2028	2029
Operations of Facilities	1,053.0	1,305.0	1,385.0	1,415.0	1,445.0	1,495.0
Safety and Environmental Operations	139.1	192.0	183.5	183.4	183.2	184.2
Maintenance and Repair of Facilities	708.0	881.0	900.0	910.0	935.0	975.0
Recapitalization	609.7	778.4	771.4	793.1	826.2	960.6
Mission Enabling Construction	75.0	143.5	210.0	90.0	138.7	197.4
Total Infrastructure and Operations	2,584.8	3,299.9	3,449.9	3,391.5	3,528.1	3,812.2

Note: Numbers may not add due to rounding

Figure 5–10. Fiscal year 2025 President's Budget Request for Infrastructure and Operations

5.7.2 Fiscal Year 2025 Budget Request Compared to Fiscal Year 2024 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:

- Increased programmatic mission tempo across the nuclear security enterprise, including 24/7 operations at LANL to achieve a 30 pits per year (ppy) capacity, and additional operations at the expanded KCNSC; and
- SRS operations of facilities, including those at K Area, previously funded through Defense Environmental Cleanup.

The increase is partially offset by a realignment in scope and funding to the Safety and Environmental Operations subprogram.

5.7.2.2 Safety and Environmental Operations

Safety and Environmental Operations provides DOE/NNSA's Nuclear Criticality Safety Program, Nuclear Safety Research and Development, Packaging subprogram, Nuclear Materials Integration subprogram and a new Environmental Operations 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. Environmental Operations consists of activities previously conducted under the Long-Term Stewardship subprogram, as well as a subset of nuclear waste management and Site-wide Environmental Impact Statement activities previously funded under Operations of Facilities.

The increase to the budget request for Safety and Environmental Operations reflects:

- Realignment of scope and funding for the Safety, Analytics, Forecasting, Evaluation, and Reporting platform, Site-wide Environmental Impact Statement activities, and Radioactive Waste Management reserve funding from Operations of Facilities;
- Remediation for contamination of the Ogallala Aquifer at Pantex Plant (Pantex); and
- Efforts to help with criticality prevention in Fukushima fuel debris removal.

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 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:

- Additional maintenance of facilities at LANL to achieve a 30 ppy capability and additional maintenance of facilities at expanded KCNSC;
- Deferred maintenance across the enterprise, including work at NNSS for site critical infrastructure—such as PULSE—and the highest risks in deferred maintenance at Y-12 and Pantex;
- Targeted support for global security needs; and
- Maintenance-related activities at SRS previously funded through Defense Environmental Cleanup and beginning to transition SRS to an enduring mission site.

5.7.2.4 Recapitalization

Recapitalization modernizes DOE/NNSA's infrastructure by prioritizing investments, including acquisition of new facilities, to improve the condition and extend the life of structures, capabilities, and systems, thereby improving the safety and quality of the workplace. Recapitalization addresses obsolete support and safety systems; revitalizes facilities that are beyond their design life; and improves 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 budget request for Recapitalization increased to support:

- KCNExT;
- Deactivation and disposal of excess infrastructure, including stabilization and risk reduction activities at high-risk facilities; and
- Transition of SRS to NNSA from DOE.

5.7.2.5 Mission Enabling Construction

These line-item projects will replace obsolete, unreliable facilities and infrastructure to reduce safety and program risk while improving responsiveness, capacity, and capabilities. DOE/NNSA uses a prioritization methodology for mission enabling line-item construction that evaluates investments in closing mission gaps, reducing infrastructure risk and safety risk, improving sustainability, and reducing deferred maintenance. Programmatic construction line-items fall under the respective programs.

The budget request for Mission Enabling Construction includes funding in FY 2025 for PULSE New Access (NNSS), Plutonium Mission Safety and Quality Building (LANL), and Electrical Power Capacity Upgrade (LANL).

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

5.7.3 Key Milestones and Metrics for Infrastructure Maintenance and Recapitalization

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 and programmatic line-items are funded through their respective programs. 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. Some projects planned in the out-years may decide to use strategies other than line-items after the completion of analyses of alternatives.

DOE/NNSA established the Infrastructure Modernization Initiative (IMI) pursuant to the *National Defense Authorization Act for Fiscal Year 2018*. In 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. Considering NNSA's DM:RPV ratio when the IMI was established, this means achieving a DM:RPV ratio of 2.67 percent by 2030. The IMI is 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.

As part of the IMI, DOE/NNSA is using BUILDER, a system developed by the U.S. 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, lifecycle, 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 calculated RPV is $149.2 billion, based on data from the end of FY 2023; $4.6 billion in excess facilities is not represented in the table. In response to Government Accountability Office recommendations, this information is provided to improve transparency in the budget.

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

Metric	*FY 2020*	*FY 2021*	*FY 2022*	*FY 2023*
DM	$5.8B	$6.1B	$6.5B	$7.7B
RPV	$116.3B	$121.5B	$131.0B	$144.5B
DM:RPV Ratio	4.99%	5.00%	4.95%	5.30%

DM = deferred maintenance
RPV = replacement plant value

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. Recapitalization continues to include deactivation and demolition of excess and underused facilities to reduce DOE/NNSA's footprint. 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 2025 DOE/NNSA infrastructure maintenance and recapitalization investments[6]

		FY 2023	*FY 2024*	*FY 2025*
RPV ($B)		144.5	145.5	146.5
Maintenance Benchmark 2%–4% RPV	Infrastructure and Safety Maintenance Investments ($K)	651,617	708,000	881,000
	Other NNSA Maintenance Investments (direct and indirect funded) ($K)	310,577	343,743	396,376
	Total NNSA Maintenance Investments ($K)	962,194	1,051,743	1,277,376
	Maintenance as % RPV	0.67%	0.72%	0.87%
Recapitalization Benchmark 1%	Infrastructure and Safety Recapitalization Investments ($K)	561,663	609,665	778,408
	Other NNSA Recapitalization Investments ($K)	359,230	427,640	648,945
	Total NNSA Recapitalization Investments ($K)	920,893	1,037,305	1,427,353
	Recapitalization as % RPV	0.64%	0.71%	0.97%

RPV = Replacement Plant Value
$B = billion dollars
$K = thousand dollars
% = percent

[5] DM and RPV totals exclude excess facilities and include Kansas City National Security Campus-leased facilities.

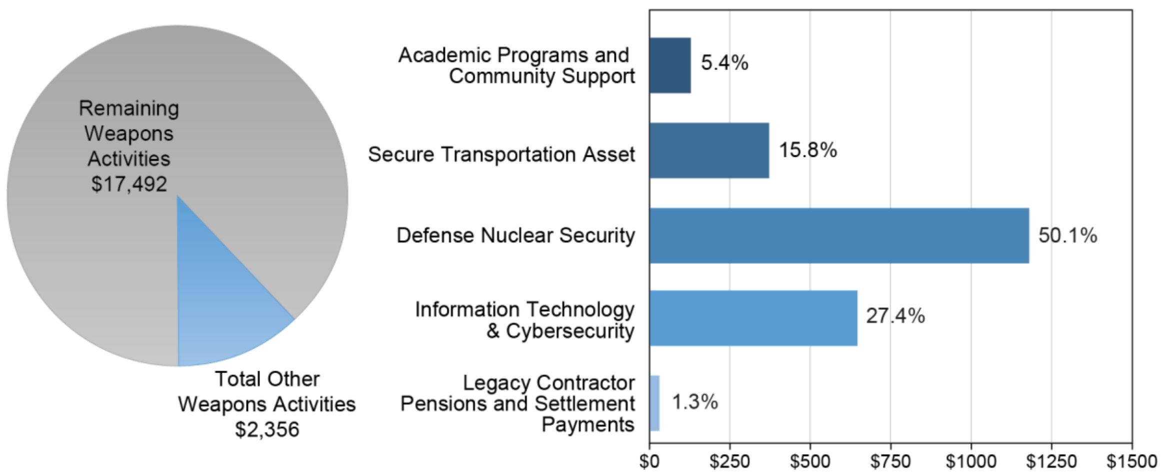
[6] RPV totals exclude excess facilities and include Kansas City National Security Campus-leased facilities.

5.8 Other Weapons Activities

5.8.1 Budget

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

Other Weapons Activities Funding Request for FY 2025
(Dollars in Millions)



	Fiscal Year ($M)					
	2024 Enacted	2025	2026	2027	2028	2029
Academic Programs and Community Support	122.0	128.2	121.9	121.9	121.9	121.9
Secure Transportation Asset	357.1	371.4	412.2	457.6	461.7	465.0
Defense Nuclear Security	1,038.4	1,180.0	1,150.7	1,202.7	1,254.1	1,280.0
Information Technology & Cybersecurity	578.4	646.0	704.9	748.5	752.1	798.3
Legacy Contractor Pensions and Settlement Payments	65.5	30.6	64.2	40.9	39.4	39.7
Total Other Weapons Activities	2,161.3	2,356.2	2,453.9	2,571.5	2,629.1	2,704.9

Note: Numbers may not add due to rounding

Figure 5–11. Fiscal year 2025 President's Budget Request for Other Weapons Activities

5.8.2 Academic Programs and Community Support

This program, formerly a subprogram within the SRT&E portfolio, is designed to support investments in science and engineering disciplines of critical importance to DOE/NNSA's nuclear security enterprise. Academic Programs and Community Support is made up of six subprograms: Stewardship Science Academic Alliance, Minority Serving Institution Partnership Program, Tribal Education Partnership Program, Joint Program in High Energy Density Laboratory Plasmas, Computational Science Graduate Fellowship, and Predictive Science Academic Alliance Program.

5.8.2.1 Fiscal Year 2025 Budget Request Compared to Fiscal Year 2024 Enacted Budget

Reflecting DOE/NNSA's continued investment in education and the establishment of the Community Capacity Building Program, the budget request increased 5.1 percent from FY 2024.

5.8.2.2 Key Milestones

Academic Programs and Community Support focuses on long-term investments in academic research awards and fellowships to promote relevant research opportunities and strengthen workforce development for talent needed to support the nuclear security enterprise. The key milestones associated with this program are the successful completion of awards that run on 3- and 5-year cycles, as well as the introduction of new fellow cohorts selected annually. Due to the cyclical nature of Academic Programs and Community Support, these key milestones recur every 1, 3, and 5 years.

5.8.3 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: Operations and Equipment and 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.

5.8.3.1 Fiscal Year 2025 Budget Request Compared to Fiscal Year 2024 Enacted Budget

The budget request for STA increased 4.0 percent from FY 2024, driven by Program Direction to support salaries and benefits for 511 full-time equivalent employees, travel, and other related expenses Federal Agents and the staff workforce.

5.8.3.2 Key Milestones

The STA milestones shown in **Figure 5–12** will enable DOE/NNSA to support transportation requirements for the current and future stockpile. There are several changes to the FY 2024 plan:

- The FY 2025 milestone, *Design and begin production of next generation armored tractor*, shifted to 2027. The shift is associated with contracting strategies.
- The FY 2028 milestone, *Begin Mobile Guardian Transporter (MGT) production*, is moved to 2029, and the FY 2038 milestone, *Complete MGT production*, is moved to FY 2040 because a re-scope of the MGT project is underway. When complete, this re-scope will provide updated requirements and schedule to meet delivery of a first production unit as close to FY 2029 as possible. The re-scope may also change the completion date, which is currently an estimation.

There were no milestones in the FY 2024 SSMP scheduled for completion in FY 2024.

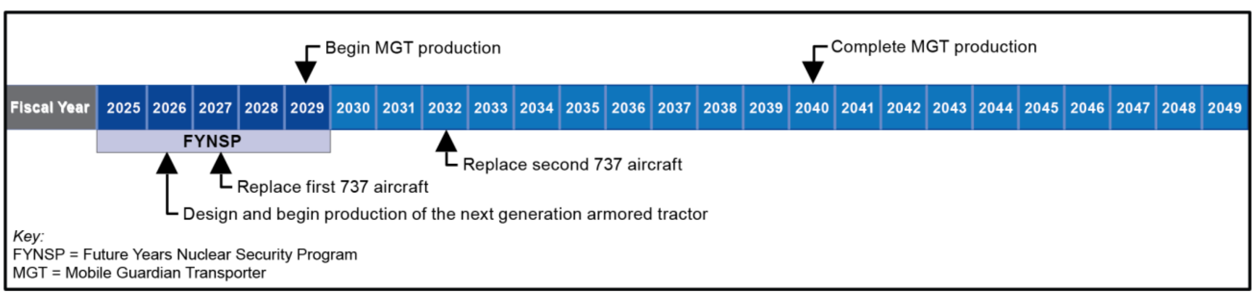


Figure 5–12. Key milestones for Secure Transportation Asset

5.8.4 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. Additional information is located in the classified annex to the FY 2025 SSMP.

5.8.4.1 Fiscal Year 2025 Budget Request Compared to Fiscal Year 2024 Enacted Budget

The budget request for DNS increased 13.6 percent from FY 2024 to support:

- Additional security requirements associated with mission growth, including plutonium pit production, KCNSC expansion efforts, preparation for Uranium Processing Facility operation, and transition of SRS to NNSA from DOE;
- Initiatives for the Physical Security Center of Excellence and the Center for Security Technology, Analysis, Response, and Testing; and
- The revised baseline of the WEPAR project.

5.8.4.2 Key Milestones

The Security Infrastructure Revitalization Program refreshes aging security infrastructure across the enterprise based on a long-range plan that is modified periodically according to DOE/NNSA's budget, mission, and needs. The DNS milestones shown 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. There are several changes to the FY 2024 plan:

- The FY 2024 milestone, *Complete Caerus development,* is moved to FY 2025 since testing is planned for summer 2024 and the timeline was extended to accommodate fixing any issues identified during testing.
- The FY 2025 milestone, *Complete Y-12 WEPAR, perimeter intrusion detection and assessment system (PIDAS) modernization, and entry control facility upgrade,* is split into two milestones. In FY 2026, WEPAR will complete PIDAS modernization and entry control facility upgrades, in line with the new FY 2028 WEPAR project closeout date. This closeout date shifted due to insufficient upfront planning, to include site interface issues, the default of the electrical subcontractor, and adjustments for as-found site conditions including unforeseen contamination.
- The FY 2027 milestone, *Complete Pantex PIDAS physical security system components and infrastructure refresh for Zone 12,* and the *FY* 2030 milestone, *Complete Pantex PIDAS physical security system components and infrastructure refresh for Zone 4,* are combined into a single FY 2032 milestone, *Complete Pantex PIDAS physical security system components and infrastructure refresh.* The Security Infrastructure Revitalization Program work at Pantex has been replanned to achieve efficiencies by combining like work activities rather than working in zones.
- The FY 2027 milestone, *Complete Caerus cutover*, is clarified to *Complete first Caerus cutover*.
- The FY 2029 milestone, *Complete SRS SRPPF PIDAS*, is moved to FY 2032 to align with SRPPF project timeline.[7]
- The FY 2032 milestone, *Complete LANL PIDAS,* is shifted to FY 2036 as a result of aligning Security Infrastructure Revitalization Program work with the site's ability to execute based on other construction activities on the site.

