Fiscal Year 2021
Stockpile Stewardship and Management Plan – Biennial Plan Summary

Report to Congress
December 2020

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

Message from the NNSA Administrator

The Department of Energy's National Nuclear Security Administration (DOE/NNSA) was created to safeguard and support our Nation's security through the application of nuclear science and engineering. Since the days of the Manhattan Project, the highly talented men and women of the nuclear security enterprise have applied unique capabilities to promote U.S. security in the face of an ever-evolving global security environment.

Nuclear deterrence has been, and remains, the cornerstone of our Nation's security posture, and its credibility serves as the ultimate insurance policy against a nuclear attack. DOE/NNSA is the only organization that can sustain the Nation's nuclear stockpile, as well as the nuclear propulsion systems of the U.S. Navy's submarines and aircraft carriers. We are the industrial base for the Nation's nuclear stockpile, and providing the tools of deterrence to our Nation's military is DOE/NNSA's highest-priority mission.

The *Fiscal Year 2021 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP) describes DOE/NNSA's plans to ensure the safety, security, and effectiveness of the U.S. nuclear weapons stockpile and to maintain the scientific and engineering tools, capabilities, and infrastructure that underpin the nuclear security enterprise. NNSA also publishes the annual *Prevent, Counter, and Respond: A Strategic Plan to Reduce Global Nuclear Threats* report to Congress as a companion document to the SSMP, which outlines the equally vital missions to reduce the threats of nuclear proliferation and nuclear terrorism. In keeping with our commitments to Congress and the public, updated versions of these reports are published each year.

The fiscal year (FY) 2021 SSMP summarizes the activities being performed within DOE/NNSA's national laboratories, production facilities, and security sites in support of our national security missions. In particular, this report describes DOE/NNSA's plan to achieve the program requirements of producing 80 plutonium pits per year during 2030; achieving the first production unit of the W80-4 Life Extension Program and W87-1 Modernization Program by FY 2025 and FY 2030, respectively; and delivering the first production units of the B61-12 Life Extension Program and the W88 Alteration 370 warheads.

In FY 2020, DOE/NNSA closed out the W76-1 Life Extension Program, provided the W76-2 low-yield ballistic missile warhead for initial deployment, and restarted design activities for the W78 replacement warhead (the W87-1) program that resumed in FY 2019. The nuclear security enterprise is at its busiest since the Cold War.

DOE/NNSA's ability to execute the priorities outlined in the 2018 *Nuclear Posture Review* depends upon a modern, flexible, and resilient nuclear security infrastructure, as outlined in the 2019 DOE/NNSA *Nuclear Posture Review Implementation Plan* report to Congress. This SSMP reflects continued investments in repair and recapitalization of the laboratories, production facilities, and security sites that are crucial to delivering on the Nation's defense priorities and, most importantly, to supporting our greatest asset, our workforce. Together with continued support from Congress, DOE/NNSA will ensure that its world-class workforce has the resources and the responsive, agile infrastructure needed to steward the systems that comprise our deterrent today and, should the need arise, to design the systems of tomorrow.

The rapidly evolving threat environment facing our Nation underscores the need for the United States to maintain a diverse set of nuclear capabilities that can provide flexible, tailored options to enhance deterrence and achieve national security objectives should deterrence fail. As described in this report, the scientific and technological expertise found at DOE/NNSA's laboratories, production facilities, and other sites is the intellectual backbone that supports the United States' continued deterrence of adversarial aggression and the preservation of peace for our Nation and our allies.

For 75 years, the nuclear security enterprise has met every challenge, leading the country in incredible scientific and engineering endeavors and discoveries that benefit the Nation as a whole. As we continue into the next decade, DOE/NNSA will continue to stand together to anticipate future security challenges and ensure that our Nation is ready to meet them.

Pursuant to statute, this FY 2021 SSMP is provided to:

The Honorable Richard Shelby

Chairman, Senate Committee on Appropriations

The Honorable Patrick Leahy

Vice Chairman, Senate Committee on Appropriations

The Honorable James Inhofe

Chairman, Senate Committee on Armed Services

The Honorable Jack Reed

Ranking Member, Senate Committee on Armed Services

The Honorable Lamar Alexander

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

The Honorable Dianne Feinstein

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

The Honorable Deb Fischer

Chairman, Subcommittee on Strategic Forces
Senate Committee on Armed Services

The Honorable Martin Heinrich

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

The Honorable Nita Lowey

Chairman, House Committee on Appropriations

The Honorable Kay Granger

Ranking Member, House Committee on Appropriations

The Honorable Adam Smith

Chairman, House Committee on Armed Services

The Honorable Mac Thornberry

Ranking Member, House Committee on Armed Services

The Honorable Marcy Kaptur

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

The Honorable Mike Simpson

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

The Honorable Jim Cooper

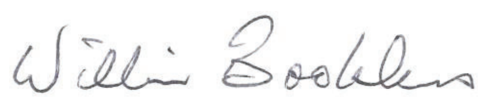
Chairman, Subcommittee on Strategic Forces
House Committee on Armed Services

The Honorable Michael Turner

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

Should you have any questions or need additional information, please contact Dr. Howard Dickenson, Acting Associate Administrator for External Affairs, at (202) 586-7332; or Ms. Katie Donley, Deputy Director for External Coordination, Office of the Chief Financial Officer, at (202) 586-0176.

Sincerely,



William A. Bookless
Acting Under Secretary for Nuclear Security
And Administrator, NNSA

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Message from the Secretary

The Department of Energy's National Nuclear Security Administration (DOE/NNSA) was established 20 years ago with the mission to enhance national security through the military application of nuclear science and engineering. Since that time, DOE/NNSA has successfully maintained a safe, secure, and effective nuclear deterrent in close coordination with the Department of Defense.

DOE/NNSA's nuclear deterrence mission remains the cornerstone of our Nation's security posture. The return to great power competition in the 21st century, coupled with an unprecedented range and mix of threats, requires the United States to maintain a diverse set of nuclear deterrent capabilities. The Nation must also maintain the means to provide flexible, tailored options to achieve national security objectives should deterrence fail. To provide a viable nuclear deterrent, the United States must maintain the current stockpile of nuclear weapons, extend the life of the stockpile, and sustain the nuclear deterrent in the long term through the modernization of laboratory and production infrastructure.

Over the past several decades, necessary weapon and infrastructure modernization program investments have been postponed for competing priorities. These delays in investments have directly affected DOE/NNSA's ability to maintain critical capabilities, recapitalize and modernize deteriorating infrastructure, and recruit and retain the workforce necessary to ensure the future viability of the deterrent. This Administration is committed to reversing these trends and investing to support a truly responsive and resilient nuclear security enterprise.

DOE/NNSA's *Fiscal Year 2021 Stockpile Stewardship and Management Plan – Biennial Summary (SSMP)* outlines the extensive work DOE/NNSA will undertake to modernize the stockpile; strengthen its significant scientific, technical, and engineering capabilities; and recapitalize supporting infrastructure to support the nuclear deterrent's modernization now and into the future. With the continued support of Congress, this program will revitalize and reinvigorate the nuclear security enterprise and ensure the safety, security, and effectiveness of the nuclear deterrent for the next 25 years and beyond.

Sincerely,

Dan Brouillette

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Executive Summary

This *Fiscal Year 2021 Stockpile Stewardship and Management Plan* (SSMP), including its classified Annex, describes the Department of Energy/National Nuclear Security Administration (DOE/NNSA) program for maintaining the safety, security, and effectiveness of the nuclear stockpile over the next 25 years. DOE/NNSA publishes the SSMP annually, either in full report form or as a summary, in response to statutory requirements, to support the President's Budget for Weapons Activities. This fiscal year (FY) 2021 SSMP is a summary report. This annual plan provides a single, integrated picture of current and future nuclear security enterprise activities and capabilities funded by the Weapons Activities account in support of the Nation's nuclear deterrent and is developed to be consistent with the *Nuclear Weapons Council Strategic Plan for FY 2019–2044.*

This SSMP reflects a rigorous mapping of the military requirements and nuclear security enterprise needs to assure an effective deterrent, and meet the nuclear deterrent objectives laid out in the *National Security Strategy* (White House 2017) and the 2018 *Nuclear Posture Review.*

Maintaining a safe secure, and effective nuclear weapons stockpile is one of several DOE/NNSA enduring missions, which also include reducing global nuclear threats, and providing the Navy's submarines and aircraft carriers with militarily effective nuclear propulsion. To accomplish these missions, DOE/NNSA must maintain a range of flexible nuclear capabilities that can only be realized through a world-class scientific and engineering workforce operating in a modern, resilient, and responsive nuclear infrastructure. The *National Nuclear Security Administration Strategic Vision* (NNSA 2019) lays out five mission priorities, three of which are directly relevant to the nuclear deterrent. Highlights of near-term and out-year mission milestones and accomplishments for these mission priorities are:

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

With several warhead modernizations underway, DOE/NNSA is executing an unprecedented variety of complex component development and production work.

Near-Term and Out-Year Mission Goals:

- Deliver the B61-12 gravity bomb
- Deliver the W88 Alteration 370 (with a refresh of the conventional high explosive)
- Achieve the first production unit of the W80-4 warhead life extension program (LEP) and ensure alignment with the Department of Defense (DoD) long range standoff cruise missile replacement program
- Support fielding the Ground-Based Strategic Deterrent and advance the W87-1 Modification Program (formerly called the W78 Replacement Warhead)
- Sustain the B83-1 gravity bomb until a suitable replacement is identified
- Provide the enduring capability to produce 80 plutonium pits per year during 2030 by expanding plutonium pit production capabilities
- Assure a continuous and reliable supply of strategic nuclear weapon components and the key materials that make up the components, to include plutonium, uranium, lithium, tritium, and high explosives
- Provide experimental and computational capabilities to support annual assessment and certification of the stockpile

Key Accomplishments:

- The W76-1 LEP was completed under budget and ahead of schedule, strengthening the Nation's safety and security by extending the warhead's service life from 20 years to 60 years.
- The W76-2 warheads were delivered to the Navy. A modification of the W76-1, the W76-2 supports the low-yield, sea-launched ballistic missile capability called for in the *2018 Nuclear Posture Review*.
- The W80-4 LEP entered Phase 6.3, Development Engineering, in FY 2019.
- In FY 2019, five additional developmental plutonium pits, a key component of nuclear weapons, were completed at Los Alamos National Laboratory (LANL), in Los Alamos, New Mexico, in support of DOE/NNSA's strategic effort to revitalize U.S. pit production capability.