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[7] The FY 2029 milestone, *Complete SRS SRPPF PIDAS*, will be revised to FY 2032 in the next revision of the Construction Project Data Sheet.

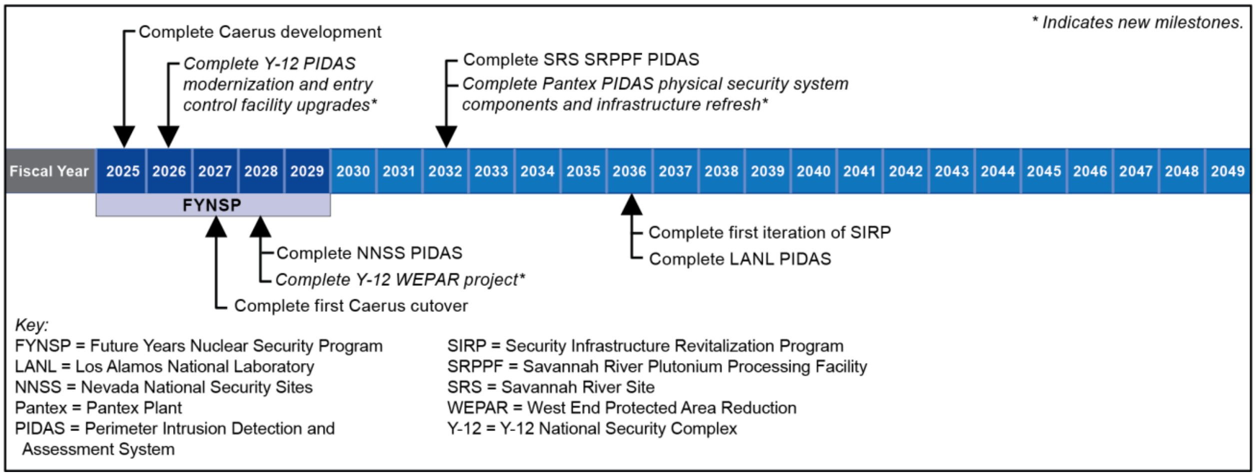


Figure 5–13. Key milestones for Defense Nuclear Security

5.8.5 Information Technology and Cybersecurity

The DOE/NNSA Office of the Associate Administrator for Information Management and Chief Information Officer supports information management, information technology (IT), and cybersecurity services and solutions to help meet security challenges. The IT and Cybersecurity program is investing in technologies that provide a set of capabilities, such as integrated communication, cloud infrastructure, collaboration services, and improved zero trust architectures. This program funds ongoing operations and invests in improvements across the nuclear security enterprise to meet the requirements of Executive Order 14028, *Improving the Nation's Cybersecurity*. Additional information is located in the classified annex to the FY 2025 SSMP.

5.8.5.1 Fiscal Year 2025 Budget Request Compared to Fiscal Year 2024 Enacted Budget

The budget request for IT and Cybersecurity increased 11.7 percent from FY 2024 to support:

- Investments in zero trust architecture, cybersecurity of operational technology, and additional cyber tools and infrastructure through the Enterprise Operations subprogram;
- Labor rate and workforce growth at the laboratories, plants, and sites to address significant increases in technology use as the DOE/NNSA mission has expanded; and
- Transfer of responsibility of SRS to NNSA from DOE.

5.8.5.2 Key Milestones

The milestones shown in **Figure 5–14** are necessary steps toward achieving a modernized IT infrastructure and cybersecurity posture for the nuclear security enterprise. There is one milestone in the FY 2024 SSMP scheduled for completion in FY 2024: *Complete the security architecture for the classified wireless network.*

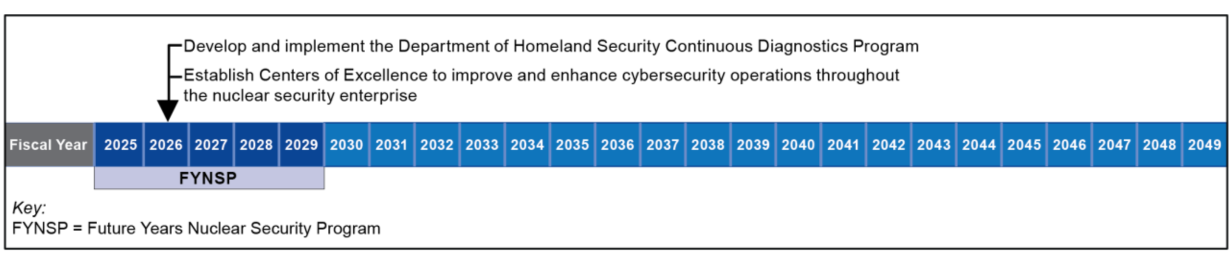


Figure 5–14. Key milestones for Information Technology and Cybersecurity

5.8.6 Legacy Contractor Pensions and Settlement Payments

In FY 2022, Legacy Contractor Pensions and Settlement Payments began including 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, which will continue through FY 2026. It formerly funded DOE/NNSA's share of the unfunded liability of the Savannah River Nuclear Solutions Multiple Employer Pension Plan; however, DOE extinguished this liability in May 2023, so DOE/NNSA will no longer direct fund contributions to the Savannah River Nuclear Solutions Multiple Employer 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 LLNL and LANL.

5.9 Weapons Activities Cost Beyond the Future Years Nuclear Security Program Period

This section explains the cost estimation methodology that DOE/NNSA uses to create an estimate of the aggregate cost of continuing the program described in this SSMP beyond the FYNSP period for which the budget request was prepared. This projection is 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, and how those resources are allocated. Budget estimates for FY 2030 and beyond reflect the costs of continuing the FYNSP program for elements of the Weapons Activities portfolio that are assumed to continue at the same level of effort; for these elements, an escalation factor of 2.1 percent was applied based on the funding level of the last year of the FYNSP. Other parts of the program, namely Stockpile Major Modernization programs and line-item construction projects, will not proceed at the same level of effort from FY 2030 through FY 2050; they instead use funding profiles unique to each project. The estimates and the basis for each of these elements of the Weapons Activities portfolio are described in Sections 5.9.1–5.9.2.

5.9.1 Stockpile Major Modernization

Stockpile Major Modernization programs extend the lifetime of the Nation's nuclear stockpile while addressing required updates and improving their safety and security as possible. The programs also develop new warheads that will not require underground nuclear explosive testing. 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.

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

Stockpile Major Modernization programs progress through the *Phase X/Phase 6.X Process*, and the governing cost estimate changes as the program matures, as illustrated in **Figure 5–15**. The *Phase X/6.X Process* provides a common framework to conduct and manage activities for new production and refurbishments of nuclear weapons. Stockpile refurbishment activities are divided into sub-elements of Phase 6, denoted by *Phase 6.X* (i.e., 6.1, 6.2, 6.2A, etc.). For purposes of the *Phase 6.X Process*, the enduring stockpile sustainment phase is designated Phase 6 and is the beginning and end point of the *Phase 6.X Process*.

Phase 1/6.1	Phase 2/6.2	Phase 2A/6.2A[1]	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 X/6.X Process*

The Office of Programming, Analysis, and Evaluation within the DOE/NNSA Office of Management and Budget 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 1/6.1, *Concept Assessment*, and are planning estimates for alternatives analysis and early programming. These planning estimates for Stockpile Major Modernization assume scopes that are in line with current policy objectives for the modernization or acquisition effort and updated annually for the SSMP.[8] They are not constrained by future budget availability and include both warhead modernization program (development and production) and non-warhead modernization program line-item costs that are critical to program success (namely Other Program Money).[9] The estimates reflect anticipated costs in the SSMP until the Weapon Design and Cost Report (WDCR) is approved. The Office of Programming, Analysis, and Evaluation planning estimates for Stockpile Major Modernization programs are:

- 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 and production of the W76-1, B61-12, W88 Alt 370) and the evaluation of the relative complexities of future systems;[11]
- 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; and
- Based on technical and programmatic inputs from Federal Program Managers, Federal field offices, and subject matter experts across the national security laboratories and nuclear weapons production facilities.

[8] 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.

[9] In estimating the cost of a warhead modernization program, the weapon programs depend on an adequately funded base of other DOE/NNSA capabilities, 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.

[10] Additional detail on the cost estimating methodology of DOE/NNSA's OMB planning estimates is 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 of the complete W76-1 and near-complete B61-12 LEP and W88 Alt 370, compared to each planned future warhead modernization program, which aids in providing a cost estimate range based on underlying technical and cost uncertainties.

[12] Lee, David. *The Cost Analyst's Companion*, 3rd ed., McLean, VA: Logistics Management Institute, McLean, VA.

The WDCR is developed by the program teams responsible for the warhead modernization programs and provides cost estimates for design, qualification, production, and lifecycle 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, *Development Engineering*. 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 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, *Production Engineering*, and 6.5, *First Production*.

5.9.1.2 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 next 25 years. Each Stockpile Major Modernization program section contains a summary table of estimates in constant FY 2024 and then-year dollars. Where appropriate, the tables also include pre-SAR values for pre-Phase 6.2, *Feasibility Study and Design Options*, costs. The low estimates presented in the tables, and shown in graphs as a green line, represent the mid-point (50th percent[13]) of the cost estimate. The high estimates represent the 85th percent for the W93; the estimate increased to the 90th percent for the future systems to reflect the greater uncertainty. Ranges reflect the underlying technical and cost uncertainty of assumed scope, and early stage programs may experience significant changes to scope based on Nuclear Weapons Council design decisions.

When comparing program costs, consider that the quantity of warhead varies by program and that constant-year cost totals are the most comparable because inflation effects become significant over warhead modernization activity timeframes. The FY 2025 SSMP's classified annex provides information on production quantities.

Table 5–4 delineates the type of cost estimate for each of the warhead modernization programs included in the 25-year plan.

[13] The referenced percent figures refers to various cost estimates and the probability that the project will cost that dollar figure or less. For example: "85th percent" means there is an 85 percent chance that the project will cost less than or equal to this estimate.

Table 5–4. DOE/NNSA cost estimates for Stockpile Major Modernization Programs[14]

Stockpile Major Modernization Program	*Type of Cost Estimate*	*Total Estimated Cost (FY 2024 dollars in billions)*	*Total Estimated Cost (then-year dollars in billions)*
B61-12 LEP	BCR/SAR	9.6	8.0
B61-13 Program	Rough Order of Magnitude	0.114	0.114
W88 Alteration Program	BCR/SAR	3.4	2.8
W80-4 LEP	BCR/SAR	12.1	12.3
W87-1 Mod Program	WDCR	14	15.9
W93 Program	Planning Estimate	20.5	27.6
Future Strategic Land-Based Warhead	Planning Estimate	22.2	40.7
Future Strategic Sea-Based Warhead	Planning Estimate	23.8	37.4
Future Air-Delivered Weapon	Planning Estimate	21.3	48.4
Submarine Launched Warhead (W76-1/2 Replacement)	Planning Estimate	26.9	58.7

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

5.9.1.3 B61-12 Life Extension Program Cost Estimate

The B61-12 LEP received authorization to enter Phase 6.5, *First Production Unit*, 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*. The values for development and production costs presented 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). These values are unchanged from the FY 2024 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.

The B61-13 Program will leverage established B61-12 production capabilities, including its modern safety, security, and accuracy features. Therefore, costs associated with B61-13 production are incremental above B61-12 estimates.

[14] For programs pre-phase 1/6.1, the 90th percent value of a representative design and quantity is provided. Then-year planning estimates are derived from constant-year estimates using escalation rates per NAP 413.6. Planning estimates include pre-Phase 2/6.2 costs, while WDCR and BCR/SAR do not. Values shown in this chart for programs with planning estimates represent the nominal value, which is the mid-point between the high and low planning estimates (85th or 90th percentile and 50th percentile).
A dedicated line–item for the SLCM-N is not currently included in the FY 2025 request, as the budget formulation process was near final when the FY 2024 NDAA was signed into law, however per Section 1640 of the FY 2024 NDAA, DOE/NNSA is coordinating with DoD to meet congressional direction and establish a program of record for SLCM-N.

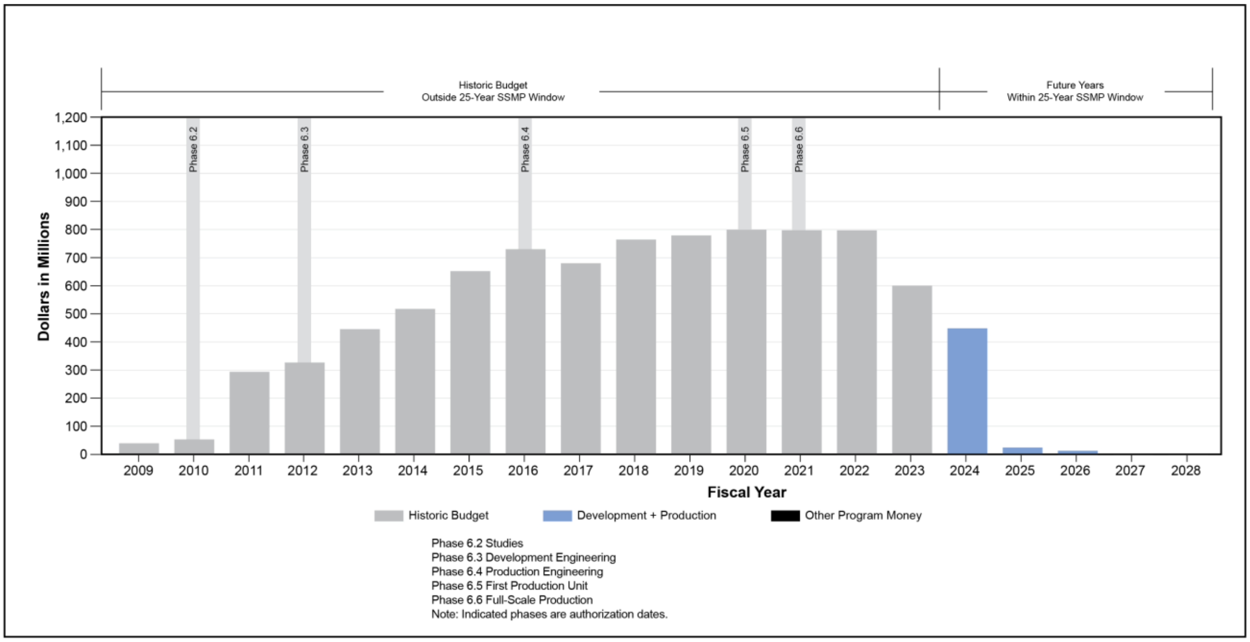


Figure 5–16. B61-12 Life Extension Program cost from fiscal year 2009 to completion

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

FY 2012–FY 2027 Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
Pre-SAR Cost	0.5	0.4
SAR Total	9.6	8.0
SAR OPM Total	0.9	0.6

OPM = Other Program Money
SAR = Selected Acquisition Report

5.9.1.4 W88 Alteration 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 authorized Phase 6.6 entry in 2022 and accepted the W88 Alt 370 into the stockpile. 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 updated BCR was reconciled with the independent cost estimate performed by the DOE/NNSA 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 (such as Other Program Money) remain unchanged at $171 million. The numbers illustrated in **Figure 5–17** and **Table 5–6** reflect the BCR update.