Strengthen Key Science, Technology, and Engineering Capabilities

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

Near-Term and Out-Year Mission Goals:

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

Key Accomplishments:

- DOE/NNSA signed a $600 million contract for its first exascale supercomputer, El Capitan, slated to be delivered at the end of 2022 and projected to be operational in 2023 at Lawrence Livermore National Laboratory, in Livermore, California, to support NNSA's weapons programs.
- DOE/NNSA approved the conceptual design and cost range, or Critical Decision 1 (CD-1; Approve Alternative Selection and Cost Range), for the Advanced Sources and Detectors (ASD) project within the Enhanced Capabilities for Subcritical Experiments portfolio. ASD will lead to a more robust Stockpile Stewardship Program by generating high-speed, high-fidelity X-ray images of

subcritical experiments. This capability will support warhead modernization, certification, and stockpile assessments.

- The Kansas City National Security Campus (KCNSC) used microreactor technology to create a type of Trigonox, which is used in the production of nuclear weapons parts but is no longer commercially available.
- DOE/NNSA announced an additional $5 million investment in developing future employees to carry out vital missions at the Savannah River Site (SRS) near Aiken, South Carolina. The Workforce Opportunities in Regional Careers Grant supports programs at five post-secondary education institutions around the site, including its first historically black college or university, Claflin University.
- DOE/NNSA funded over $100 million in grants and cooperative agreements with top universities across the country, such as the Stewardship Science Academic Alliances Program and the Minority Serving Institution Partnership Program.
- The Z pulsed power facility successfully measured temperature on dynamically compressed plutonium in a regime relevant for primary performance.
- National Ignition Facility operations enabled the completion of several high-energy-density science campaigns for stockpile stewardship, including radiation-transport studies in support of the W80-4 LEP and the first plutonium equation of state experiment on the National Ignition Facility, a culmination of platform development that will enable plutonium experiments to inform issues associated with plutonium pit lifetimes.
- Developed methods to characterize explosives in support of the W80-4 LEP.

Modernize the Nuclear Security Infrastructure

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

Near-Term and Out-Year Mission Goals:

- Recapitalize existing infrastructure to implement a plan to produce 80 pits per year during 2030. The recommended strategy is a two-site solution:
  - Produce 30 pits per year at the Plutonium Facility at LANL, beginning in 2026
  - Repurpose the Mixed Oxide Fuel Fabrication Facility at SRS as part of the Savannah River Plutonium Processing Facility to produce 50 pits per year during 2030
- Enable phasing out mission dependency on Building 9212 at the Y-12 National Security Complex (Y-12) in Oak Ridge, Tennessee, by relocating the facility's enriched uranium processing capabilities into existing facilities and the Uranium Processing Facility and extend the operational lifetime of key existing facilities into the 2040s
- Assure long-term actinide chemistry and materials characterization and deliver the Chemistry and Metallurgy Research Replacement project
- Modernize lithium facilities
- Modernize tritium facilities
- Increase production of tritium using two reactors to meet stockpile needs

- Recapitalize the high explosive and nuclear weapons assembly infrastructure
- Provide new laboratory space and equipment within the U1a Complex to support the Enhanced Capabilities for Subcritical Experiments portfolio through the U1a Complex Enhancements Project and the ASD Major Item of Equipment.
- Provide modern office and laboratory spaces to support the world-class workforce needed to maintain capabilities of the nuclear weapons stockpile
- Reduce deferred maintenance and required repairs by not less than 30 percent by 2025

Key Accomplishments:

- Construction of Uranium Processing Facility at Y-12 remains on budget and on schedule.
- NNSA completed a tool upgrade at the Sandia National Laboratories (SNL) facility in Albuquerque, NM responsible for making integrated circuits that will enable continued production using current supply chain materials.
- NNSA produced the first high explosive part at the new High Explosives Pressing Facility at the Pantex Plant near Amarillo, TX after DOE/NNSA authorized full-scale operations. The modern 45,000 square-foot facility replaces infrastructure that is over 50 years old, improving worker safety.
- NNSA finished the exterior structure of the Albuquerque Complex which will provide a modern, safe, and reliable workspace to approximately 1,200 employees.
- NNSA completed the award and construction of its first new-construction, net-zero energy facility, Mercury Building 1, powered from the Mercury solar field at the Nevada National Security Site near Las Vegas, Nevada.
- DOE/NNSA began using its BUILDER software, revolutionizing management of infrastructure and maintenance and allowing the agency to track the status of over 3,000 buildings across the nuclear security enterprise. Using BUILDER provides more accurate, timely, consistent, comprehensive, and risk-based data on infrastructure condition and costs than historical approaches and will greatly improve management of deferred maintenance.
- NNSA completed CD-0, Approve Mission Need, for the Power Sources Capability and Combined Radiation Environments Survivability Testing Complex at SNL.
- NNSA completed CD-1 for the Lithium Processing Facility at Y-12.
- NNSA completed CD-1 for the Tritium Finishing Facility at SRS.

Challenges in Executing the Stockpile Stewardship and Management Plan

DOE/NNSA and DoD together deliver the capabilities that will provide the Nation with the ability to adapt and respond to a dynamic security environment, emerging strategic challenges, and geopolitical and technological changes. Weapon Activities capabilities are the foundational mechanisms for achieving mission deliverables and priorities. DOE/NNSA must continue to invest in advancing existing capabilities and developing emerging capabilities to assure a strong nuclear deterrent. A summary of the required capabilities and their current status is found in Chapter 3.

Major aspects of DOE/NNSA's capabilities are overdue for replacement or recapitalization to ensure a modern, responsive, and resilient nuclear security enterprise that can meet the U.S. national security missions today and into the future. Many key facilities that enable weapon activity capabilities must be replaced or reinvigorated as they do not meet modern safety standards and require significantly increased investment to maintain them. This is particularly critical for the production capabilities of the nuclear security enterprise necessary to meet DoD warhead deliverables. The NNSA continue to invest in modernizing and developing the nuclear security enterprise's capabilities and supporting infrastructure.

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Fiscal Year 2021 Stockpile Stewardship and Management Plan – Biennial Plan Summary

Table of Contents

Legislative Language

Title 50 of United States Code Section 2523 (50 U.S.C. § 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/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 2021 Stockpile Stewardship and Management Plan (SSMP) is a biennial plan summary report of DOE/NNSA's 25-year program 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 Department of Energy/National Nuclear Security Administration (DOE/NNSA) draws authority for managing the Nation's nuclear stockpile from the *Atomic Energy Act of 1954* (42 United States Code [U.S.C.] § 2011 *et seq.*) and more specifically, the *National Nuclear Security Administration Act* (50 U.S.C. § 2401 *et seq*.). DOE/NNSA's broad set of enduring missions are to protect the Nation by maintaining a safe, secure, and effective nuclear weapons stockpile, reducing global nuclear threats, and providing nuclear propulsion for Navy submarines and aircraft carriers.

The 2018 *Nuclear Posture Review* recognized that the global security environment is growing increasingly dangerous and uncertain. Countries such as Russia, China, and North Korea are investing in efforts to modernize, expand, and diversify nuclear arsenals. The United States' nuclear deterrent is the cornerstone of America's national security strategy and is important to maintaining global stability. It is imperative for the United States to continue to modernize delivery platforms, warheads, and the supporting elements of the nuclear security enterprise, to continue to assure friends and allies and deter adversaries.

Key Changes Affecting the FY 2021 SSMP

- *Identification of new Department of Defense (DoD) warhead requirements*
- *Detailed assessment and mapping of warhead and DoD platform and synchronization requirements onto DOE/NNSA enterprise requirements, including production infrastructure*
- *Higher-fidelity scope, schedule, and site information*
- *Improved construction project execution and cost information*
- *Lessons from ongoing warhead and capital equipment acquisition processes*
- *Application of continuous improvements across the nuclear security enterprise*

Every leg of the Nation's nuclear triad is undergoing modernization. DOE/NNSA must synchronize modernized warheads with Department of Defense (DoD) weapons delivery platform modernization efforts, and this requires a responsive and resilient production and scientific infrastructure. Modernizing the U.S. nuclear stockpile requires investment in three main areas: production capabilities, technical and scientific expertise and tools, and infrastructure. DOE/NNSA is the sole provider of most of these critical capabilities. These capabilities cannot be outsourced.

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

- The SSMP documents DOE/NNSA's plans to maintain the current stockpile, modernize the stockpile as needed to respond to evolving deterrent needs, employ science-based stockpile stewardship to enhance understanding of the internal nuclear weapons function, maintain and modernize the supporting infrastructure, and sustain DOE/NNSA's highly skilled workforce.
- The SSMP provides DOE/NNSA's formal response to multiple statutory reporting requirements, which can be found in Appendix A, "Requirements Mapping."

This fiscal year (FY) 2021 SSMP serves as the biennial plan summary required by statute. The 25 year strategic plan summarized within this report was developed to be in line with the 2018 *Nuclear Posture Review,* the *Nuclear Weapons Council's Strategic Plan for Fiscal Years (FY) 2019–2044, the National*

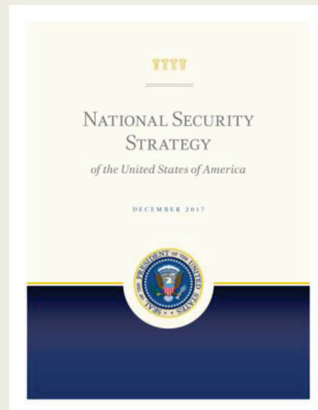
Security Presidential Memorandum (NSPM) – 22, FY 2019 – 2024 Nuclear Weapons Stockpile Plan, and other policy directives (see Section 1.1). A detailed assessment and mapping of warhead and DoD platform and synchronization requirements onto DOE/NNSA enterprise requirements resulted in a number of key changes to the DoD and DOE/NNSA programs of record, as agreed by the Nuclear Weapons Council. Key changes affecting the SSMP are summarized in the call-out box.

The FY 2021 SSMP Biennial Plan Summary includes budget information for the FY 2021 Future Years Nuclear Security Program, along with stockpile modernization schedules, preliminary infrastructure resource planning, and the long-term DOE/NNSA strategy through FY 2045 to ensure the Nation's nuclear deterrent.[1] The document is structured primarily around the unique capabilities necessary to sustain and modernize nuclear weapons, better understand nuclear weapon performance, maintain confidence in the aging and evolving stockpile, so that the Nation's nuclear security enterprise remains responsive and resilient. Details of each capability are examined in Chapter 3.

1.1 Policy Framework Summary

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

Several policy documents provide additional direction and guidance to DOE/NNSA on accomplishing the nuclear weapons mission. These include the 2017 *National Security Strategy* and DoD's 2018 *Nuclear Posture Review* and *National Defense Strategy*. The 2018 *Nuclear Posture Review* reinforced the requirement for a nuclear weapons infrastructure that has the design, engineering, and manufacturing capabilities necessary to be flexible, responsive, and resilient enough to meet changing geopolitical challenges. DOE/NNSA performs the nuclear weapons stockpile mission in close collaboration with DoD as members of the Nuclear Weapons Council.