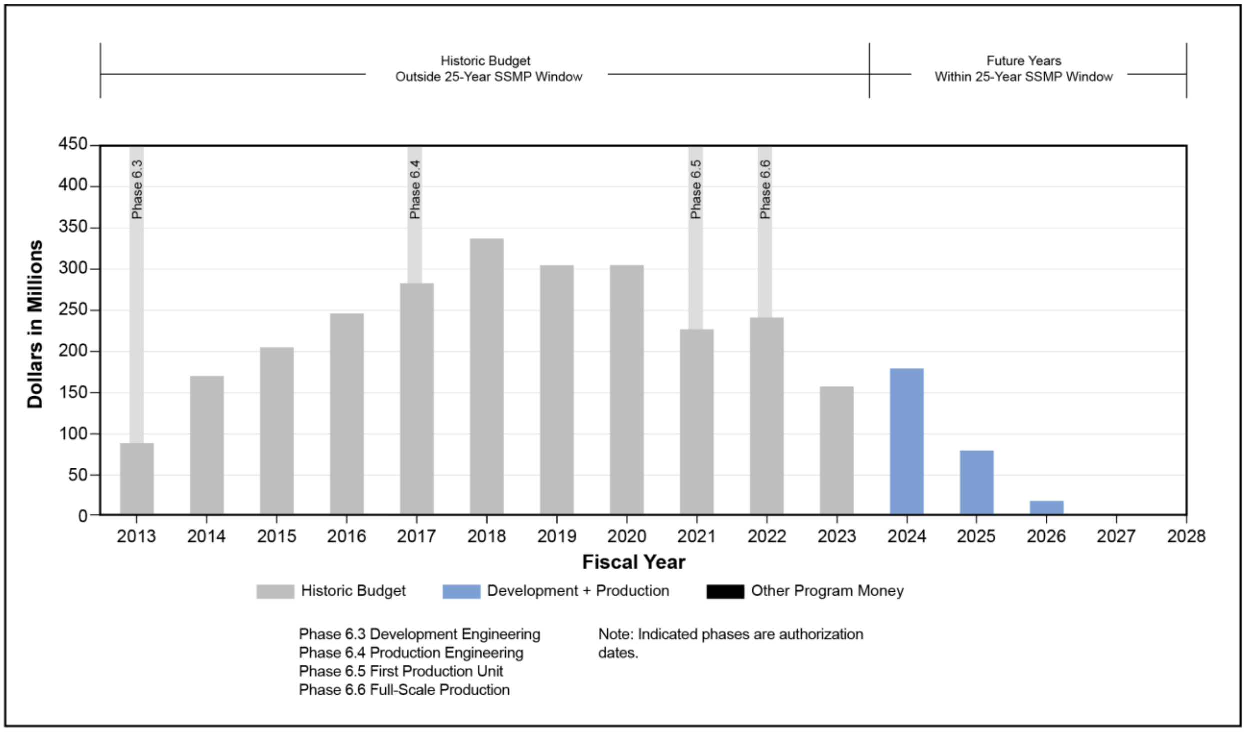


Figure 5–17. W88 Alteration 370 Program (with conventional high explosive refresh) from fiscal year 2013 to completion

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

FY 2013–FY 2027 Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
Pre-SAR Cost	0.1	0.1
SAR Total	3.4	2.8
SAR OPM Total	0.2	0.2

OPM = Other Program Money
SAR = Selected Acquisition Report

5.9.1.5 W80-4 Life Extension Program Cost Estimate

In FY 2023, the W80-4 received authorization to enter Phase 6.4 and published its BCR and an update to its 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**; however, the project is revising its baseline and estimates will be updated upon completion of that revised estimate.

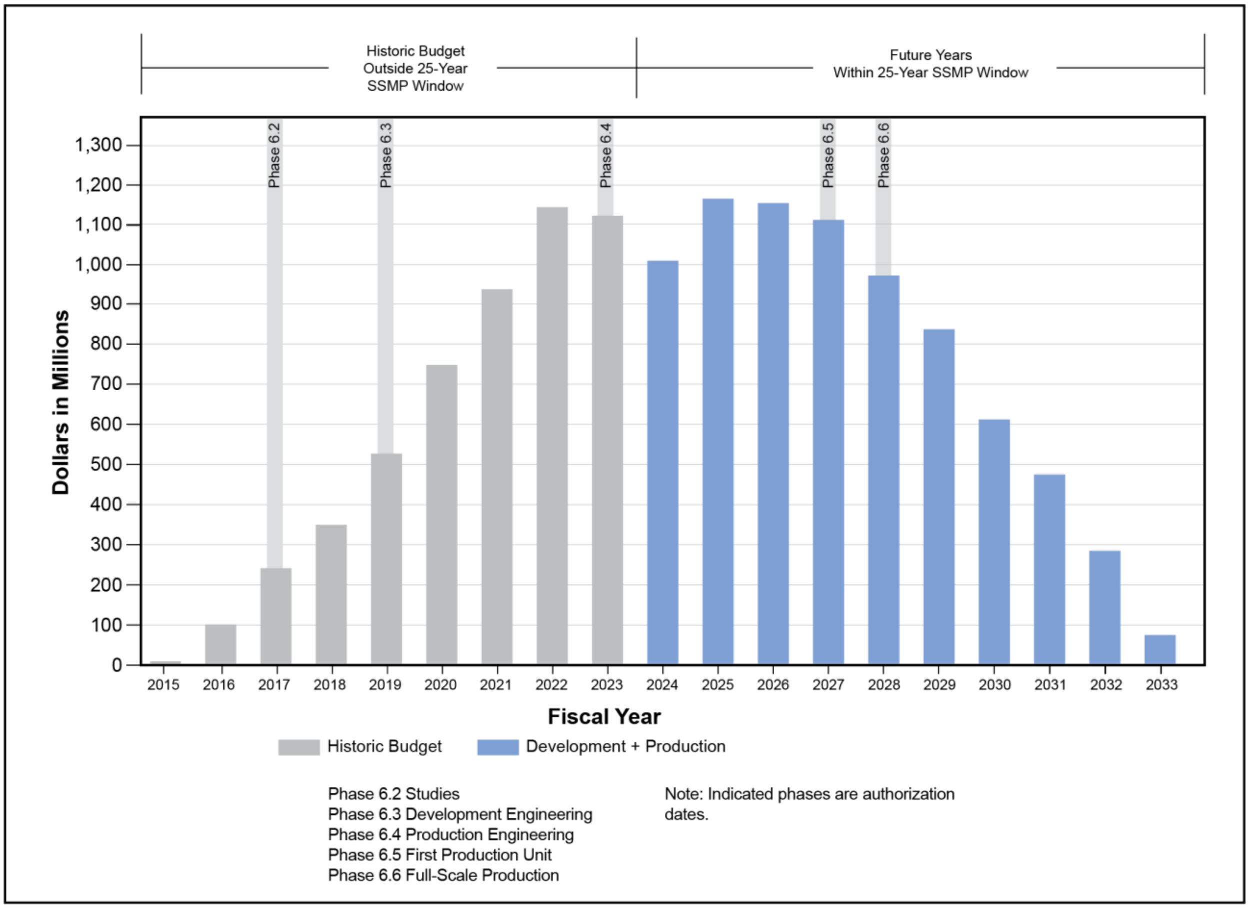


Figure 5–18. W80-4 Life Extension Program cost from fiscal year 2015 to completion

Table 5–7. Total estimated cost for W80-4 Life Extension Program

FY 2015–FY 2032 Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
Pre-SAR Cost	0.9	0.7
SAR Total	12.1	12.3
SAR OPM Total	0.2	0.2

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

5.9.1.6 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, which is slated to deploy on the LGM-35A Sentinel 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 the W87-1 Mod Program. DOE/NNSA continues to evaluate other component design options and trades. In FY 2021, the W87-1 Mod Program completed Phase 6.2 and entered Phase 6.2A. In FY 2023, the W87-1 entered Phase 6.3 and completed its WDCR—the associated cost estimate is shown in **Figure 5–19**. The estimates presented in Figure 5–19 and **Table 5–8** do not include costs associated with the production of plutonium pits for the W87-1 Mod Program after the capability to produce 30 ppy is demonstrated at LANL and 50 ppy at SRS; those costs are contained in Plutonium Modernization.

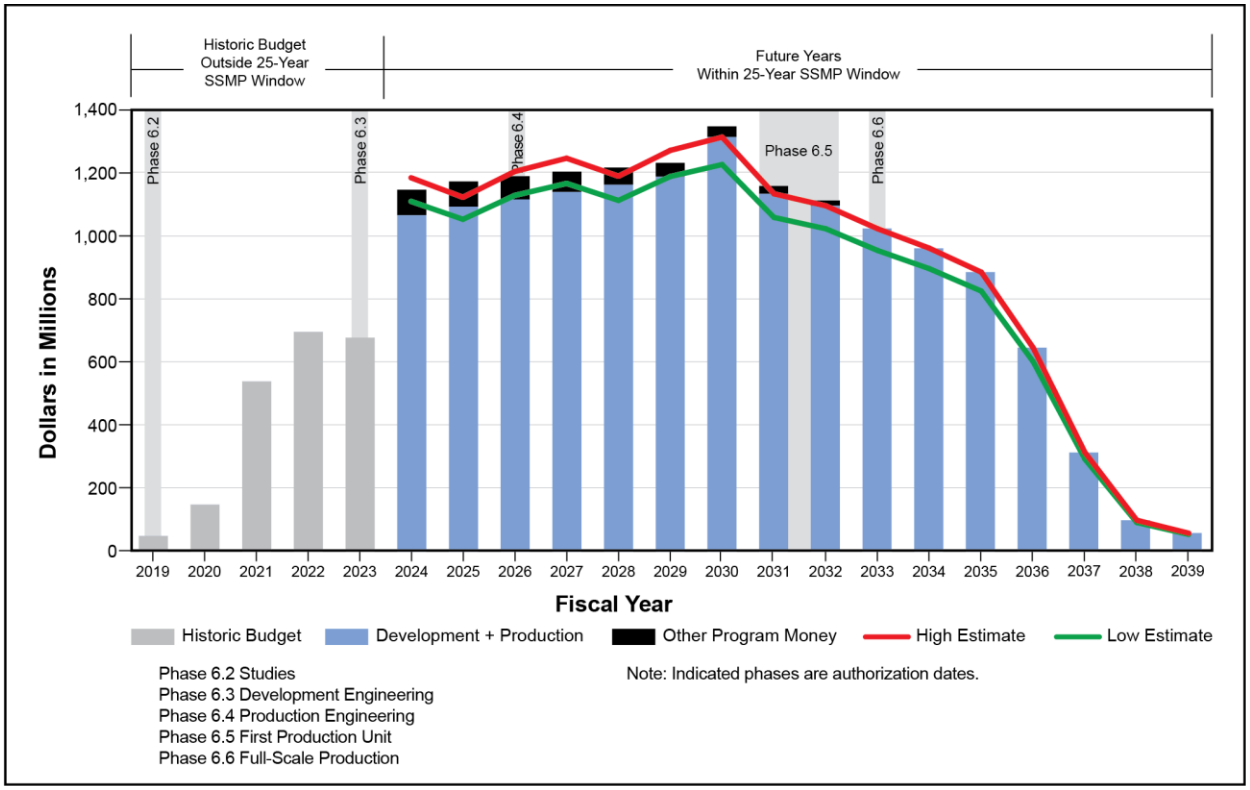


Figure 5–19. W87-1 Modification Program cost from fiscal year 2019 to completion[15]

Table 5–8. Total estimated cost for W87-1 Modification Program

FY 2019–FY 2037 Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
WDCR Estimate	14.0	15.9
Planning Estimate (High)[a]	15.3	18.5
Planning Estimate (Low)[a]	13.8	16.7

[a] Excluding OPM

5.9.1.7 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 **Figure 5–20 and Table 5–9**) is based on preliminary assumptions for one of the W93 designs and provides a planning estimate only. The estimates in Figure 5–20 and Table 5–9 do not include costs associated with the production of plutonium pits for the W93 Program or the Navy's estimated share of the warhead cost. The W93 Program is working with the Plutonium Modernization program office to finalize a cost sharing

[15] The W87-1 WDCR includes both a point estimate and Management Reserve and Contingency at the 20th percent and 80th percent levels based on risk assessments. The high and low values displayed in this graphic show that uncertainty range.

agreement between NNSA and the Navy. These estimates will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