"Nuclear weapons…are the foundation of our strategy to preserve peace and stability by deterring aggression against the United States, our allies, and our partners."

Maintaining a safe, secure, and effective nuclear weapons stockpile is one of several DOE/NNSA enduring broader missions, which also include reducing global nuclear threats and providing the Navy with safe, militarily-effective naval nuclear propulsion plants. As laid out in the 2019 *National Nuclear Security Administration Strategic Vision* (2019 *NNSA Strategic Vision*), execution of these overarching missions by DOE/NNSA is built along five mission priorities:

- Maintain the safety, security, and effectiveness of the Nation's nuclear deterrent
- Reduce global nuclear security threats and strengthen the nuclear enterprise
- Provide safe and effective integrated nuclear propulsion systems for the Navy
- Strengthen key science, technology, and engineering capabilities
- Modernize the national security infrastructure

[1] See 50 U.S.C. § 2453, Future-years nuclear security program, for a detailed description.

The first, fourth, and fifth mission priorities for the Nation's nuclear deterrent are directly supported by the plans laid out in subsequent sections.

1.2 Nuclear Weapons Stockpile Summary

The size and composition of the nuclear stockpile has evolved as a consequence of the changing global security environment and U.S. national security needs. Increasingly diverse and advanced nuclear threats and challenges facing the United States continue to put a premium on a U.S. nuclear deterrent that is robust, flexible, adaptive, and well-positioned to meet future requirements.

Maintaining the Nation's safe, secure, and effective nuclear weapons requires the technical expertise and scientific capabilities and resources that reside only within the DOE/NNSA nuclear security enterprise. Failure to ensure any of these necessary capability requirements puts the nuclear deterrent at risk.

Many weapons are well past original design life and require unique capabilities for the effectiveness of the stockpile. National level guidance, as defined by *NSPM – 22* and the *FY 2019 – 2024 Nuclear Weapons Stockpile Plan*, requires an appropriate number of weapons to support active and strategic hedge capabilities, as necessary to meet military requirements. Retired weapons are not included in the count of stockpile weapons. **Table 1–1** reflects the major characteristics of the Nation's current nuclear weapons stockpile, which consists of two types of submarine-launched ballistic missile warheads, two types of intercontinental ballistic missile warheads, several types of bombs, and a cruise missile warhead.

The classified Annex provides specific technical details 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***	***Military***
W78	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LANL/SNL	Surface to surface	Air Force
W87	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LLNL/SNL	Surface to surface	Air Force
W76-0/1/2	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
W88	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
Bombs—Aircraft Platforms					
B61-3/4	Non-strategic bomb	F-15, F-16, certified NATO aircraft	LANL/SNL	Air to surface	Air Force/Select NATO forces
B61-7/11	Strategic bomb	B-2 bombers	LANL/SNL	Air to surface	Air Force
B83-1	Strategic bomb	B-2 bombers	LLNL/SNL	Air to surface	Air Force
Warheads—Cruise Missile Platforms					
W80-1	Air-launched cruise missile strategic weapons	B-52 bomber	LLNL/SNL	Air to surface	Air Force

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

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

1.3 Overall Strategy and Goals of Weapons Activities

DOE/NNSA is committed to implementing the policy direction provided by the 2018 *Nuclear Posture Review* as managed by the Nuclear Weapons Council. Modernization activities provide nuclear warheads that meet DoD performance requirements and DoD and DOE/NNSA safety and security requirements. DOE/NNSA maintains the capabilities to perform this critical work as well as the ability to annually assess the current stockpile and certify modernized warheads for entry into the stockpile without the need for a return to explosive nuclear testing.

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

Modernization activities address issues such as aging, the unavailability of replacement parts, and different weapon system flight characteristics due to changes in DoD delivery platforms. DOE/NNSA extends the service life of weapons that have reached the end of their original design life through life extension programs. Other modernization efforts include alterations, which do *not* change the weapon's operational capabilities, as well as modifications, which *do* change the weapon's operational capabilities. DOE/NNSA also conducts surveillances and assessments to confirm that weapons currently in the stockpile remain safe, secure, and reliable and reports on findings through the annual assessment process.

DOE/NNSA modernizes and sustains the stockpile through a joint acquisition process for nuclear weapons, in partnership with DoD and coordinated through the Nuclear Weapons Council. This acquisition process includes the entire life-cycle of the weapon and addresses DoD and DOE/NNSA warhead modernization needs from concept assessment to full-scale production to retirement or storage. With five concurrent warhead modernization activities underway, DOE/NNSA is implementing an unprecedented variety and volume of complex technology development and production work and continues to make progress across all five programs. In addition to coordinating weapon modernization and sustainment efforts, DOE/NNSA and DoD synchronize nuclear weapon delivery system programs. These coordinated efforts are the basis of the Nation's ability to maintain the nuclear deterrent as the United States faces an increasingly uncertain security environment.

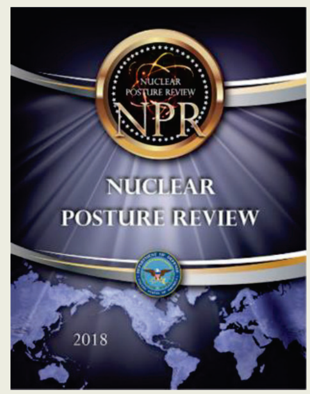
DOE/NNSA uses several major strategies to sustain and maintain the stockpile and support the DOE/NNSA mission priorities to maintain the safety, security, and effectiveness of the Nation's nuclear deterrent; strengthen key science, technology, and engineering capabilities; and modernize the national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

- Assess the stockpile annually through science-based stockpile stewardship
  - Assess whether the safety, reliability, and performance of the current and future nuclear stockpile can be assured in the absence of underground nuclear testing
  - Renew and develop science capabilities to assess effects of aging, remanufacture, and evolving threat environments
  - Maintain a nuclear test capability as a safeguard
- Extend the life of the nuclear deterrent through modernizations
  - Replace obsolete technology
  - Enhance stockpile safety and security
  - Meet military requirements

- Assure the capabilities to support the nuclear deterrent in the near and long term (these capabilities are discussed in Chapter 3, "Weapons Activities Capabilities that Support the Nuclear Security Enterprise.")
  - Renew and sustain critical production, manufacturing, and research capabilities
- Advance innovative experimental platforms, diagnostic equipment, and computational capabilities
  - Keep technical expertise and capabilities at the cutting edge to support a responsive and resilient enterprise
- Provide safe and secure transport of nuclear weapons, weapon components, and special nuclear materials to meet mission requirements

1.4 Summary of Key Challenges in Implementing the Stockpile Stewardship and Management Plan

One of the most critical challenges that DOE/NNSA must address is the modernization and recapitalization of existing infrastructure in parallel with increasing mission requirements. DOE/NNSA's infrastructure has long been overdue for the upgrades necessary to create a modern, responsive, and resilient nuclear security enterprise that can meet national security missions today and into the future. This is particularly critical for the production capabilities of the nuclear security enterprise given the recent increased scope and requirements. Currently, roughly 30 percent of NNSA's facilities date back to World War II, and more than half are over 40 years old. As determined in NNSA's 2020 Master Asset Plan, more than a third of NNSA's total infrastructure assets (as a percentage of replacement plant value) are in poor or very poor condition and are insufficient to meet mission needs. These assets include strategic materials facilities critical to the Nation's nuclear deterrent.



"Recapitalizing the nuclear weapons complex of laboratories and plants is also long past due; it is vital we ensure the capability to design, produce, assess, and maintain these weapons for as long as they are required."

DOE/NNSA must re-establish a number of full-rate production capabilities to meet planned DoD warhead deliveries. A number of key facilities do not meet modern safety standards and require significantly increased investment to maintain. Safety and efficiency remain important concerns to be addressed by reinvestments. If any of these facilities experience operational shutdowns due to these mounting issues, stockpile maintenance and warhead deliveries may be affected. Considering that it can take a decade or more to plan and complete facility replacement projects, it is critical to address shortfalls now to assure facility availability when needed for mission deliverables and to proactively maintain the existing facilities until the replacements are online.

DOE/NNSA has put in place a plan to renew the essential time-critical manufacturing capabilities prioritized to meet DoD near- to intermediate-term warhead deliveries and for workforce safety. This plan focuses on five areas:

- Establishing a production capability of 80 pits per year during 2030
- Re-establishing high explosive synthesis, formulation, and production capabilities

- Modernizing and enhancing the facilities and capabilities needed to meet near- to long-term needs for tritium
- Modernizing the production capabilities for secondary assemblies, radiation cases, and replacement of the current lithium production facility
- Modernizing and enhancing non-nuclear component development and production capabilities

The next 10 years are critical for modernizing the production capabilities needed for the stockpile. The ability to continue delivering life-extended warheads in the future depends on rebuilding the infrastructure and capabilities to supply feedstock and warhead materials now. **Figure 1–1** shows the necessary timeline to meet warhead needs.

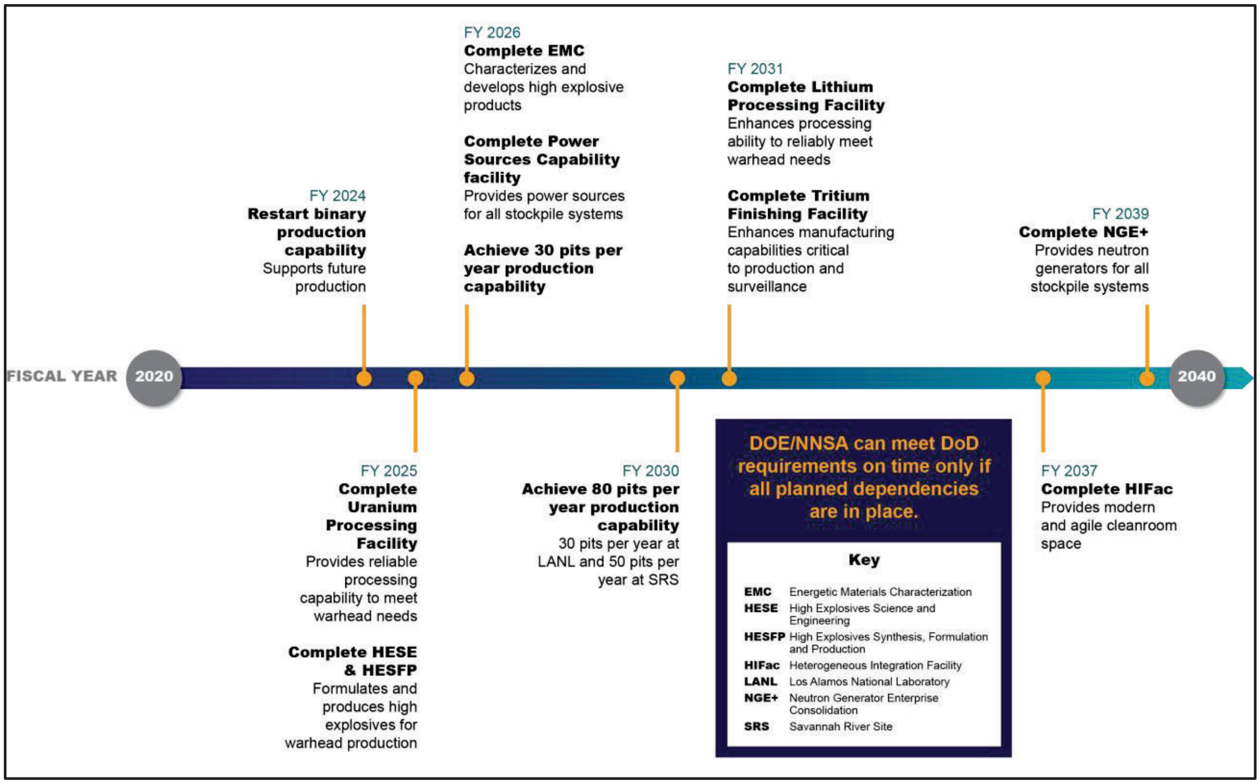


Figure 1–1. Timeline for key infrastructure and capability investments for future warheads[2]

Failure to meet these timelines may increase the risk to the deterrent and personnel safety, reduce operational efficiency, increase operating costs, and hinder recruitment of the workforce.

Even as the production infrastructure is modernized, DOE/NNSA must continue to rely on an enterprise whose buildings' average age is over 40 years old. Holding the average age of just the highest-priority assets constant requires a significant sustained investment. **Figure 1–2** shows the projected average age of major programmatic facilities over time with planned investments. Without such investments, the average age and risk to DOE/NNSA's mission will continue to increase.

[2] DOE/NNSA obtained Critical Decision (CD)-0, Achieve Mission Need, approval for the Power Sources Capability (PSC) facility in FY 2019 and for the Energetic Materials Characterization (EMC) facility in FY 2020. DOE/NNSA is working toward CD-4, Approve Start of Operations or Project Completion, approval for both projects in FY 2026 based on the clearly defined capability gap and mission need. The Analysis of Alternatives process for EMC, Conceptual Design for PSC, and subsequent cost estimates for both will inform future budget planning profiles.

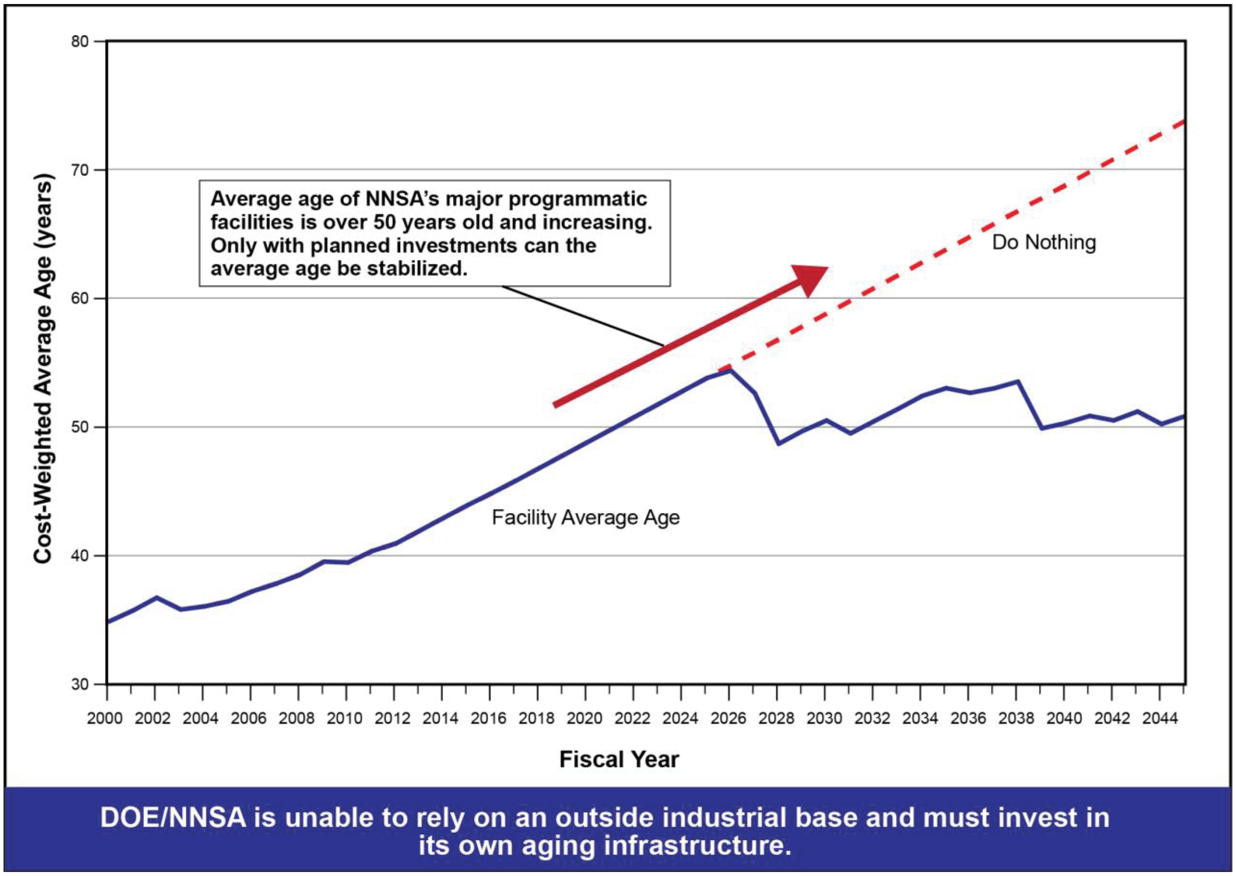


Figure 1–2. Historical average age growth of NNSA major programmatic facilities and a projection of the planned stabilization of average age after executing the FY 2021 President's Budget Request-Informed Line-Item Plan

The condition of the facilities in the nuclear security enterprise imposes a risk to the mission. Accordingly, DOE/NNSA is prioritizing strategies to address the infrastructure challenge across the enterprise to assure continuity of mission by planning for both recapitalization of the existing infrastructure and the future needs of the enterprise.

While infrastructure is at the forefront of DOE/NNSA's key challenges, DOE/NNSA is also addressing other areas of current and emerging challenges in:

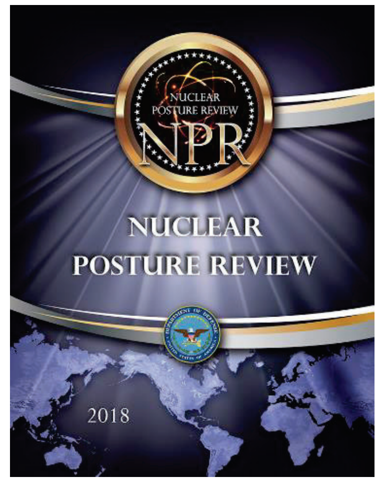
- The current stockpile program of record represents a continued increase in scope, including restarting production operations that have been dormant for decades and increasing overall production rates of many components. DOE/NNSA is restoring capabilities and enhancing capacity at the production plants to address current stockpile needs and to prepare for future uncertainty.
- The nuclear weapons stockpile needs updated technologies that require investment in new processes, technologies, and tools to produce, qualify, and certify warheads in accordance with stringent and evolving stockpile specifications and requirements. The increased number of concurrent weapon system builds requires three things:
  - Maturing new options with shortened development cycles
  - Advancing the ability to predict weapon performance in configurations that were not tested underground

   - Evaluating the impact of new materials and processes, the reuse of aging components in future systems, and enhancing production throughput

- The trustworthiness of the nuclear weapons supply chain must be sustained to protect against potential counterfeit and sabotage. DOE/NNSA has implemented several initiatives through the Nuclear Enterprise Assurance program to assure supply chain protection. For example, DOE/NNSA's nuclear security enterprise provides the tools and capabilities needed for trusted radiation-hardened silicon microelectronics. To assure continued capability, DOE/NNSA is installing new tooling, and planning recapitalization efforts to extend the life critical facilities. DOE/NNSA is also interacting and collaborating with partners to establish research and development efforts that could also serve as a future production capability.

- The DOE/NNSA nuclear security enterprise has many retirement-eligible employees who are expected to leave the workforce in the near future. To prepare for these high numbers of retirements, new hiring initiatives are necessary to recruit, train, or retain high-quality individuals capable of obtaining security clearances and to provide new personnel with opportunities that establish the experience and expert judgment necessary to sustain the stockpile. DOE/NNSA has undertaken an enterprise-wide corporate approach to recruiting and retaining the next-generation workforce to maintain a world-class workforce now and into the future.

Chapter 2
Managing the Stockpile



In support of DoD's highest priority mission – nuclear deterrence – DOE/NNSA is responsible for ensuring that U.S. nuclear weapons meet military requirements and remain safe, secure, and militarily effective. DOE/NNSA stockpile management activities are synchronized with DoD sustainment and modernization programs, providing the President with flexible deterrence options.

This chapter describes the manner in which DOE/NNSA accomplishes Weapons Activities mission priorities through sustaining, modernizing, and dismantling nuclear weapons; maintaining and modernizing production operations; and optimizing the scientific tools underpinning these efforts.

Key changes resulted from the identification of new DoD warhead requirements and an in-depth assessment and mapping of warhead, DoD delivery platform, and synchronization of requirements onto DOE/NNSA enterprise requirements. Specifically, these changes include the W93 (a recently established program of record), W80-4, W87-1, and modernization of the production infrastructure as needed to improve efficiency and have in place the manufacturing operations needed to meet future requirements. Chapter 5 details the major changes in the Stockpile Management budget portfolio.

> ***Key Changes Affecting FY 2021 Stockpile Management Activities***
>
> - *DoD warhead requirements for W93*
> - *DoD requirements for the W87-1 and W80-4*
> - *Production infrastructure modernization to improve base capabilities to enable weapon operations (assembly, disassembly, and production) planned for the warhead modernization programs, stockpile systems, and weapons dismantlement and disposition programs to meet delivery requirements*
> - *Higher fidelity inputs to weapons cost and life cycle estimates, based on lessons learned from ongoing weapons developments*

DOE/NNSA manages the stockpile through four major activities:

- **Stockpile Sustainment** performs single-system and multi-system sustainment activities (i.e., assessment, surveillance, maintenance, and response to emerging issues) for all weapons systems in the stockpile. Stockpile Sustainment includes limited life component (LLC) exchanges, surveillance activities, significant finding investigations (SFI), weapons reliability reporting, and annual assessments that provide a comprehensive understanding of the health of the stockpile.
- **Stockpile Major Modernization** includes life extension programs (LEPs), modification programs (Mods), and major alterations (Alts) that extend the life of weapons in the stockpile, enhance system security and safety features, and address issues related to aging or component obsolescence. This includes modernization programs not possible through an LEP, Alt, or Mod.