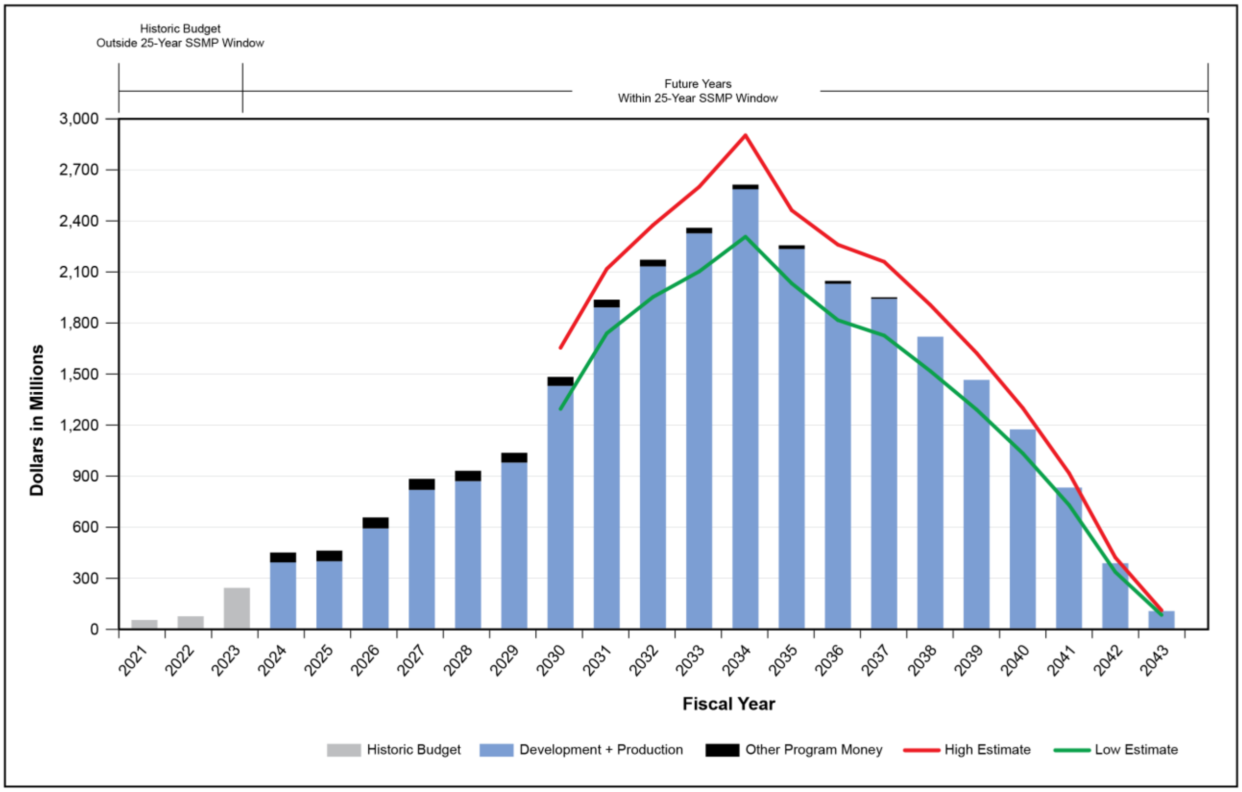


Figure 5–20. W93 Modification Program cost from fiscal year 2021 to completion

Table 5–9. Total estimated cost for W93 Program

FY 2021– FY 2044 Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
Planning Estimate (High) [a]	23.3	30.5
Planning Estimate (Low) [a]	18.9	24.7
Proposed Budget	20.5	27.6

[a] Including Other Program Money

5.9.1.8 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.

The Future Strategic Missile Warhead cost estimates (see **Table 5–10**, **Table 5–11**, **Table 5–12**, and **Table 5-13**) provide a planning estimate for notional systems. These estimates are based on an existing stockpile weapon with increased uncertainty in design scope and quantities, adjusted for out-year escalation and are informed by the W93 planning estimate. The planned timelines for these future warheads are also under consideration and have shifted later than shown in previous SSMPs. 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

Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
Planning Estimate (High) [a]	24.5	44.8
Planning Estimate (Low) [a]	19.9	36.5
Proposed Budget	22.2	40.7

[a] Including Other Program Money

Table 5–11. Total estimated cost for Future Strategic Missile – Sea-Based Warhead

Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
Planning Estimate (High) [a]	26.1	41.1
Planning Estimate (Low) [a]	21.4	33.6
Proposed Budget	23.8	37.4

[a] Including Other Program Money

Table 5–12. Total estimated cost for Future Air-Delivered Weapon

Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
Planning Estimate (High) [a]	23.4	53.2
Planning Estimate (Low) [a]	19.1	43.5
Proposed Budget	21.3	48.4

[a] Including Other Program Money

Table 5–13. Total estimated cost for Submarine Launched Warhead (Future W76-1/2 Replacement)

Dollars in Billions	*FY 2024 Dollars*	*Then-Year Dollars*
Planning Estimate (High) [a]	29.7	65.0
Planning Estimate (Low) [a]	24.1	52.4
Proposed Budget	26.9	58.7

[a] Including Other Program Money

5.9.1.9 Summary of Cost Estimates

Figure 5–21 represents the aggregation of cost estimate ranges for all presently known warhead modernization programs from FY 2024 through FY 2050 based on schedule assumptions that are subject to change. The higher estimates in the 2040s reflect the inclusion of the Submarine-Launched Warhead, which will enable replacement of the W76-1/2; this weapon system was not included in the FY 2024 SSMP projection.

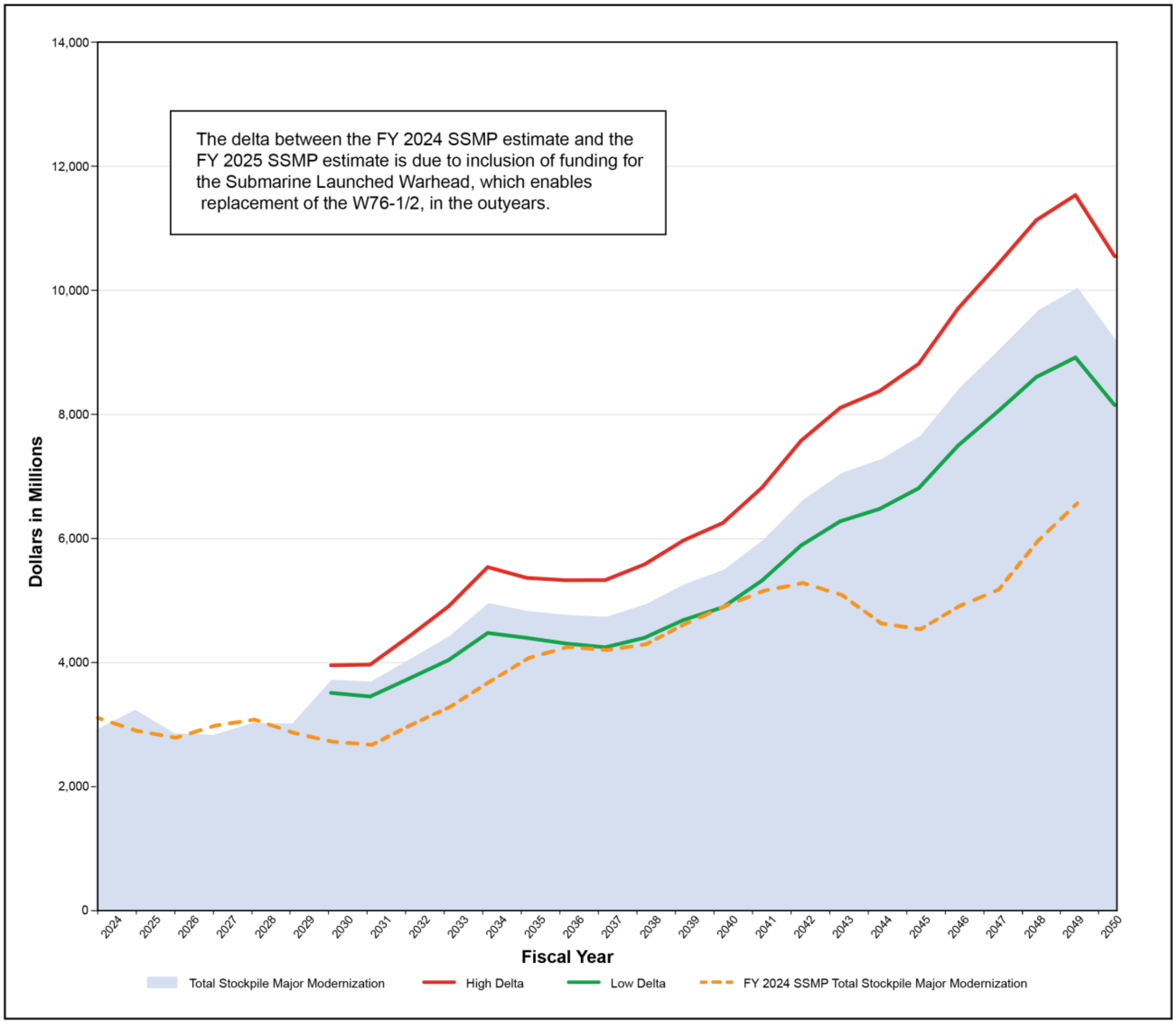


Figure 5–21. Total projected Stockpile Major Modernization costs for fiscal years 2024–2050 with high and low estimates (then-year dollars)

5.9.2 Construction

5.9.2.1 Cost Estimation for Capital Acquisitions

In FY 2020, DOE/NNSA began publishing cost estimates for both early-stage and ongoing capital acquisitions. For ongoing projects, the latest approved estimate is provided. For early-stage projects, which may be more than a decade away from initial approval, NNSA conducts planning estimates to inform long-term cost projections. Notably, the early stage cost estimates are:

- Performed by an organization separate from the Federal program office;[16]
- Developed with a top-down parametric method that accounts for cost and scope uncertainty;
- Based on historic DOE/NNSA project schedules, costs, and phasing;
- Based on anticipated project scope;

[16] The DOE/NNSA OMB Office of Programing, Analysis, and Evaluation performs the cost estimates on behalf of Defense Programs.

- Informed by affordability analysis; and
- Updated annually.

Once a project begins the acquisition process, it moves through the CD process described in DOE Order 413.3B. At each decision or new baseline, DOE/NNSA approves an official cost estimate of record. To determine the official estimate, DOE/NNSA reconciles the project cost estimate with an independent cost estimate performed by either the DOE/NNSA Office of Cost Estimating and Program Evaluation (before baseline) or DOE's Office of Project Management (after baseline).

The early-stage planning estimates reflect an assumed preliminary scope for the potential project. However, this does not predetermine the project's actual scope, acquisition strategy, or any other decision to be made as part of the CD process. Specifically, the project scope is not decided until the selection of an alternative, development of the design, and baselining of the project.

The Association for the Advancement of Cost Engineering International is a professional cost estimation society which has published a cost estimate classification system[17] based on the scope definition of the project. DOE/NNSA has mapped the Association's cost estimate classes to the most common uses for capital acquisitions.[18] **Table 5–14** summarizes this classification system, including the level of project definition, expected uncertainty range, and 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.

Table 5–14. Capital Acquisition Cost Estimate Classification System

	Primary Characteristic	*Secondary Characteristic*			
Estimate Class	***Maturity Level of Project Definition (percent)***	***DOE Capital Acquisition Milestone***	***Typical Types of Estimates***	***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	N/A	N/A	Detailed unit cost with detailed take-off	Low: -3 to -10 High: +3 to +15

CD = Critical Decision

5.9.2.2 Fiscal Year 2025 through Fiscal Year 2050 Estimates

The budget request for capital acquisitions in FY 2025 reflects the latest estimates for approved construction projects. DOE/NNSA continues to execute the schedules of multiple ongoing major capital

[17] 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.
[18] DOE Guide 413.3-21A, Cost Estimating Guide.

acquisition projects. Both project- and portfolio-level planning initiatives are in progress to ensure DOE/NNSA is consistently funding the highest-priority infrastructure investments across the enterprise. Details on major capital acquisition projects and project proposals are in Chapter 4, "Infrastructure and Operations."

5.9.3 Budget Projections

The FY 2025 President's Budget Request fully supports DOE/NNSA's risk-informed, complex, and time-constrained modernization and recapitalization effort being conducted in coordination with DoD. DOE/NNSA is making concerted investments in its production facilities so that the necessary capabilities and infrastructure will be available to execute modernization programs to meet DoD timelines. Additionally, DOE/NNSA is working to maintain and upgrade its science and technology infrastructure so that it can continue supporting the cutting-edge science that underpins science-based stockpile stewardship and enables continued confidence in the reliability of the nuclear stockpile without the need for underground nuclear explosive testing.

Figure 5–22 depicts Weapons Activities budget projections beyond the FYNSP, based on the FY 2025 President's Budget Request and a continuation of the program of record. The budget projection incorporates the Stockpile Major Modernization program cost estimates described in Section 5.9.1 and the cost estimates for the planned major programmatic construction projects described in Chapter 4, Section 4.2.2. These estimates are augmented by as-yet-unplanned construction beginning after FY 2039. Significant out-year estimates included in Figure 5–22 are:

- Reestablishing a plutonium pit production capability;
- Reestablishing a DUE capability;
- Revitalizing depleted uranium manufacturing capability;
- Prioritizing scientific and engineering investments in areas that enable DOE/NNSA to outpace threats (e.g., technology maturation) in alignment with updated science and technology investment strategy; and
- Developing KCNExT.

The FY 2025 budget assumes a National Defense topline, including the DOE/NNSA topline, for FY 2030 through FY 2034 that grows at 0.7 percent. However, for illustrative purposes of this affordability analysis and to conform to assumptions in prior versions of the SSMP, DOE/NNSA assumes that funding for FY 2030 through FY 2051 will be escalated at 2.1 percent.

This projection does not and cannot include unknown requirements, which may necessitate additional Stockpile Major Modernization programs, enhanced Stockpile Sustainment activities, R&D efforts, or further infrastructure investments. Out-year projections are adjusted annually as part of the programming process to align the total resource needs with available resources. As projected available resources are made clearer for years outside of the FYSNP, current capability and mission needs are examined and prioritized to build a program that maximizes the safety, security, and effectiveness of the nuclear deterrent while staying within the available resources. If there are significant changes to future requirements, DOE/NNSA, in conjunction with DoD, would be forced to make difficult decisions, with respect to scope and schedule of projects, or defer construction or recapitalization projects.