- **Weapons Dismantlement and Disposition (WDD)** dismantles retired weapons and disposes of weapon components and provides components and materials for weapons activities and other DOE/NNSA mission areas.
- **Production Operations** provides DOE/NNSA with a manufacturing-based program that drives individual site production base capabilities for warhead modernization activities, weapon maintenance, surveillance, weapon assembly and disassembly, and weapon reliability and safety testing. The scope of Production Operations encompasses sustainment of all weapon systems capabilities that enable individual weapon production and are not specific to one material stream. It works closely with production modernization, which focuses on the special nuclear materials and components (such as plutonium and uranium), as well as non-nuclear component modernization, discussed in Chapter 3.

Stockpile Management Accomplishments (through September 30, 2019)

- *Completed Cycle 23 of the Annual Assessment Review process*
- *Completed W76-1 last production unit*
- *Completed W76-2 first production unit*
- *Qualified and sold the first additive manufactured component to War Reserve production stores*
- *Qualified Confined Large Optical Scintillator Screen and Imaging System (CoLOSSIS II) at the Pantex Plant (see Chapter 3, Figure 3–5)*
- *Delivered a substantial subset of first production units of B61-12 and W88 Alt 370 weapon components early or on time at the Kansas City National Security Campus*

Managing the stockpile requires comprehensive planning for all stockpile elements to fit cohesively into an integrated development and production system. This chapter documents all of these planning and execution activities; 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. These individual capabilities and the linkages to stockpile management are described at length in Chapter 3. Chapter 4 addresses two specific elements of these capabilities, infrastructure and workforce, across all capabilities at an enterprise level, further reinforcing the need to sustain the health of capabilities in support of the stockpile mission work.

2.1 Stockpile Sustainment

Stockpile sustainment activities are responsible for the day-to-day health of the stockpile. These activities include surveillance, annual assessments, and routine maintenance to ensure weapons remain safe, secure, and reliable over the projected lifecycle. Weapons that remain in the stockpile are eventually modernized through modernization programs to address any anomalies and to meet updated safety and security standards. These modernization activities (LEPs, Mods, and some major Alts) are addressed through the Stockpile Major Modernization activities discussed in Section 2.2.

2.1.1 Assessing the Stockpile

The status of the stockpile is monitored through continuous, multi-layered assessments of the safety, security, and military effectiveness of each U.S. nuclear weapon system. The annual stockpile assessment process evaluates the state of weapons by conducting physics and engineering analyses, experiments, surveillance and flight testing, and computer modeling. Assessments may also evaluate the effects of aging on performance and quantify performance thresholds, uncertainties, and margins. These evaluations rely on all available sources of information, including surveillance, hydrodynamic tests, subcritical experiments, materials evaluation, modeling and simulation, and enhanced surveillance techniques. These evaluations also involve assembling a body of evidence to assess performance at the part, component, subsystem, and system levels to determine whether all of the required performance characteristics are met. The processes are quantitative and combine data and theories with simulations of nuclear weapons to arrive at a conclusion that also relies on expert judgment.

2.1.1.1 Annual Assessment

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

The assessments and conclusions in the Annual Assessment Reports are peer reviewed by Red Teams and subject matter experts appointed by each laboratory's director, program managers, and senior laboratory management. This effort culminates in a written summary and conclusion of the assessments from each laboratory Director and the USSTRATCOM Commander, which are included as unabridged attachments to the statutorily required *Report on Stockpile Assessments* that is submitted to the president on an annual basis.

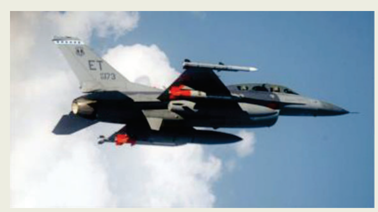
2.1.1.2 Weapon Reliability

Every September, DOE/NNSA publishes the Weapons Reliability Report, which provides a summary of reliability and yield characteristics of all weapons in the stockpile. The report communicates to DoD two key contributors to military effectiveness and is the principal DOE/NNSA report on weapon systems reliability that USSTRATCOM uses for strategic planning actions and targeting. This report also informs the Annual Assessment Review process and incorporates data from surveillance activities.

2.1.1.3 Advanced Certification and Qualification

Advanced Certification activities improve the methodology and physics-based capabilities used to ensure that the evolving stockpile will operate as intended. These activities deliver matured technologies, diagnostic techniques, data analysis methods, and design options for future stockpile needs. Advanced Certification activities also preserve and reanalyze legacy nuclear test data and conduct simulations of data to benchmark simulation codes. These activities enhance DOE/NNSA's understanding of a weapon's performance and possible failure modes, improve the technical components of the quantification of margins and uncertainties methodology, and improve the fidelity and agility of certification methodologies.

DOE/NNSA concentrates on stewarding, advancing, and qualifying nuclear weapons components, subassemblies, and integrated systems to meet military characteristics across the stockpile-to-target sequence environmental requirements (i.e., normal, abnormal, and hostile environments specified in the stockpile-to-target sequence). These activities are defined in qualification plans



Using modeling and simulation, Sandia National Laboratories worked with Los Alamos National Laboratory to provide predictions of B61-12 nuclear safety timelines used to quantify system safety. Thermal analysis models were applied by the B61-12 project to predict weapon nuclear safety for credible accident scenarios and weapon configurations not considered in qualification testing because of schedule and cost constraints. The abnormal thermal environment qualification and nuclear safety arguments were presented by systems engineering during B61-12 system final design review.

and use experimental and modeling and simulation capabilities as well as production data to ensure system functionality. Experimental capabilities include flight tests, shock and vibration tests, thermal environment tests, and exposure to various forms of radiation. Modeling and simulation are used to interpolate and extrapolate into regions not addressed by testing and experiments.

2.1.1.4 Quantification of Margins and Uncertainties

Assessing weapon performance through predictive capabilities requires the coordination of many resources and expertise. Performance is gauged through the quantification of margins and uncertainties methodology, which evaluates the degree to which the operation of a weapon is judged to be within the bounds of specified operating characteristics. This methodology supports nuclear stockpile decision making and enables risk-informed decisions. This methodology's confidence factor of a prediction is the ratio of margin (M) to uncertainty (U), or M/U. Stockpile Research, Technology, and Engineering activities (also referred to as Stockpile Stewardship activities) aim to increase the margin when possible and to reduce uncertainty by performing R&D in areas such as material properties and improving the fidelity of the models used to simulate operation of the warhead.

2.1.1.5 Responsiveness

The 2018 *Nuclear Posture Review* called for rapid implementation of the Stockpile Responsiveness Program established by Congress in Section 3112 of the *National Defense Authorization Act for Fiscal Year 2016* to "effectively respond to emerging threats, unanticipated events, and technological innovation through science and engineering" (Senate Report 114-236, *Energy and Water Development Appropriations Bill, 2017*). This program develops and exercises the capabilities required to support all phases of the joint nuclear weapons life cycle process, transfers knowledge and skills to the newer generation of nuclear weapon designers and engineers, strengthens integration between DoD and DOE/NNSA, and uses potential responses to future threats to explore the acceleration of design, engineering, testing, production, and qualification methodologies that could increase the responsiveness of the enterprise.

2.1.2 Stockpile Surveillance

Surveillance activities provide data to evaluate the safety, security, reliability, and performance of weapons in the stockpile in support of annual assessments. The cumulative body of this data supports future stockpile decisions regarding weapon LEPs, Alts, and Mods. The surveillance program has six goals:

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

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

2.1.2.1 Anomaly Investigative Process

When anomalies are detected that could affect weapon safety, security, reliability, or performance, surveillance data are taken and assessed to determine whether observations are serious enough to open an SFI for specific weapon or component issues. SFIs are also opened for anomalies discovered anywhere in the stockpile when unexpected phenomena are observed. Such occurrences are investigated by the national security laboratory responsible for the anomalous component. Investigations may include modeling of historical data, focused materials experiments, research and studies, major system test replication (i.e., hydro tests), and subsystem and subcomponent testing. SFIs may remain active through several annual assessment cycles. SFIs are closed once an assessment of the impacts to system performance or safety is complete and follow-up actions are determined. A tracking and reporting system is in place to monitor the progress of an SFI from discovery of the anomaly to submission of the closure report, along with the status of any corrective actions. Most SFIs are closed with little to no impact to weapon system safety and reliability.

2.1.3 Maintaining the Stockpile

Maintaining the current stockpile requires many ongoing activities:

- LLC exchanges such as gas transfer systems (GTSs), power sources, and neutron generators that require periodic replacement to sustain system functionality
- Responses to emerging issues that do not rise to the level of a major Alt or LEP through maintenance, such as changing the type of LLC, minor repairs and rebuilds, incorporation of surety features, and other changes
- Developing joint test assemblies (JTAs) that represent the original build to the extent possible by directly reusing non-nuclear components and substituting surrogate parts for the nuclear components
- Modernizing JTAs to replace sunset technologies and improve the capability to assess stockpile performance in the absence of underground nuclear testing
- Maintaining an Authorization Basis by conducting periodic nuclear explosives safety studies
- Program management of each stockpile system

2.1.3.1 Limited Life Components

Weapons contain LLCs that require periodic replacement to sustain system functionality and performance. Age-related changes affecting these components are predictable and well understood, and surveillance is conducted to ensure the components continue to meet performance requirements throughout the projected lifecycle. 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 and are highly complex, enhance weapon safety and reliability, and must meet stringent requirements for proper weapon functionality.

2.2 Stockpile Major Modernization

Stockpile Major Modernization activities are achieved through a series of planned LEPs, Mods, and Alts that are supported by a strong set of science, technology, and engineering activities. These modernization activities fully reflect on requirements stated in the 2018 *Nuclear Posture Review* and priorities established by the Nuclear Weapons Council. **Figure 2–1** displays these plans.

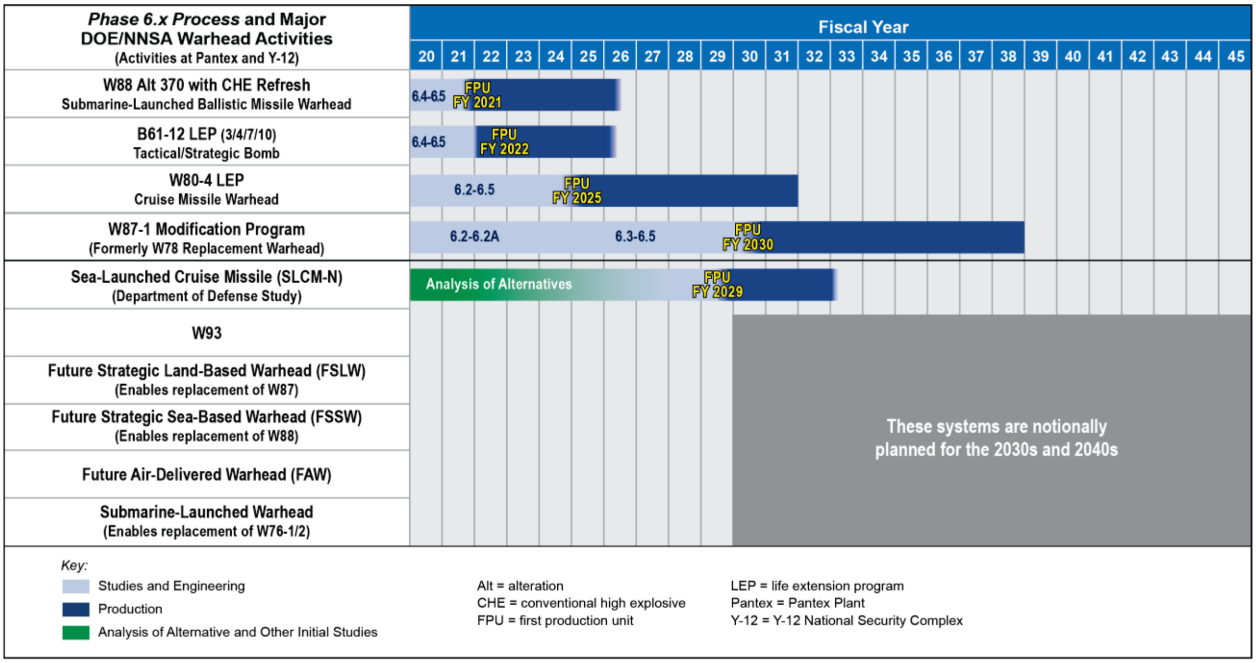


Figure 2–1. DOE/NNSA warhead activities[1]

This long-term vision of the stockpile seeks to build flexibility for the Nation to enable rapid response to unforeseen contingencies while incorporating features and technologies that enhance safety and security as appropriate and practicable. Within this strategy, DOE/NNSA will consider flexibility-enabling design strategies and an advanced digital enterprise that promotes the accomplishment of future system modernization actions with greater speed. Incorporating these improvements will enhance the Nation's ability to counter adversaries' capabilities, stockpile aging, and variables associated with supporting U.S. hedge capabilities.

To meet requirements for the resilience of the U.S. nuclear deterrent, qualification- and certification-ready options for materials, components, and systems must be available when needed for down-select decisions, development, and production. In addition to developing options, the qualification and certification pathways for these options must be matured ahead of time to be viable for consideration. The activities that lead to this state of readiness depend on advanced scientific and engineering capabilities that support qualification and certification processes and improve the responsiveness of the nuclear security enterprise in terms of cycle time and digital design tools. Because of the crucial role of science and

DOE/NNSA Warhead Modernization Activities

DOE/NNSA is currently executing three types of warhead modernization activities:

- *An LEP refurbishes warheads of a specific weapon type to extend the service life of a weapon while increasing safety and security.*
- *A Mod changes a current weapon type's operational capabilities. It may enhance margin against failure, increase safety, replace LLCs, etc.*
- *An Alt is a material change to a nuclear weapon or major assembly that does not alter operational capability, but is sufficiently important to the user in terms of assembly, maintenance, storage, or test operations.*

[1] The SLCM-N first production unit is illustrative and subject to the outcome of the analysis of alternatives process.

technology in shaping the future stockpile, the current NNSA Strategic Vision also includes strengthening key science, technology, and engineering capabilities among five mission priorities. Technologies and capabilities must be developed and continually matured to assure viable technology options for future insertion opportunities supporting nuclear weapon modernization programs.

2.2.1 W76-1 Life Extension Program

DOE/NNSA successfully completed the last production unit for the W76-1 LEP in December 2018 and delivered the final warhead to DoD in April 2019. Some of these units were converted to meet the requirement for the low-yield W76-2 warhead.

> *"Expanding flexible U.S. nuclear options now, to include low-yield options, is important for the preservation of credible deterrence against regional aggression. It will raise the nuclear threshold and help ensure that potential adversaries perceive no possible advantage in limited nuclear escalation, making nuclear employment less likely."*

2.2.2 W76-2 Modification Program

The W76-2 is the nation's response to the low-yield ballistic missile requirement called for in the 2018 *Nuclear Posture Review*. In FY 2020, assembly of the W76-2 was completed, with the full quantity produced and delivered to the Navy.

2.2.3 W88 Alteration 370 Program

The W88 warhead has been deployed for more than three decades, and several updates are required to address aging and to maintain readiness. The W88 Alt 370 modernizes the arming, fuzing, and firing subsystem; improves surety; replaces the conventional high explosive and associated materials; and incorporates a lightning arrestor connector, trainers, flight test assemblies, and associated handling gear. The W88 Alt 370 conversion is scheduled to run concurrently with LLC exchanges of GTSs and neutron generators.

2.2.3.1 Status

The W88 Alt 370 is now in Phase 6.4, *Production Engineering*, with delivery of the first production unit scheduled for the fourth quarter of FY 2021. DOE/NNSA experienced technical issues associated with a very limited number of electrical components. DOE/NNSA is coordinating closely with DoD to mitigate delays to this weapon program. The program has planned component production rates to work toward the original baseline schedule for components not affected by the base metal electrode capacitor issue.

2.2.3.2 Challenges and Strategies

Table 2–1 provides a high-level summary of W88 Alt 370 Program challenges and the strategies to address each.

Table 2–1. Summary of W88 Alteration 370 Program challenges and strategies

Challenges	*Strategies*
Technology and component manufacturing synchronization between DOE/NNSA and DoD partner programs lead to shared impacts from any program change or delay.	DOE/NNSA is closely aligned with DoD partners to manage production impacts. Collaboration is key for keeping scope, schedule, and cost decisions aligned with strategic-level priorities.
Managing baseline system first production unit schedule impacts from capacitor component change.	DOE/NNSA has coordinated with DoD to mitigate impacts. A new timeline was coordinated with DoD and endorsed by the Nuclear Weapons Council, with a new system first production unit scheduled for the fourth quarter of FY 2021.

2.2.4 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 a 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, -7, and -10 bomb variants.

2.2.4.1 Status

The B61-12 LEP is also in Phase 6.4, *Production Engineering.* Similar to the W88 Alt 370 a lifetime reliability concern with base metal electrode capacitors in electrical components necessitated a delay of the B61-12 first production unit delivery to FY 2022. All -other major components unaffected by the capacitor failures are continuing with production and readiness activities. The B61-12 will maintain the initial operational capability schedule and the adjusted plan has received concurrence by the Air Force and Nuclear Weapons Council. Certification and system qualification activities are ongoing.

2.2.4.2 Challenges and Strategies

Table 2–2 provides a high-level summary of B61-12 LEP challenges and the strategies to address each.

Table 2–2. Summary of B61-12 Life Extension Program challenges and strategies

Challenges	*Strategies*
Managing baseline system first production unit schedule impacts from capacitor component change.	DOE/NNSA has coordinated with DoD to mitigate impacts. A new timeline was coordinated with DoD and endorsed by the Nuclear Weapons Council, with a new system first production unit scheduled for the first quarter of FY 2022.

2.2.5 W80-4 Life Extension Program

The W80-4 LEP will deploy with the Air Force Long Range Standoff (LRSO) cruise missile. This integrated program will replace the aging AGM-86 air-launched cruise missile. 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.

2.2.5.1 Status

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

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

The W80-4 program office coordinated with DOE/NNSA's management and operating (M&O) partners to develop standardized Earned Value Management practices and schedules across the sites by implementing a state-of-the-art software tool to expedite Earned Value Management System data analysis.

2.2.5.2 Challenges and Strategies

Table 2–3 provides a high-level summary of W80-4 LEP challenges and the strategies to address each.

Table 2–3. Summary of W80-4 Life Extension Program challenges and strategies

Challenges	*Strategies*
The program faces the challenge of a parallel design with the Air Force Long Range Standoff (LRSO) cruise missile.	DOE/NNSA closely aligns W80-4 LEP efforts with those of DoD's LRSO program to refine program goals and define the interface scope in detail between the warhead and missile. This collaboration enables coordinated cost-informed decisions and interdepartmental schedule alignment.
DOE/NNSA must manage schedule requirements while reducing uncertainty.	DOE/NNSA is identifying and implementing opportunities that reduce schedule uncertainty and risk; modifying, reducing, or eliminating irrelevant requirements; developing a design to encompass both warhead and missile environmental requirements; and developing processes for increased communication and efficiency between design and production agencies.

2.2.6 W87-1 Modification Program

DOE/NNSA's W87-1 Modification Program will replace the aging W78 warhead by modifying the existing legacy W87-0 design. Once the B61-12 achieves initial operational capability, the W78 warhead will become the oldest weapon system in the stockpile. Critical W78 components continue to age, while the military requirements for the safety and security features of W78 warhead have changed since entering the stockpile in 1979. The W87-1 Modification Program will meet DoD and DOE/NNSA requirements for performance, safety, and security and is slated to deploy as part of the Ground-Based Strategic Deterrent by 2030, as specified in the 2018 *Nuclear Posture Review*.

2.2.6.1 Status

The Nuclear Weapons Council authorized a restart of Phase 6.2*, Feasibility Study and Design Options*, in September 2018. The program is on track to deploy with the Ground-Based Strategic Deterrent by 2030. DOE/NNSA established a W87-1 Federal program office along with the requisite staff, program plans, and management documents. In 2019, the Nuclear Weapons Council selected a single surety architecture for the W87-1, and DOE/NNSA continues to evaluate component features through feasibility and trade studies. In FY 2021, the W87-1 Modification Program is expected to seek Nuclear Weapons Council approval to enter Phase 6.3, *Development Engineering*.

2.2.6.2 Challenges and Strategies

Table 2–4 provides a high-level summary of W87-1 Modification Program challenges and the strategies to address each.

Table 2–4. Summary of W87-1 Modification Program challenges and strategies

Challenges	*Strategies*
Integrating W87-1 Modification Program schedule and acquisition efforts with those of the Air Force.	DOE/NNSA is a member of the Air Force Project Officers Group and regularly communicates with the Air Force and related acquisitions programs.
Production is predicated on all newly manufactured components. Modernizing nuclear component and material manufacturing capabilities requires large, multi-year investments.	DOE/NNSA is supporting commodity and capability programs that will provide the materials, components, and capabilities for the future stockpile. The W87-1 Modification Program established inter-program agreements with applicable commodity and capability programs to identify requirements, dependencies, risks reporting, and inter-program management strategies. Chapters 3 and 4 contain more information.