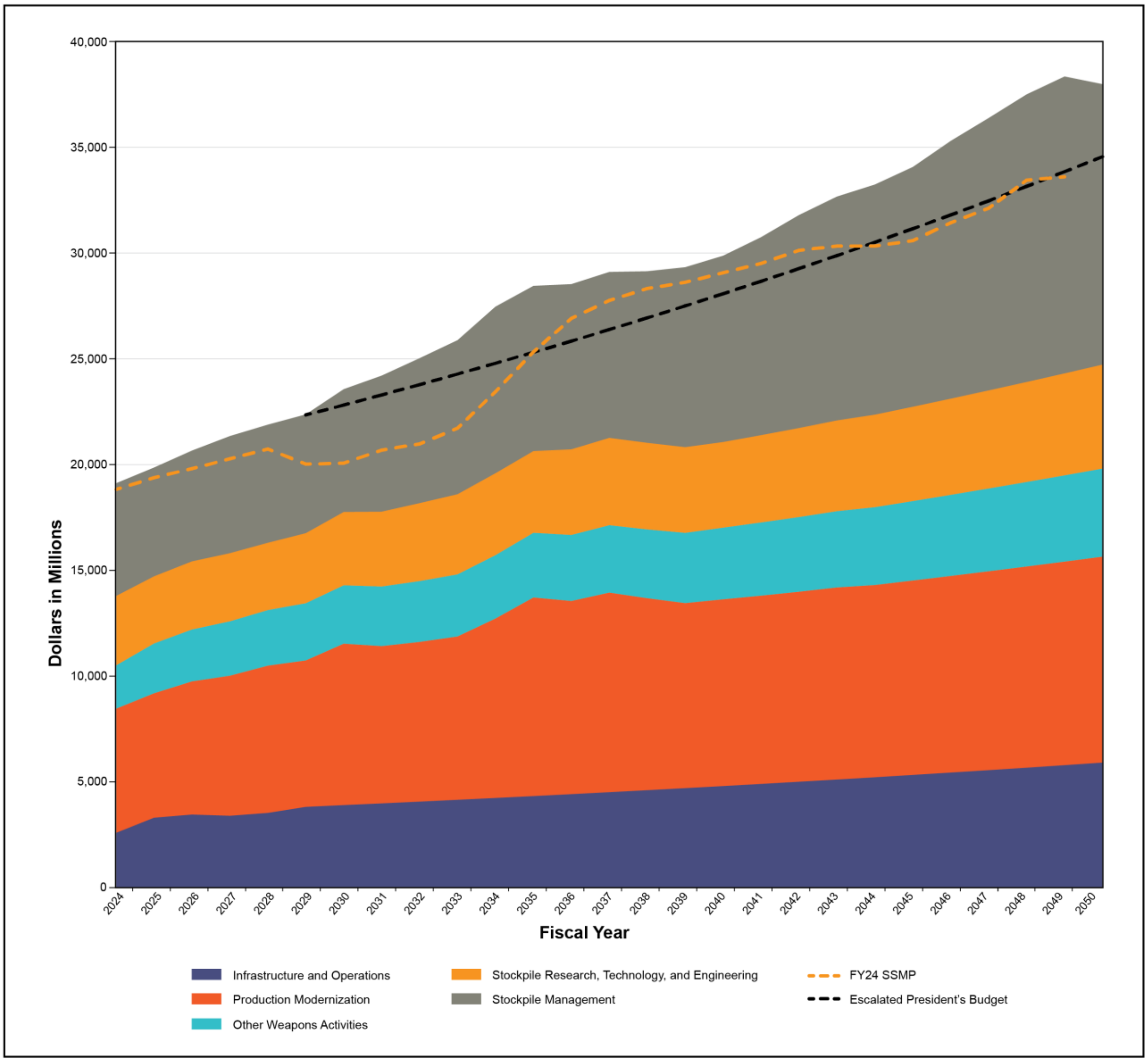


Figure 5–22. Projected out-year budget estimates for DOE/NNSA Weapons Activities in then-year dollars, including the escalated President's Budget Request

Chapter 6
Conclusion

This Department of Energy's National Nuclear Security Administration (DOE/NNSA) *Fiscal Year 2025 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (FY 2025 SSMP), together with its classified annex, is a key planning document for the nuclear security enterprise. It is the culmination of planning efforts across numerous DOE/NNSA programs and organizations, documenting the 25-year plan for ensuring the safety, security, and effectiveness of the U.S. nuclear stockpile. The FY 2025 SSMP details efforts to maintain the scientific and engineering tools, capabilities, and infrastructure that underpin the current and future nuclear deterrent. The report 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 (DoD) through the Nuclear Weapons Council.

The global threat environment is rapidly evolving and becoming increasingly dangerous, complex, and uncertain. In response to this changing environment, the United States must develop a modern, resilient, and flexible nuclear security enterprise to provide DoD with the necessary capabilities to continue to execute its critical nuclear deterrent mission. With support from Congress, DOE/NNSA will provide the nuclear security enterprise workforce with the resources and responsive, agile infrastructure needed to steward the systems that comprise the deterrent today, while preparing for the cutting-edge research and development that will inform the national security mission solutions of tomorrow.

Appendix A
Requirements Mapping

A.1 National Nuclear Security Administration Response to Statutory Reporting Requirements and Related Requests

The *Fiscal Year 2025 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (FY 2025 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 FY 2025 SSMP.

A.2 50 United States Code § 2523

50 U.S.C. § 2523	*FY 2024 Response*	*FY 2025 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* Message from the NNSA Administrator; Message from the Secretary; Chapters 2, 4, 6, 7; Appendix D *Classified Annex*	*Unclassified* Message from the NNSA Administrator; Message from the Secretary; Chapters 2, 4, 6; Appendix C, D
(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).	*Unclassified* Message from the NNSA Administrator; All Chapters	*Unclassified* Message from the NNSA Administrator; 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).		*N/A*
(3) The summaries and reports required by this subsection shall be submitted in unclassified form, but may include a classified annex.		*N/A*
(c) Elements of biennial plan summary Each summary of the plan submitted under subsection (b)(1) shall include, at a minimum, the following:		*N/A*
(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.		*Unclassified* Chapter 2, Section 2.2, Figure 2-2

50 U.S.C. § 2523	*FY 2024 Response*	*FY 2025 Response*
(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.		*Unclassified* Chapter 5, Figures 5-16–5-20, Tables 5-4–5-13
(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.		*Unclassified* Chapter 2, Sections 2.1.1–2.1.3; Chapter 3, Sections 3.1, 3.1.1–3.1.6
(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.		Appendix C; Chapter 4; Chapter 5
(5) A summary of the status, plans, and budgets for carrying out the stockpile responsiveness program under section 2538b of this title.		Appendix D
(6) A summary of the plan regarding the research and development, deployment, and lifecycle sustainment of technologies described in subsection (d)(7).		Chapter 3, Sections 3.1-3.6
(7) A summary of the assessment under subsection (d)(8) regarding the execution of programs with current and projected budgets and any associated risks.		*Unclassified* Chapter 5, Sections 5.9.1, 5.9.3, Table 5-14
(8) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).		*Unclassified* Message from the NNSA Administrator; Message from the Secretary; Executive Summary
(9) Such other information as the Administrator considers appropriate.		*Unclassified* All Chapters
(d) Elements of biennial detailed report Each detailed report on the plan submitted under subsection (b)(2) shall include, at a minimum, the following:		*N/A*
(1) With respect to stockpile stewardship, stockpile management, and stockpile responsiveness—		*N/A*
(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 1.3, Table 1-1 *Classified Annex*	*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 2, Section 2.2, Figure 2-2; Chapter 8, Sections 8.9, 8.9.2.2, 8.9.2.3, Table 8-4 *Classified Annex*	*N/A*

50 U.S.C. § 2523	*FY 2024 Response*	*FY 2025 Response*
(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; Chapter 8, Section 8.9.2, Figures 8-16–8-21, Tables 8-5–8-20 *Classified Annex*	*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, Sections 2.1, 2.2, 2.3; Chapter 4, Sections 4.2.2, 4.3.2 *Classified Annex*	*N/A*
(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, Sections 2.1.1, 2.1.1.1; Chapter 4, Section 4.2.1, Figure 4-2 *Classified Annex*	*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 1, Overview; Chapter 6, Section 6.1 *Classified Annex*	*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 3, Sections 3.1, 3.2, 3.4; Chapter 4, Sections 4.2.1, 4.2.4, Figure 4-2	*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 4, Sections 4.2.4, 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 1.2; Chapter 7, Sections 7.3.3, 7.4; Appendix F	*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 1, Section 1.2.1; Chapter 7, Section 7.3.1.1 *Classified Annex*	*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 8.9.2.2, 8.9.2.3, Table 8-4	*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, Table 8-1	*N/A*

50 U.S.C. § 2523	*FY 2024 Response*	*FY 2025 Response*
(M) the status, plans, activities, budgets, and schedules for carrying out the stockpile responsiveness program under section 2538b of this title;	*Unclassified* 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 8.3, Table 8-1	*N/A*
(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—		*N/A*
(A) a description of the information needed to determine that the nuclear weapons stockpile is safe and reliable;	*Unclassified* Chapter 2, Sections 2.1.1, 2.1.1.1; Chapter 4, Sections 4.2.1, 4.3.1 *Classified Annex*	*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 2, Section 2.2; Chapter 4, Section 4.3	*N/A*
(C) the criteria developed under section 2522(a) of this title (including any updates to such criteria).	*Classified Annex*	*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—		*N/A*
(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 4.3.1–4.3.4, Tables 4-1–4-4 *Classified Annex*	*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 4, Sections 4.3.4, Table 4-4	*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 4, Sections 4.2, 4.3, Table 4-4	*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 4, Section 4.3, 4.3.1–4.3.5, Figure 4-3, Tables 4-1–4-4	*N/A*
(i) the number of scientists, engineers, and technicians, by discipline, required to maintain such competencies; and	*Unclassified* Chapter 7, Section 7.1.2, Figure 7-2	*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, Table 7-1	*N/A*
(4) With respect to the nuclear security infrastructure—		*N/A*

50 U.S.C. § 2523	*FY 2024 Response*	*FY 2025 Response*
(A) a description of the modernization and refurbishment measures the Administrator determines necessary to meet the requirements prescribed in—		*N/A*
(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* Executive Summary; Chapter 6	*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* Executive Summary; Chapter 6	*N/A*
(iii) the most recent Nuclear Posture Review as of the date of the plan;	*Unclassified* Executive Summary; Chapter 6	*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, Section 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, 8.9.3, Figure 8-122, Table 8-13	*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, Table 8-2	*N/A*
(5) With respect to the nuclear test readiness of the United States—		*N/A*
(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; Appendix F, Section F.4.1.5	*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; Appendix F, Section F.4.1.3	*N/A*

50 U.S.C. § 2523	*FY 2024 Response*	*FY 2025 Response*
(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; Appendix F, Sections F.4.1.3, F.4.1.5	*N/A*
(6) A strategy for the integrated management of plutonium for stockpile and stockpile stewardship needs over a 20-year period that includes the following:	*Unclassified*	*N/A*
(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 4, Sections 4.3.1, 4.3.2	*N/A*
(D) An assessment of computational models of plutonium performance under static and dynamic loading, including manufactured and nonmanufactured conditions.	*Unclassified* Chapter 4, Section 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 8.6.1, Figure 8-8	*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 8-3, Table 8-1	*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 3.1.1	*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, Sections 5.2, 5.3 *Classified Annex*	*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, Section 5.3.2 *Classified Annex*	*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 8, Sections 8.8.4, 8.8.5 *Classified Annex*	*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	*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.C. § 2523	*FY 2024 Response*	*FY 2025 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	*Unclassified* Appendix F

A.3 50 United States Code § 2538a

50 U.S.C § 2538a	***FY 2024 Response***	***FY 2025 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, Sections 3.3.1, 3.1.1.2, Table 3-1; Chapter 6, Section 6.3.1.4	*Unclassified* Executive Summary; Chapter 3, Sections 3.4.1, 3.4.1.1, 3.4.1.2, Table 3-4; Chapter 5, Sections 5.5.2, 5.5.2.1, 5.7.2.5, Figures 5-3, 5-22
(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).	*N/A*	*Unclassified* Chapter 2, Sections 2.1.1, 2.1.1.1
(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 2024 Response***	***FY 2025 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 D

[1] H. Rept. 117-98 accompanying the *Energy and Water Development and Related Agencies Appropriations Bill, 2022* restated this annual Stockpile Responsiveness Program 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, Department of Energy's National Nuclear Security Administration (DOE/NNSA) submitted the report as a standalone document to provide as timely updates as possible and resubmitted within the SSMP, 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.

A.5 H.R. 244

H.R.244 – Consolidated Appropriations Act, 2017, P.L. 115-31	*FY 2024 Response*	*FY 2025 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.		*N/A*
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]]		*N/A*
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 United States Code § 2521

50 U.S.C § 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.C § 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 18th power floating point operations per second.

A.7 Related Legislation: 50 United States Code § 2522

50 U.S.C. § 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 United States Code § 2524

50 U.S.C. § 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.
(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 United States Code § 2538b

50 U.S.C. § 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.

50 U.S.C. § 2538b
(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: H.R. 6395 NDAA for Fiscal Year 2021

H.R. 6395 NDAA for FY 2021
§ 3113. 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.

A.11 Related Legislation: S. 1605 NDAA for Fiscal Year 2022

S. 1605 for FY 2022 NDAA	*FY 2024 Response*	*FY 2025 Response*
§ 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 Government or the private sector to address such risks and gaps."	*Unclassified* Appendix E	*Unclassified* Appendix E

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 grouped into seven interdependent areas, each of which constitutes a major facet of Weapons Activities work. 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 comprises four elements:

- Human capital (experience, skill, people)
- Physical assets (facilities, infrastructure, equipment)
- Resources (materials, secure supply chain)
- 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 compromised, the capabilities cannot function as a system.

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 warheads for the future stockpile.