Challenges	*Strategies*
Program success is contingent on development of new materials and technologies to address antiquated design, material obsolescence, and performance expectations, improving life expectancy, reducing manufacturing cost and development time, increasing safety and security, and improving maintainability.	The W87-1 Modification Program has established inter-program agreements with technology maturation programs to identify requirements, dependencies, risk reporting, and inter-program management strategies. The program is incorporating lessons learned from previous LEPs and major modernization programs into program plans.

2.2.7 Sea-Launched Cruise Missile

DoD is conducting an analysis of alternatives (AoA) study to develop requirements and schedules for the Sea-Launched Cruise Missile (SLCM-N). The DoD Office of Cost Analysis and Program Evaluation is serving as lead, with DOE/NNSA participating as an observer. The AoA is charged to consider options to support a material solution, if required. DOE/NNSA has involved key players in the nuclear security enterprise to support the study.

2.2.8 W93

The W93 will address future Navy ballistic missile requirements. The W93 will incorporate modern technologies to improve safety, security, and flexibility to address future threats and will be designed for ease of manufacturing, maintenance, and certification. DOE/NNSA is coordinating with DoD through the Nuclear Weapons Council in developing the deterrence strategies as defined in the 2018 *Nuclear Posture Review*.

2.2.9 Future Warheads

DOE/NNSA is coordinating with DoD to define the appropriate ballistic missile warheads to support threats anticipated in 2030 and beyond, in accordance with the 2018 *Nuclear Posture Review*. These warheads are notional and currently include the future strategic land-based warhead and the future strategic sea-based warhead, as well as a replacement air-delivered warhead and submarine-launched warhead (for the W76-1/2) that will be needed in the 2040s.

2.3 Weapon Dismantlement and Disposition

WDD activities disassemble retired weapons into major components. Those components are then assigned for reuse, storage, surveillance, or disposal. The dismantlement schedule for retired nuclear weapons is planned to provide the material and components required for the stockpile (in particular, LEPs, Mods, and Alts). WDD also maintains the proficiency of technicians and balances work scope at the production sites. Dismantlement rates are affected by many factors, including appropriated program funding, logistics, legislation, weapon system complexity, and the availability of qualified personnel, equipment, and facilities. DOE/NNSA's current five year Dismantlement Plan balances these constraints while maintaining strict adherence to legislative guidance. The WDD work scope includes management of retired nuclear weapon systems (e.g., managing safety issues), characterization of weapon components, disassembly of weapons and components, and final component disposition (e.g., component reuse and material recycle and recovery). WDD activities occur across all sites in the nuclear security enterprise.

2.3.1.1 Status

DOE/NNSA continues to make significant progress on dismantling weapons and component disposition. WDD is on pace to complete a goal of dismantling weapons that were retired at the end of FY 2008. DOE/NNSA has developed return schedules to remove retired weapons from DoD facilities while meeting DoD operational requirements. WDD continues to characterize components coming off of the dismantlement line, and sites are eliminating excess component inventories on schedule.

2.3.1.2 Challenges and Strategies

Table 2–5 provides a high-level summary of WDD challenges and the strategies to address each.

Table 2–5. Summary of Weapons Dismantlement and Disposition challenges and strategies

Challenges	*Strategies*
Meeting WDD requirements within legislative direction (National Defense Authorization Act language).	Use process and cost models to evaluate future dismantlement excursions so decision makers can make informed dismantlement plans with greatest possible impact.
Ensuring dismantlement and component disposition plans provide sufficient material, components, and canned subassemblies (CSAs) for reuse by the warhead modernization programs.	Work closely with all weapon program managers to balance material and component needs against future reuse possibilities. Develop alternative CSA dismantlement plans that provide needed materials while not dismantling CSAs with high reuse potential.
Reducing site legacy inventories of weapon components.	Eliminate hazardous items from the legacy inventories first and target storage bottlenecks to make adequate space available to support warhead modernization program work.

2.4 Production Operations

Production Operations activities provide a manufacturing-based program that drives individual site production base capabilities for warhead modernization activities, weapon maintenance, surveillance, weapon assembly and disassembly, and weapon safety and reliability testing. It enables individual site capability and capacity to sustain the nuclear security enterprise's production mission, and it encompasses the workforce, facilities, and equipment that provide manufacturing and capacity across multiple sites. The program's goal is to maintain the base capability required to sustain a responsive and resilient stockpile through focused management and production process engineering, manufacturing, and production technologies.

> ***Production Accomplishments***
>
> - *Completed over 1,800 critical equipment calibrations on time in support of production activities*
> - *Completed approximately 55,000 analytical tests*
> - *Upgraded high-resolution computed tomography servers supporting CoLOSSIS I and II (see Chapter 3, Figure 3–5)*
> - *Upgraded vacuum arc remelt controller*

Production Operations also serves as the demand signal for the modernization of production capabilities to improve efficiency and maintain manufacturing operations that will meet future requirements. The program requires close coordination with the Non-Nuclear Component (which provides funding to modernize component production) and Advanced Manufacturing Development programs, which are charged with development and initial deployment of new or replacement manufacturing and production component capabilities. It also heavily depends on required infrastructure modernizations (as discussed in Chapter 1, Section 1.4, throughout Chapter 3, and in Chapter 4) to have in place base capabilities with adequate capacities, space, and equipment. Production Operations base capability activities also include sustaining and improving the capability for calibration and analytical accuracy via certified reference material provision to the enterprise and programmatic partners. This activity is vital to process control and product certification in Defense Programs as well as partners in Naval Nuclear Propulsion and Defense Nuclear Nonproliferation.

2.4.1 Status

The Production Operations work scope provides the base capabilities to enable weapon operations (assembly, disassembly, and production) planned for the warhead modernization activities, Stockpile Systems, and WDD programs to meet delivery requirements. These activities include preventive and corrective maintenance, calibrations, quality assurance, supply chain management, logistics, Nuclear Enterprise Assurance policy planning meetings, manufacturing execution systems, process flow, and scheduling. Model-based enterprise pilot efforts will be funded out of Production Operations through FY 2023.

2.4.1.1 Challenges and Strategies

Table 2–6 provides a high-level summary of Production Operations challenges and the strategies to address each.

Table 2–6. Summary of Production Operations challenges and strategies

Challenges	*Strategies*
Maintaining a knowledgeable and qualified labor force.	Work with M&O partners to identify hiring needs and mitigate turnover through knowledge capture and next generation work force recruitment.
Difficulty sustaining operations due to decreasing reliability of aging capital equipment.	Categorize and prioritize key production equipment so it can be replaced prior to failure.
Completing infrastructure modernizations that are needed for adequate base capabilities, adequate space, and equipment capacities.	Identify infrastructure and space needs and develop methodologies to enable prioritization.
Difficulty in implementing digital transformation of product realization.	Determine the cultural, technological, and process-based challenges to model-based engineering, provided piloting solutions, and generate paths forward through the Model-Based Enterprise Transition Initiative (MBET-I).
Address evolving Nuclear Enterprise Assurance (NEA) requirements.	Continue integration working groups and NEA Steering Group across DOE/NNSA to maintain focus on the highest-priority NEA activities implementation at the sites.

Chapter 3
Weapons Activities Capabilities That Support the Nuclear Security Enterprise

> ***Key Changes to Weapons Activities Capabilities***
>
> - *Reestablishment of weapons production capabilities*
> - *Increase in capacity and enhancement of capabilities to support weapons requirements*
> - *Improvements to assessment and certification capabilities*

Chapter 2 describes how DOE/NNSA fulfills the critical mission to assess, surveil, modernize, qualify, and certify that the nuclear weapons stockpile is safe, secure, and effective. Chapter 3 focuses on the Weapons Activities capabilities required to accomplish that mission. DOE/NNSA, in partnership with DoD, delivers the capabilities required for an effective nuclear deterrent that will provide the Nation with the ability to adapt and respond to a dynamic security environment, emerging strategic challenges, and geopolitical and technological changes.

The Weapons Activities capabilities described in this chapter directly contribute to and support Mission Priority #1, maintaining the safety, security, and effectiveness of the Nation's nuclear deterrent as detailed in the 2018 *NNSA Strategic Vision*. In order to accomplish that mission, DOE/NNSA must:

- Maintain the safety, security, and reliability of all U.S. nuclear weapons
- Extend the life of weapons as necessary to assure operational readiness
- Prepare for the future by ensuring that the nuclear deterrent is modern, robust, flexible, and resilient
- Develop and sustain a highly capable workforce and resilient infrastructure that is responsive to future threats

This chapter describes the elements that define a Weapons Activities capability, and expounds on the crucial roles each contribute to maintaining and modernizing the stockpile. The 30-plus Weapons Activities capabilities are introduced as a key aspect of the functional portfolios to explain the unique nature of the capabilities and to demonstrate the interdependencies in support of the enterprise. Each portfolio and associated constituent capabilities is described in detail including the capability health status, challenges, and strategies to address those challenges. For an enterprise-level overview of major infrastructure investments tied to Weapons Activities capabilities and the supporting workforce, see Chapter 4.

3.1 Weapons Activities Capabilities in Context

Weapons Activities capabilities are vital to the successful conduct of DOE/NNSA's nuclear deterrence mission and comprise the elements illustrated in **Figure 3–1**. These elements represent the human capital, physical assets, resources, and enabling processes underpinning the Weapons Activities capabilities. All four elements need to be sustained and modernized to meet current and future missions. If any of these elements are missing, the capabilities cannot function as a system.

Figure 3–1. Weapons Activities capability elements

Weapons Activities capabilities require periodic evaluation across all four elements to assess a capability's health and investment needs. DOE/NNSA must continue to invest in advancing existing capabilities and developing emerging capabilities for a strong nuclear deterrent in light of aging or emerging new production processes.

DOE/NNSA is the sole source provider of many functions that comprise Weapons Activities capabilities. The highly specialized materials, variability in supply chain component lot sizes, and stringent manufacturing specifications required for nuclear weapons production make it difficult or unprofitable work for commercial providers. DOE/NNSA must sustain the health of the Weapons Activities capabilities for continued availability of these niche functions. In addition, the national security requirements for nuclear weapons require trusted domestic vendors for certain materials and processes.

While Weapons Activities capabilities are nuclear-weapon centric, a number of the capabilities are also used to support activities in non-proliferation, naval reactors, and counterterrorism. Examples are discussed throughout this chapter.

3.2 Weapons Activities Capabilities

More than 30 key Weapons Activities capabilities support the core mission functions, and each capability may support multiple parts of the nuclear weapon life cycle. This interdependency between missions and capabilities, as well as among the capabilities, is described throughout Chapter 3. These capabilities are presented as facets of seven interdependent portfolios, each containing a suite of capabilities that together address a particular aspect of Weapons Activities. **Figure 3–2** illustrates these capability portfolios. The next sections describe the portfolios, their constituent capabilities, specific support to the nuclear deterrent mission, and the linkage and integration with other portfolios and capabilities.