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, while 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 nuclear explosive 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, Chemistry, High Explosives and Energetics Science and Engineering, and Actinide Science	In the context of stockpile stewardship, materials science is the study of how materials in a nuclear weapon are produced, age, and are replaced. Chemistry is the study of elemental composition, structure, bonding, and properties of matter. The stability of material properties and the nature of reactions and interactions are both 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 and is useful to understanding the 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 comprise 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 to understand 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 to Study Extreme Conditions (Lasers, Accelerators, and Pulsed Power)	This capability area includes laser, pulsed power, and accelerator technologies that are focused on creating extreme conditions for studying weapons-relevant matter and radiation behavior. Lasers are coherent light sources that deliver 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, and 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 with these technologies 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 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 encompasses the software, hardware, and facilities of sufficient power that achieve the dimensionality, resolution, and complexity in simulation codes to accurately model the performance of weapon systems and components and the fundamental physical processes critical to nuclear operation. This capability includes research and development in computer, information, and mathematical sciences to support developing and operating high performance computing.
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 lifecycle 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.
Lithium Management	Components that contain lithium materials require special conduct of operations, physical security protection, facilities, and equipment to handle, package, process, manufacture, and inspect these components.
Tritium Management	Tritium has a 12-year half-life and must be periodically replenished in gas transfer systems (GTS). 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 GTS reservoirs and inspecting reservoirs. Tritium is also recovered from returned GTSs.
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).
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, which would include, 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 all 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 all 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	Non-nuclear weapon components and assembly processes require special manufacturing, assembly, and inspection protocols. These components support many functions within the weapon: arming, fuzing, firing, safety, surety, and structural components; power supplies, microelectronics components and packaging, cables and interconnects, detonator assemblies, neutron generators and GTSs. Non-nuclear components comprise a large percentage of a weapon's makeup, which prevents unintended detonation or unauthorized use and ensure function when authorized by the President. In turn, those functions are provided by weapon specific components: radars stronglinks, firing sets, environmental sensors, weapon control units, batteries, lightning arresting connectors, surety electrical assemblies, reservoirs, valves, pads, cushions, spacers, mounts, cases, and other components. Many non-nuclear components require materials unique to weapons applications or with specification exceeding typical commercial materials including getters, desiccants, ceramics, polymers, silicones, plastics, adhesives, and composites. There are also items external to the weapon supporting test flights and DoD activities: joint test assemblies and transmitters, handling and testing gear and weapon trainer assemblies.
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 costs or production time.
Weapon Component and System Prototyping	Development, qualification, and manufacture of high-fidelity, full-scale prototype weapon components and systems reduce costs and lifecycle 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 research and development to reduce costs, reduce component development and production time, improve safety and performance, and control waste streams. Examples of these techniques include additive manufacturing, use of microreactors, microwave casting, and electrorefining.

B.6 Weapon Assembly, Storage, Testing, and Disposition

After weapon components are produced, each component 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 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, and 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.
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.
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.

B.7 Transportation and Security

The Transportation and Security area involves 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.
Safeguards and Security	Safeguards and security protect the Nation's nuclear materials, infrastructure assets, and workforce at DOE/NNSA sites involved in Weapons Activities. They protect 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 (IT) and Cybersecurity	IT and cybersecurity provide infrastructure and protection for 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 its highly skilled scientific, engineering, production, and manufacturing workforce, without which DOE/NNSA could not meet its vital national security missions. Those missions continue growing as DOE/NNSA transitions its focus from sustainment to modernization and acquisition, from legacy to new or revitalized production processes, all while maintaining the current stockpile. As DOE/NNSA undertakes seven weapon programs, including the first new weapon in over 30 years, and modernizes its production infrastructure to support those programs, the workforce is growing to meet the increased scope of work, as shown in **Figure C–1**. The workforce has generally grown year to year since fiscal year (FY) 2000, accelerating in FY 2010 as DOE/NNSA initiated multiple modernization programs. The management and operating (M&O) workforce has seen the majority of these gains, with the Federal workforce size decreased in real terms relative to work scope. Since many roles within the nuclear security enterprise require specialized training or years of experience to develop proficiency, effectively training personnel, then retaining them, is essential to success.

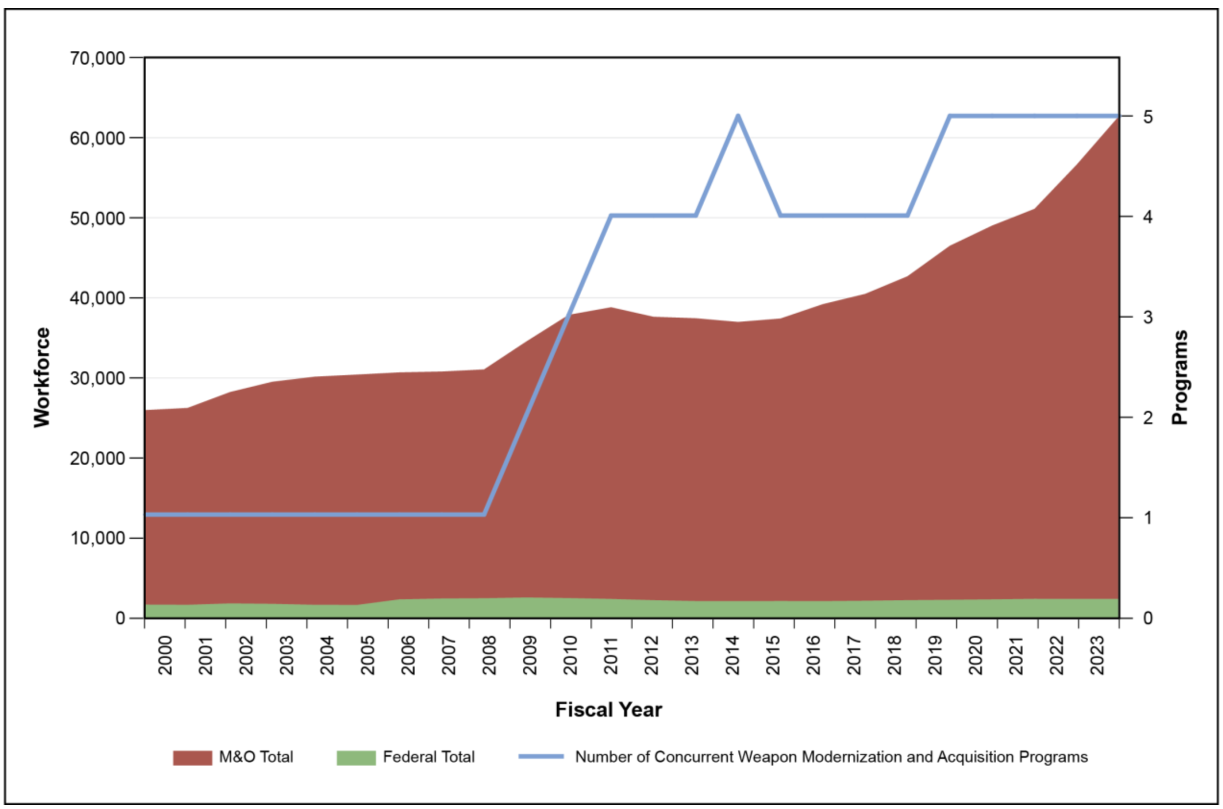


Figure C–1. Nuclear security enterprise workforce growth responding to increased scope of work[1]

[1] Workforce and weapon program data as of September 30, 2023.

This appendix provides the summary of human capital retention required in 50 U.S. Code § 2523c(4) and includes a demographic snapshot of the workforce across the nuclear security enterprise as of September 30, 2023. A detailed discussion of the DOE/NNSA workforce is contained in Chapter 7 and Appendix F of the *Fiscal Year 2024 Stockpile Stewardship and Management Plan* (FY 2024 SSMP).

C.1 Demographics

As of September 30, 2023, the nuclear security enterprise reported a headcount of 62,842[2] employees (Federal and M&O combined) with a net increase of 34 Federal employees and 4,940 M&O employees from the number reported in the FY 2024 SSMP. **Figure C–2** shows the distributions of ages, years of service, and common occupational classification system for the Federal and M&O workforce.

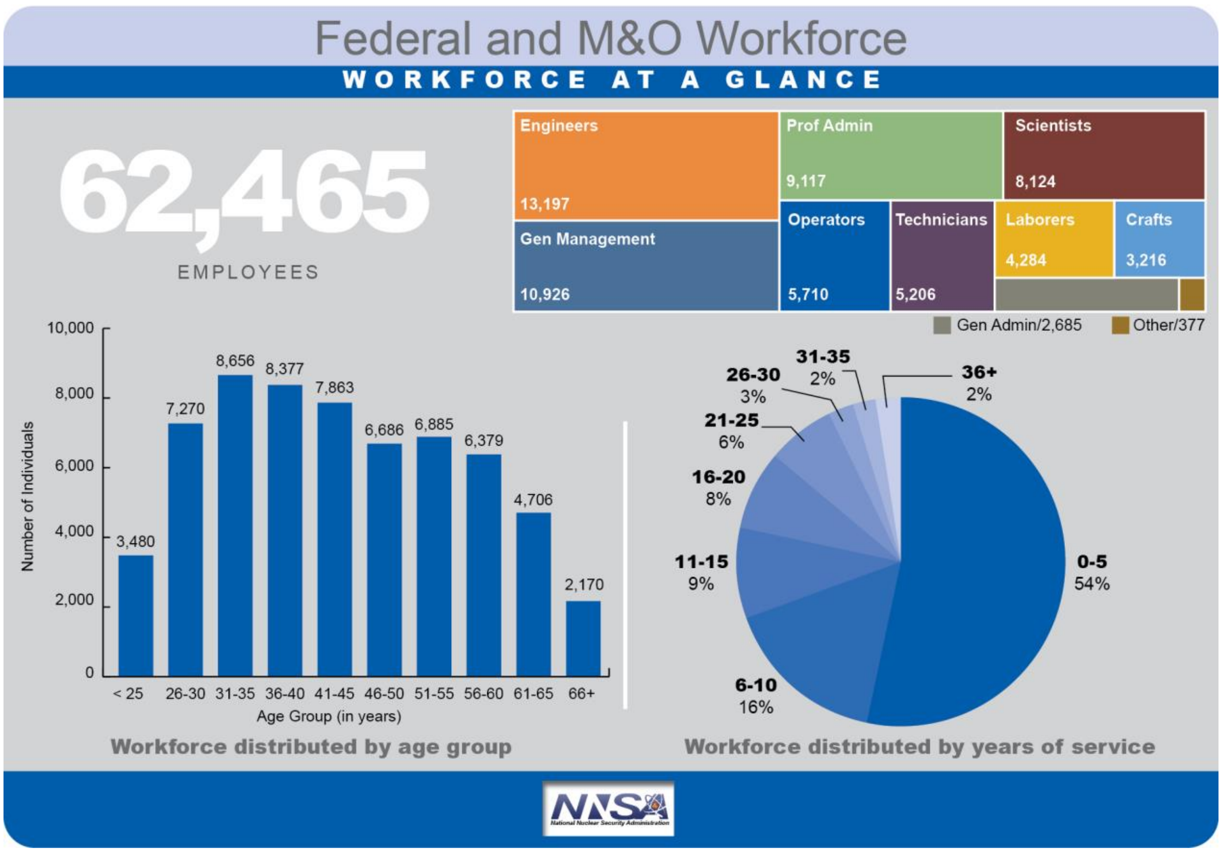


Figure C–2. Nuclear security enterprise demographics

DOE/NNSA is restarting manufacturing processes and resuming some activities that only the most experienced employees or retirees may have witnessed, making knowledge capture, preservation, and transfer programs crucial. Currently, 11,728 employees are retirement eligible,[3] representing 18.8 percent of the workforce. The percent of retirement-eligible workers has decreased almost linearly from 33.0 percent in FY 2016 to 18.8 percent in FY 2023 as the size of the workforce has grown. While the experience of the current workforce is essential for high-quality and rapid work, many of those who are retiring did not participate in warhead production and are most experienced at stockpile sustainment

[2] This number omits support service contractors and staff augmentation.

[3] Each M&O defines "retirement-eligible" differently—some by age cutoffs, others counting only those who meet the retirement criteria for their legacy pension plan or some other combination of age and years of service.

activities. Even so, notable numbers of retirees return on a limited basis as contract support employees because they have specialized knowledge or skills. Retirements make up a significant portion of separations for age groups over 50. As shown in **Figure C–3**, 29.6 percent of separations in FY 2023 are retirements.[4]

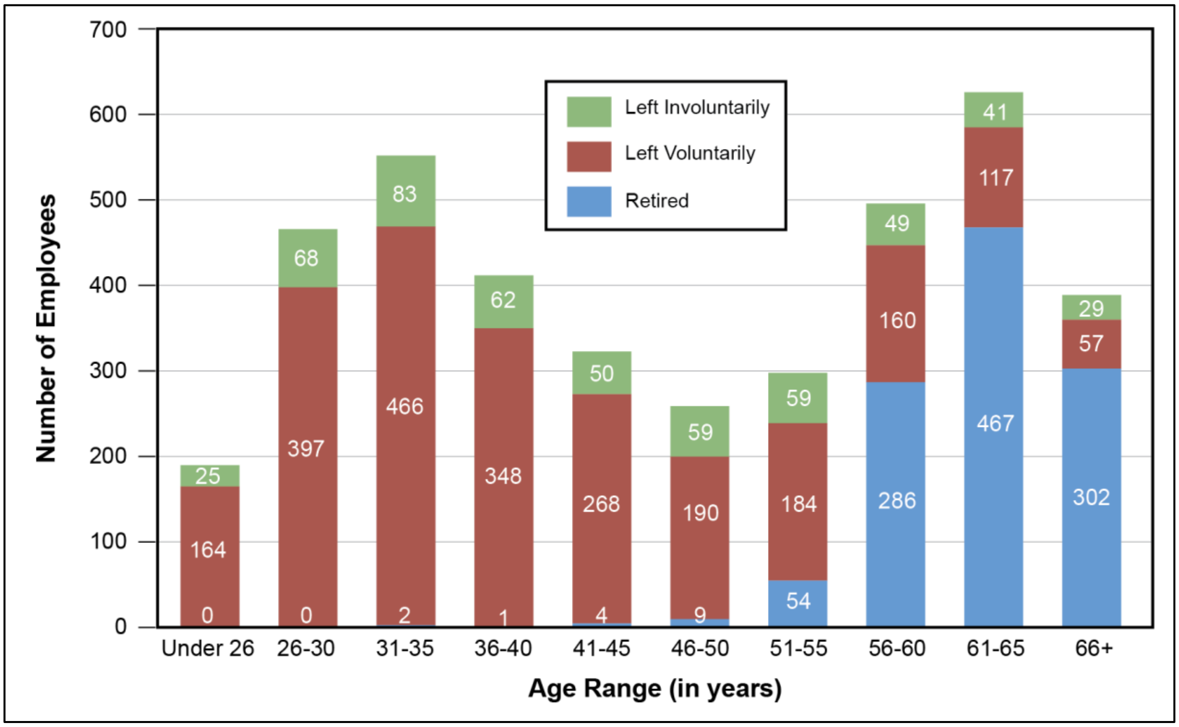


Figure C–3. Separation by age[5]

At the other end of the experience spectrum, over half of the nuclear security enterprise workforce—33,412 individuals—has less than 5 years of experience at its current location. While a startling statistic, this number is unsurprising given the rapid growth of the nuclear security enterprise over the last several years, from 42,690 employees in FY 2018 to 62,472 in FY 2023. Even if *all* employees hired over the last 5 years were retained, 31.7 percent of the workforce would have less than 5 years of experience. While the turnover *rate* of employees with less than 5 years of experience is lower than other groups, their absolute *numbers*—2,044 separations—account for over half of all separations due to the large proportion of the workforce that they comprise.

Retaining newly hired individuals so they can fill the pipeline of talent and gain valuable on-the-job experience is essential. The distribution across age groups is relatively flat, showing that newly hired individuals often arrive with previous work experience, but will require onboarding and specialized training depending on their positions. M&O contractors are adjusting their training models to accommodate the large numbers of new workers and expectations about how long employees will stay. Specialized science, technology, and manufacturing facilities are essential for bringing workers' levels of

[4] Each M&O defines a retirement differently—some through a combination of age and years of service, others by departing personnel self-identifying as retiring, and others as people who will earn a pension. This diversity reflects the shift from pension-based systems to 401(k)-based systems.

[5] 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.

knowledge and experience up to the required levels. DOE/NNSA is actively working on a Science and Technology Investment Strategy to meet these needs.

Several career specialties—cybersecurity; Nuclear Material Couriering; skilled trades; and science, technology, engineering, and math (STEM)—experience more acute hiring and retention challenges than other specialties. DOE/NNSA sites compete with the private sector to recruit and retain personnel with highly valued skills, and there is limited availability of U.S. citizens trained in skilled trades, such as welders, electricians, pipefitters, or with STEM skill sets. The Strategic Posture Commission recognized the need to "establish and increase technical education and vocational training programs required to create the nation's necessary skilled-trades workforce for the nuclear enterprise."[6] It additionally recognized that security clearance requirements further limit the pool of potential applicants and increase hiring times; nuclear security positions require extensive security screening and no drug use, which is complicated by numerous states legalizing use of substances still prohibited at the Federal level. Given demand for these skills, qualified applicants can command significant salaries, benefits, and workplace flexibility from companies outside the nuclear security enterprise.

C.2 Turnover Trends and Retention Strategies

Significant turnover is a threat to mission assurance. DOE/NNSA experienced rising turnover rates[7] from FY 2020 through FY 2022 due to changes in the national work landscape, but saw turnover rates return to normal in FY 2023. While it is impossible to determine all the factors that influence individuals' decisions to change jobs or to stay at their current employer, DOE/NNSA is working to provide the best employee value proposition possible while making efficient use of taxpayer resources. The employee value proposition includes more than just salary and benefits; it encompasses the totality of the work experience. DOE/NNSA offers meaningful work, cutting-edge tools and facilities, growth and mobility, connection and community, and health and well-being. DOE/NNSA is actively working to hire and retain Federal personnel and is coordinating with its M&O contractors to ensure they have the tools needed to meet their hiring and retention targets. For instance, DOE/NNSA authorized a mid-year compensation increase for M&O employees FY 2022 that aimed to reduce high turnover rates and is working to improve facilities across the nuclear security enterprise. External factors, such as layoffs at tech companies or rising interest rates, may also have influenced employees' decision making.

As shown in **Figure C–4**, the M&O turnover rate decreased from 10.56 percent in FY 2022 to 6.71 percent in FY 2023, and the number of separations also decreased dramatically from 5,306 individuals in FY 2022 to 2,950 in FY 2023. Involuntary separations remained relatively constant while retirements decreased slightly; voluntary separations contributed the most to the lower turnover rate, decreasing by more than a third from FY 2022 to FY 2023.

[6] *America's Strategic Posture: The Final Report of the Congressional Commission on the Strategic Posture of the United States*. Madelyn Creedon, et al. October 2023.

[7] The SSMP has previously used "attrition" interchangeably with "turnover," which incorrectly implied that positions would not be backfilled after an employee departed. Turnover is calculated as: (number of separations during FY)/[(headcount at beginning of FY + headcount at end of FY)/2]*100.

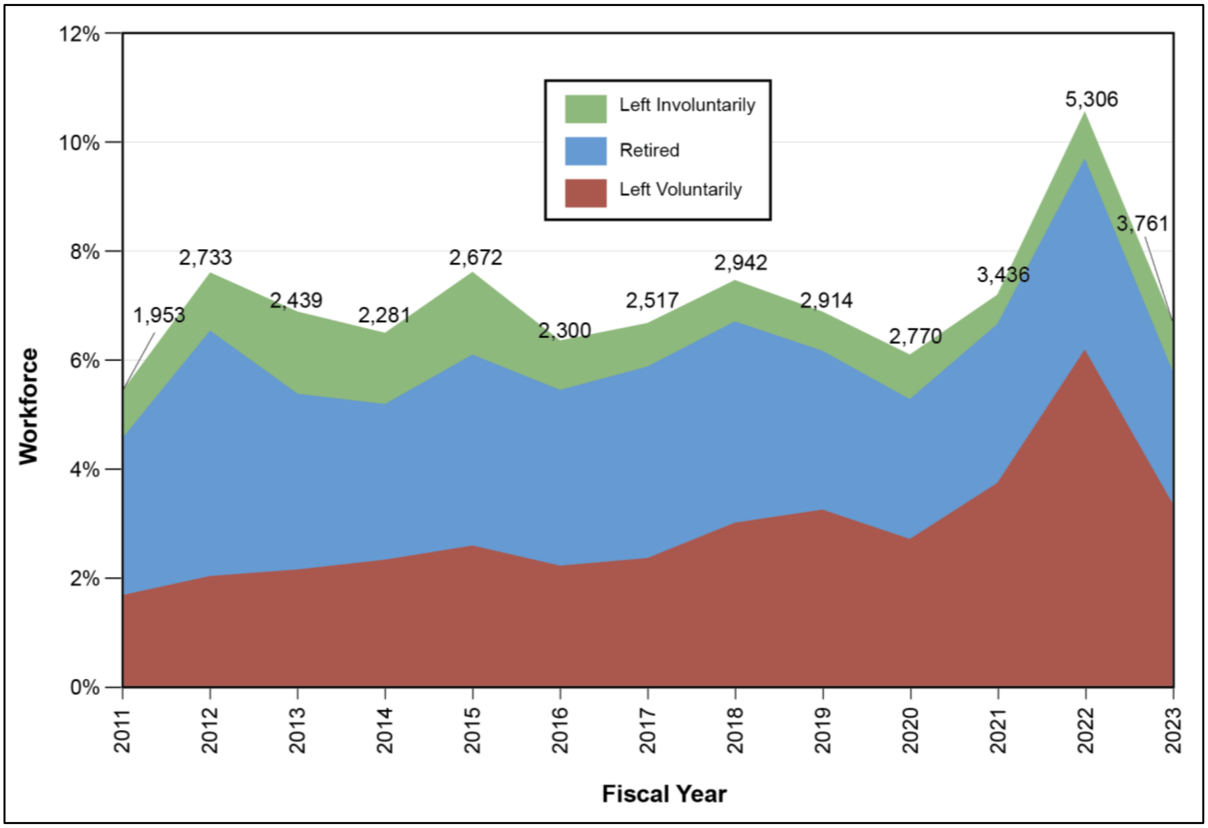


Figure C–4. M&O turnover trends in percent, with total number of separations annotated[8]

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. The Future of Work initiative is polling employees and leaders, then providing recommendations to NNSA leadership on promoting a strong workplace culture and meaningful interactions at NNSA Headquarters and Field Offices. The FY 2022 Strategic Outlook Initiative, which was sponsored by the NNSA Administrator with active engagement from all of the laboratories, plants, and sites, took an enterprise-wide, strategic-level look "over-the-horizon" to identify DOE/NNSA workforce issues over the next 5 to 20 years. It provided several recommendations for actions that could be taken now to ensure DOE/NNSA has the workforce it needs in the future, which some laboratories, plants, and sites are beginning to successfully implement.

NNSA Headquarters, site offices, and M&O partners support retention through a variety of programs:

- Critical skill retention programs to offer pay incentives or graduate education for hard-to-fill positions;
- Employee leadership development programs, educational opportunities and assistance, and apprentice programs to encourage career growth;
- Emphasis on employee engagement through employee resource groups, mission-related programming, career development tools, workshops, and mentoring;

[8] This graphic does not include the expiration of a term of service for a limited term employee working on the Uranium Processing Facility; there were 1,170 expirations of terms of service in FY 2023.

- Strong university relationships that sponsor research, capacity building, curriculum development, internships and/or apprenticeships, and introduce students to the nuclear security enterprise;
- Employee recognition programs that highlight achievements or accomplishments;
- A mid-year compensation increase in April 2022, in addition to annual and evaluation of employee benefit policies, such as paid time off accrual;
- Flexible and alternate work schedules to support work/life balance by leveraging remote and hybrid work situations, when appropriate; and
- Modernization of office spaces and digital tools.

Appendix D
Stockpile Responsiveness Program

This appendix is provided pursuant to 50 U.S. Code § 2523, which requires inclusion of plans for the Stockpile Responsiveness Program (SRP) in the Stockpile Stewardship and Management Plan (SSMP).

Section 3112 of the *National Defense Authorization Act for Fiscal Year 2016* established that "[i]t 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." Section 3112 created the SRP to achieve this policy in coordination with already existing Stockpile Stewardship and Stockpile Management Programs.

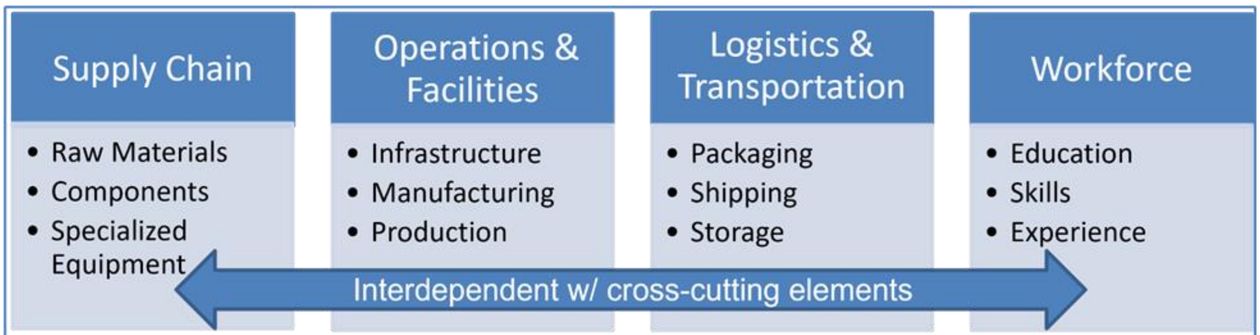
The SRP is intended to exercise and enhance capabilities through the entire nuclear weapons lifecycle to improve the responsiveness of the United States to future threats, technology trends, and international developments not addressed by existing life extension programs. Technology development teams also provide leadership opportunities for early-career staff members while SRP activities fully exercise the abilities of the workforce and allow the enterprise to identify efficiencies for current and future programs. The SRP is organized according to major technical efforts and heavily focuses on improving production responsiveness along with joint activities with the Office of the Under Secretary of Defense for Research and Engineering. The March 2024 report to Congress, *2024 Status of and Plans for Projects and Activities within the Stockpile Responsiveness Program*, provides information regarding the program's purpose, planned budget, governance, and priorities.

H. Rept. 117-98, which accompanies the *Energy and Water Development and Related Agencies Appropriations Bill, 2022*, restated an annual SRP reporting requirement and noted that since the SSMP does not typically accompany the annual budget request, including the report within the SSMP, it "therefore does not offer a useful and timely companion to the budget." This direction was reiterated through the 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 submitted the report as a standalone document most recently in May 2024 to provide as timely updates as possible.

Appendix E
Industrial Base

E.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, and workforce. DOE/NNSA uses these pillars to identify the full scope of industrial base challenges in maintaining the nuclear stockpile, including those internal to the nuclear security enterprise, such as material production and workforce management, and external, such as vendor resiliency. DOE/NNSA stands apart from many other U.S. Departments and Agencies in that it is both a producer and consumer of manufactured goods, made possible through its laboratories, plants, and sites. The types of activities that are considered when examining the NIB are listed under the pillars in **Figure E–1**.



- **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 E–1. The nuclear security enterprise industrial base framework

E.2 Risk Management

Risk management is an area of increased attention across the nuclear security enterprise. Programs and sites within the enterprise employ varying risk management methods to identify, characterize, monitor, and manage risks, including tracking and monitoring global events to identify emerging risks to the enterprise. These efforts include the development of program-specific and supply chain-focused risk matrices (which track risks from raw material procurement through product acceptance), as well as the implementation of supplier transparency software for a more proactive approach to supply chain risk management. Groups such as the Supply Chain Risk Management Team (SCRMT) are undertaking significant efforts to develop a common methodology for risk management. SCRMT, which consists of DOE/NNSA representatives and mission partners from across the laboratories, plants, and sites, is working to standardize the methods used to identify, monitor, and respond to supply chain risks across the nuclear security enterprise. SCRMT works across all four pillars of the NIB, adding rigor to risk management processes by considering the holistic picture. There are several risk factors that can affect DOE/NNSA's ability to provide continued viability of the nuclear weapons stockpile. These factors are not unique to the nuclear security enterprise, as they affect the private and public sectors. Examples of these factors are listed in **Table E–1**.

Table E–1. The nuclear security enterprise industrial base risk factors

Human Capital Gaps	Industry is unable to hire or retain U.S. workers with the necessary skill sets.
Single Source Vendors	Only one supplier is qualified to provide the required capability and/or product.
Constrained Market	Capacity is unavailable in required quantities or time due to competing market demands.
Product Security	Lack of cyber and physical protection resulting in eroding integrity and confidence.
Sunset Technologies	Product or material obsolescence resulting from decline in relevant suppliers.
Foreign Dependency	Domestic industry does not produce the product or does not produce in sufficient quantities.
Eroding Infrastructure	Loss of specialized capital equipment needed to integrate, manufacture, or maintain capability.
Regulatory Changes	Laws (e.g., labor, environmental, transportation) outpace industry's ability to develop alternative processes.
Inflation	Changes to the global market causing uncertainty in supplier pricing models, thereby increasing costs in material, labor, and freight over a short period of time.
Global Events	Manmade and/or natural events (e.g., the war in Ukraine and the COVID-19 pandemic) that negatively impact the supplies of critical goods and services.

COVID-19 = Coronavirus Disease 2019

E.2.1 Monitoring

The NIB is complex and multi-faceted. Numerous diverse groups, both internal and external to the nuclear security enterprise, address industrial base issues that are typically limited to their own programs or activities. This does not always allow for a broad view of the industrial base. Therefore, DOE/NNSA leverages the Nuclear Security Enterprise Industrial Base Monitoring Program to monitor these groups, allowing for visibility into the entirety of the industrial base, and increase data sharing across various program offices. Such communication allows for coordinated responses to emerging industrial base challenges, such as reduced availability of per- and polyfluoroalkyl substances (PFAS) and its associated impact to mission-critical processes, as well as loss of key suppliers in this specialty market.

E.2.1.1 Evolving Challenges

Industrial base monitoring efforts focus on evolving challenges affecting multiple areas of the nuclear security enterprise. Working groups within DOE/NNSA and the interagency are tracking developments in the regulatory environment of PFAS and other widely used chemicals. This includes changes to regulation and restriction under legislation such as the *Toxic Substances Control Act* and the *American Innovation and Manufacturing Act*. DOE/NNSA further works with the laboratories, plants, and sites to understand usage of such materials across the nuclear security enterprise as well as the impact of their restriction on weapons production and other critical processes. These monitoring activities assist DOE/NNSA in proactively detecting and preparing for future product discontinuation and market exits, as well as coordinating enterprise-wide responses to changes in the supply chain. Other overarching issues affecting the nuclear security enterprise involve microelectronics and critical minerals and materials. Groups are working across the nuclear security enterprise to address challenges such as supply chain shocks, limited domestic manufacturing, and foreign export control restrictions, all of which may affect product availability.

E.2.2 Mitigation

Within the Stockpile Stewardship and Management Plan, each of the four NIB pillars are addressed in additional detail in their relevant sections along with actual or potential challenges (risks and issues) and mitigation strategies. While not a complete index of references, some noteworthy examples are:

- Supply chain challenges are discussed throughout the document but primarily in Chapter 3, "Weapons Activities Capabilities that Support the Nuclear Security Enterprise." Specific examples include managing material obsolescence and vendor risks, developing sufficient capacity for energetic materials, maintaining a reliable tritium supply chain, and mitigating supply chain disruptions that affect a range of microelectronic materials.
- Operations and facilities challenges are discussed primarily in Chapter 3 and Chapter 4, "Infrastructure and Operations." Specific examples include issues stemming from outdated and aging infrastructure, the need to invest in both modern infrastructure and emerging technology, and lack of capacity to meet emerging mission requirements.
- Logistics and transportation challenges are primarily discussed in Chapter 2, "Stockpile Management"; Chapter 3; and Appendix B, Section B.7, "Transportation and Security." Specific examples include sustaining the Safeguards Transporter fleet, manufacturability, and sourcing limitations of future secure transportation programs. These could increase cost and scheduling risks.
- Workforce challenges are primarily discussed in Appendix C, "Workforce Retention," and Chapter 3. Specific examples of challenges to the workforce include DOE/NNSA'S need to hire, train, qualify, and retain additional plutonium pit production personnel to meet growing requirements, as well as commercial competition and increased turnover among key talent in mission critical areas.

E.3 Interagency Coordination

DOE/NNSA participates in numerous interagency forums such as the Joint Industrial Base Working Group, which acts as the advisory committee to the Department of Defense-led Industrial Base Council. The Council functions as the principal advisory forum on prioritized industrial base matters for the Department of Defense 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/NNSA continues to expand its coordination with interagency partners, such as the Strategic Radiation-Hardened Electronics Council and the PFAS Sub-Interagency Policy Committee, to address issues related to foreign export control of microelectronic components and the regulation of critical materials, as well as other shared concerns.

DOE/NNSA also participates in the review of certain foreign investments in U.S. industry sectors that are critical to the nuclear security enterprise through the Committee on Foreign Investment in the United States (CFIUS). DOE is a statutory member of CFIUS, an interagency committee led by the Department of Treasury, that reviews these foreign investments to determine the effect of such transactions on U.S. national security. Many of these transactions have specific nuclear security enterprise equities, and DOE/NNSA coordinates across the laboratories, plants, and sites to recommend strategies to mitigate any risks to the enterprise. In 2023, DOE/NNSA analyzed approximately 94 transactions with potential ties to the NIB or tangentially relevant industries. Mitigation strategies were instituted on 16 of these transactions to provide assurances for products and services vital to the nuclear security enterprise and prevent the transfer of critical technologies.

Appendix F
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—A material change to, or a prescribed inspection of, a nuclear weapon or major assembly that does not alter its operational capability, but 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 underground 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 and that the weapon will operate correctly when a unique signal to do so is properly activated.

artificial intelligence—A machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments. Artificial intelligence systems use machine- and human-based inputs to perceive real and virtual environments; abstract such perceptions into models through analysis in an automated manner; and use model inference to formulate options for information or action.

attrition—The naturally occurring reduction of the workforce due to separations where the organization leaves the position vacant or eliminates the position. Calculated as the total number of employee departures during the period divided by the average number of employees during the period.

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 explosives—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 explosives.”

critical decision (CD)—The five levels that a Department of Energy (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; and CD-4, *Approve Start of Operations or Project Completion*. See DOE Order 413.3B for additional details.

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—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 the Department of Energy's National Nuclear Security Administration (DOE/NNSA) as verifiably meeting all applicable quality and qualification requirements. The first production unit for a weapon is a production milestone. For milestone completion, the Department of Defense or the Nuclear Weapons Council must accept the design, and DOE/NNSA must verify that the first produced weapon meets the design specifications.

fiscal year—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—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—A warhead component that enables tritium, a radioactive isotope of hydrogen, to boost the yield of a nuclear weapon.

high energy density 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. HE 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 explosives" and "insensitive high explosives."

high-performance computing—The use of supercomputers and parallel processing techniques with multiple computers to perform complex computational science tasks.

ignition—The point at which a nuclear fusion reaction becomes self-sustaining (i.e., more energy is produced and retained in the fusion target than the energy used to initiate the nuclear reaction).

information technology—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—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 explosives—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—(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, and (2) A National Nuclear Security Administration (NNSA)-developed configuration, based on NNSA and Department of Defense requirements, for use in the flight test program.

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.

lifecycle—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.

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—A weapon component or subsystem whose performance degrades with age and must be periodically replaced (e.g., 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 set of techniques that can be used to train AI algorithms to improve performance at a task based on data. Machine learning applies mathematical models to data to extract knowledge and find patterns that humans would likely miss. Machine learning also recommends actions, but it does not direct systems to take action without human intervention.

major item of equipment (MIE)—Capital equipment with a cost that exceeds $2 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 Critical Decision process as line-item capital asset projects. See DOE Order 413.3B for additional details.

Manufacturing Readiness Level (MRL)—A means of communicating the degree to which a component or subsystem is ready 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.

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. For physical infrastructure that supports the nuclear security missions, modernization is 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 the Department of Energy's National Nuclear Security Administration 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—For computing, information technology and cybersecurity, a network is a communications medium responsible for the transfer of data, information and all attached components.

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 a 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.

neutron generator—A limited life component that provides neutrons at specific times and rates to initiate weapon function.

non-nuclear components—The parts or assemblies that do not contain special nuclear materials and are designed for use in nuclear weapons or in nuclear weapons trainers. Examples include radiation-hardened electronic circuits and microelectronics; cables; detonator assemblies; power supplies or arming; fuzing, firing, safety, surety, structural, and gas transfer system components; custom formulated materials; joint test assembly components; trainers; and handling and testing gear. Non-nuclear components comprise 80 percent of the components in a weapon, preventing unintended detonation or unauthorized use and ensure function when authorized by the President.

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 Sites, that sustain the research, development, production, and dismantlement capabilities needed to support the nuclear weapons stockpile.

nuclear stockpile/nuclear weapons stockpile—The nuclear stockpile and nuclear weapons stockpile includes both active and inactive warheads. Active warheads include strategic and non-strategic weapons maintained in an operational and ready-for-use configuration, warheads that must be ready for possible deployment within a short timeframe, and logistics spares. They have tritium bottles and other limited life components installed. Inactive warheads are maintained at a depot in a non-operational status and have their tritium bottles removed. A retired warhead is removed from its delivery platform, is not functional, and is not considered part of the nuclear stockpile. Warheads awaiting dismantlement constitute a significant fraction of the total warhead population. A dismantled warhead is a warhead reduced to its component parts.

Nuclear Weapons Council—The joint Department of Energy/Department of Defense 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.

Other Program Money—Funding that is found outside of a life extension program (LEP) funding line (i.e., in other program lines), but is directly (or uniquely) attributed to an LEP. Such funding would not be needed without 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 lifecycle.

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—The Savannah River Site, Y-12 National Security Complex, Kansas City National Security Campus, and Pantex Plant, which 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 (e.g., War Reserve, Training, Evaluation) and generally includes national security laboratory (i.e., 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—For 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.

resilience—The ability of the nuclear security enterprise to recover from an insult or stress in a sufficiently timely manner to not compromise the national deterrence mission.

responsive—The capability and capacity of the nuclear security enterprise to respond in a timely manner to technical and/or geopolitical surprises (and the requirements they generate).

Safeguards Transporter—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 Department of Energy's and its contractors' facilities, property, and equipment.

security system—The combination of personnel, equipment, hardware and software, structures, plans and procedures 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—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 life cycle.

Stockpile System—Weapons systems that are currently in the stockpile (B61-3/4/10/11/12, B83, W80-1, W88-0 [and Alt 370], W87-0, W76-0/1/2, W78).

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 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—A National Nuclear Security Administration program to modify and maintain a set of nuclear weapon systems (see "stockpile sustainment"). For 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.

turnover—The loss of employees due to separations where the organization intends to refill the position. Calculated as the total number of employee departures during the period divided by the average number of employees during the period.

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 is critical to national security.

uranium enrichment—The process of increasing the concentration of the uranium-235 isotope in any given amount 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 fulfills its intended purpose. For 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 life extension program (LEP)—An LEP 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 Minuteman III LGM-30.

W80-4 life extension program (LEP)—An LEP for the W80 warhead aboard a Long Range Standoff 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 alteration program 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 LGM-35A Sentinel, formerly known as the Ground Based Strategic Deterrent, planned to replace the aging Minuteman III ICBM system.

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.

weapon—(1) A warhead and its delivery system (e.g., missile) and (2) a gravity bomb (e.g., B61-12), which can be referred to as a weapon even when separate from the aircraft carrying it.

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 National Nuclear Security Administration budget covering these activities.

Weapon System—Combination of one or more National Nuclear Security Administration nuclear weapons with all related equipment, and Department of Defense materials, services, personnel, and means of delivery and deployment (if applicable) required for self-sufficiency including aircraft, missiles, ships, submarines, and launchers.

Appendix G
Acronyms and Abbreviations

ACRR	Annular Core Research Reactor
Alt	Alteration
AMLI	Advanced Machine Learning Initiative
AoA	Analysis of Alternatives
ASC	Advanced Simulation and Computing
BCR	Baseline Cost Report
CBI	Capability Based Investments
CD	Critical Decision
CFF	Contained Firing Facility
CFIUS	Committee on Foreign Investment in the United States
CHE	conventional high explosives
COVID-19	Coronavirus Disease 2019
CREST	Combined Radiation Environments for Survivability Testing
D&I	disassembly and inspection
DARHT	Dual-Axis Radiographic Hydrodynamic Test
DM	deferred maintenance
DNS	Defense Nuclear Security
DoD	Department of Defense
DOE	Department of Energy
DU	depleted uranium
DUE	domestic uranium enrichment
DUF_6	depleted uranium hexafluoride
ECSE	Enhanced Capabilities for Subcritical Experiments
EMC^2	Enhanced Minor Construction and Commercial Practices
FA	Federal Agent
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
HEATT	High Efficiency Adaptable Telemetry Transmitter
HED	high energy density
HESE	high explosives science and engineering
HESFP	High Explosives Synthesis, Formulation, and Production
HEU	highly enriched uranium
HFTOC	High-Fidelity Training and Operations Center
HPC	high-performance computing
HPDU	high purity depleted uranium
HSE	hydrodynamic and subcritical experiments

ICF	inertial confinement fusion
IDC	integrated design code
IHE	insensitive high explosives
IIP	Integrated Infrastructure Planning
IMI	Infrastructure Modernization Initiative
IT	information technology
JTA	joint test assembly
KCNExT	Kansas City Non-Nuclear Component Expansion Transformation
KCNSC	Kansas City National Security Campus
KC STEP	Kansas City Short-Term Expansion Plan
kV	kilovolt
LAMP	LANSCE Modernization Project
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
NDAA	*National Defense Authorization Act*
NEA	Nuclear Enterprise Assurance
NIB	nuclear security enterprise industrial base
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Sites
OMB	Office of Management and Budget
Omega	Omega Laser Facility
OT	operational technology
Pantex	Pantex Plant
PFAS	per- and polyfluoroalkyl substances
PF-4	Plutonium Facility
PIDAS	perimeter intrusion detection and assessment system
PPBE	planning, programming, budget, and evaluation
ppy	pits per year
PULSE	Principal Underground Laboratory for Subcritical Experimentation
R&D	research and development
RACR	Radiography/Assembly Capability Replacement
RPV	replacement plant value
SAR	Selected Acquisition Report
SCRMT	Supply Chain Risk Management Team

SFI	significant finding investigation
SGT	Safeguards Transporter
SLCM-N	Sea Launched Cruise Missile-Nuclear
SME	subject matter expert
SNL	Sandia National Laboratories
SNM	special nuclear material
SRP	Stockpile Responsiveness Program
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
STAR	Standardized Acquisition and Recapitalization
STEM	science, technology, engineering, math
STS	stockpile-to-target sequence
TA	Technical Area
TFF	Tritium Finishing Facility
TPBAR	tritium-producing burnable absorber rod
TRL	technology readiness level
TVA	Tennessee Valley Authority
UCEP	U1a Complex Enhancements Project
USSTRATCOM	U.S. Strategic Command
VIM	Vacuum Induction Melt
VAR	Vacuum Arc Remelt
WBN	Watts Bar nuclear reactors
WDCR	Weapon Design and Cost Report
WDD	Weapons Dismantlement and Disposition
WR	War Reserve
Y-12	Y-12 National Security Complex
Z	Z pulsed power facility

Appendix H
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A Report to Congress

Fiscal Year 2025 Stockpile Stewardship and Management Plan – Biennial Plan Summary

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U.S. Department of Energy
National Nuclear Security Administration
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