Figure 3–2. DOE/NNSA Weapons Activities capability portfolios

3.3 Weapon Material Processing and Manufacturing Portfolio

The Weapon Material Processing and Manufacturing portfolio 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. Components that contain special nuclear material (SNM)[1] or energetic materials require a special conduct of operations, physical security protection, facilities, and proper equipment to handle, package, process manufacture, and inspect these components.

The current stockpile maintenance and modernization programs will continue to demand SNM, high explosives (HE) and energetic materials. The nuclear security enterprise must maintain reliable production; scientific, technological, and engineering (ST&E) capabilities; integrated infrastructure; and logistics (handling, storage, delivery, and supply chain management) for raw materials and War Reserve products. Energetic materials are integral to the design and performance of weapon components and systems. R&D for energetic materials is covered under Section 3.7.10.

The capability to handle, package, process, manufacture, and inspect SNM-based products requires the support of many specialized facilities and programs throughout the nuclear security enterprise. The obsolescence, age, or severely degraded nature of many of the facilities required to produce and process SNM presents operational risks that require focused management attention to reliably produce nuclear weapon components. The strategies detailed throughout this section for the overall capability are organized by the individual materials and supporting programs and address any necessary bridging strategy or solution currently being implemented as capability investments for each type of SNM, as well as major programmatic infrastructure projects.

[1] The *Atomic Energy Act of 1954* defines SNM as all isotopes of plutonium, or uranium enriched in the isotopes of uranium-233 or uranium-235. Tritium is considered a Security Category III nuclear material.

3.3.1 Special Nuclear Materials Handling, Packaging, and Processing (Plutonium and Uranium)

3.3.1.1 Plutonium

The United States must reestablish the capability to manufacture primaries for nuclear weapons, in particular plutonium pits to support the W87-1 Modification Program and other planned and future weapon modernization programs. As required by statute and as part of a major initiative of the 2018 *Nuclear Posture Review,* DOE/NNSA provided Congress with the recommended two site approach to produce plutonium pits at a rate of no fewer than 80 pits per year during 2030. Through this two-site solution, DOE/NNSA will:

- Continue to invest in the Los Alamos National Laboratory (LANL) to produce 30 pits per year during 2026; DOE/NNSA will assess opportunities for LANL to produce above that quantity to help reduce schedule risk associated with pit production at the Savannah River Site
- Repurpose the former Mixed Oxide Fuel Fabrication Facility (MFFF) at the Savannah River Site (SRS) as the Savannah River Plutonium Processing Facility (SRPPF) to produce 50 pits per year during 2030;

This two-pronged 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 against shutdowns, incidents, or other factors that may affect operations at a single site.

The requirement to recapitalize the Nation's pit production capability and produce no fewer than 80 pits per year during 2030 comes from three major factors:

- DoD and DOE/NNSA requirements to enhance warhead safety and security
- Risk mitigation against plutonium aging through deliberate, methodical replacement of older existing plutonium pits with newly manufactured pits
- Renewed competition among global powers that may lead to changes in deterrent requirements

The plutonium capability is also used for radioisotope thermoelectric generator production, pit surveillance, plutonium science and aging studies, subcritical experiments, National Aeronautics and Space Administration space exploration, and nonproliferation programs.

3.3.1.1.1 Status

The Nuclear Weapons Council certified[2] that DOE/NNSA remains on track to:

- produce no fewer than 80 pits per year during 2030
- meet the requirements outlined in 50 U.S.C. 2538a
- meet established milestones and deliverables necessary to produce 30 pits per year at LANL by 2026.

DOE/NNSA is conducting a *National Environmental Policy Act* (NEPA) review of the recommendation described above. The NEPA strategy articulates a three-tiered approach to address pit production activities, site-specific environmental impacts, and programmatic actions across the nuclear security

[2] Public Law 115-232, § 3120(e) requires the Chair of the Nuclear Weapons Council to annually certify to Congress that the DOE/NNSA plutonium pit production plan meets DoD military requirements, and remains on track to achieve all milestones and deliverables.

enterprise. In the first half of FY 2020, the three analysis documents identified as necessary to meet the requirements of NEPA were all released for public comment.[3, 4, 5] A final Supplement Analysis to the 2008 LANL Site-Wide Environmental Impact Statement was released in the fourth quarter of FY 2020.

In addition to dedicated infrastructure efforts at LANL and SRS, DOE/NNSA is recapitalizing existing facilities through a series of reinvestment projects, including several line item projects, to replace the current aging capability to manufacture and certify pits. The Chemistry and Metallurgy Research Replacement project maintains continuity in analytical chemistry and material characterization capabilities by transitioning these activities from the nearly 70-year old Chemistry and Metallurgy Research (CMR) facility to newer facilities. The Material Recycle and Recovery program is conducting risk reduction activities by removing the nuclear material inventory currently housed in the CMR facility.

3.3.1.1.1.1 Approach at LANL for 30 Pits Per Year

DOE/NNSA will establish a reliable capability at LANL to deliver 30 pits per year during 2026. An increase in the workforce at LANL is planned over the next few years to accomplish this expanded pit production mission, including cost-effective, supporting infrastructure investments for operations support, waste management, offices, parking, training, etc. There are several key steps to delivering 30 pits per year during 2026:

- Advance the science and mature the engineering to meet the LLNL design agency specifications for plutonium pit production
- Maintain and update Technical Area 55 (TA-55) Plutonium Facility (PF-4) to ensure reliability and continued compliance with all relevant safety requirements
- Reconfigure TA-55 PF-4 for efficient pit production by completing the ongoing equipment installations and facility modification to optimize the pit production process flow and establish the capacity for a reliable 30 pits per year production rate
- Increase the workforce required for the pit production mission to manufacture pits; maintain and operate facilities; provide security for pit production activities and materials and provide a broad range of support functions
- Under the guidance of the Pit Product Realization Team, provide acceptable components and support for the experiments and evaluations specified by Lawrence Livermore National Laboratory (LLNL) in the Pit Certification Plan

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

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[3] Notice of Availability for the *Final* S*upplement Analysis to the Complex Transformation Programmatic Environmental Impact Statement,* published in the *Federal Register* January 8, 2020.
[4] Notice of Availability of the *Final Supplement Analysis of the 2008 Site-Wide Environmental Impact Statement for the Continued Operation of Los Alamos National Laboratory for Plutonium Operations*, August 2020.
[5] Notice of Availability for the *Final Environmental Impact Statement for Plutonium Pit Production at the Savannah River Site in South Carolina,* published in the *Federal Register* September 30, 2020.

3.3.1.1.1.2 SRS Approach to Producing a Minimum of 50 Pits Per Year

DOE/NNSA will reach production of 50 plutonium pits per year during 2030 by repurposing the former MFFF as the proposed SRPPF. Preliminary design of the SRPPF and some long-lead procurement of equipment will proceed in FY 2021.

The former MFFF is a Security Category 1/Hazard Category 2 structure that provides an opportunity to achieve pit production in a facility designed to meet stringent security and safety requirements for plutonium operations. Conceptual design efforts for the proposed SRPPF are underway using knowledge gained from LANL, LLNL, and other sites.

The proposed pit production mission will need a skilled workforce at the site. Early estimates indicate that design and construction activities will require approximately 2,000 staff, and manufacturing 50 pits per year at SRS will require more than 700 production staff. These early estimates will continue to be refined as the project's design matures. LANL is supporting the training rotation pipeline for the SRS pit production mission with subject matter expertise.

3.3.1.1.1.3 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. Conduct of these activities requires close coordination between the sites to execute the disassembly activities, evaluations, experiments, analysis, and recovery.

DOE/NNSA manages numerous facilities that house plutonium handling, processing, characterization, experimental, and storage facilities that must be sustained. A responsive plutonium infrastructure requires proper storage facilities, safe and secure disposal pathways, and unique equipment and facilities for R&D activities.

3.3.1.1.2 Challenges and Strategies

Table 3–1 provides a high-level summary of plutonium capability challenges and the strategies to address them.

Table 3–1. Summary of Plutonium Handling, Packaging, and Processing challenges and strategies

Challenges	*Strategies*
Meeting the W87-1 Pit Product Realization Team schedule to achieve an enduring production rate of 30 pits per year at LANL during 2026.	Continue to invest in LANL plutonium facilities to meet pit production milestones – achieving first production unit capability in 2023 then achieve an enduring production rate of 30 pits per year during 2026.
Repurposing of the former Mixed Oxide Fuel Fabrication Facility at SRS to achieve a production rate of 50 pits per year during 2030.	Implement a tailored approach to achieve CD-1 (Approve Alternative Selection and Cost Range) and CD-2 (Approve Performance Baseline) in order to support producing 50 War Reserve pits per year during 2030.
Meeting warhead modernization program requirements timelines, mitigating risk against plutonium aging, and responding to changes in the deterrent.	Continue prioritizing recapitalization investments for the pit production capability to produce 80 pits per year at LANL and SRS during 2030. Use LANL and LLNL subject matter experts to support building plutonium production capabilities at SRS.
Executing environmental testing/surety/qualification of plutonium pits without nuclear test.	Use and expand thermal and mechanical testing capabilities to evaluate newly manufactured and legacy pits in the STS normal environments. Establish equipment and systems to evaluate additional normal and abnormal environments that pits could experience.

CD = Critical Decision
STS = stockpile-to-target sequence

3.3.1.2 Uranium

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

3.3.1.2.1 Highly Enriched Uranium

HEU is uranium in which the concentration of the fissile isotope uranium-235 is increased to 20 percent or greater. This capability includes the ability required to recover, recycle, and purify HEU, and then cast and machine it into parts that support the current and future stockpile. HEU is required for nuclear component production to maintain and modernize the stockpile through warhead modernization programs and modifications. HEU is processed into precision components through complex processes that must meet stringent requirements. These processes include chemical conversion, special processing, casting, machining, assembly, and inspection. The demand for HEU continues to increase based on the needs of the stockpile. HEU is recycled from dismantled and disassembled weapon components to support production requirements.

3.3.1.2.1.1 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 the Y-12 National Security Complex (Y-12) and other locations across the nuclear security enterprise. Much of the infrastructure at Y-12 is deteriorating; some of the facilities are more than 70 years old, predating many of the modern safety standards applicable to nuclear facilities. DOE/NNSA is decreasing mission dependency on these older facilities by relocating certain uranium enrichment processes to existing recapitalized facilities at Y-12, as well as through construction of the Uranium Processing Facility. Modernizing the infrastructure that supports this capability will improve resiliency and responsiveness for future mission requirements.

Sustaining uranium processing capabilities requires targeted resources to address mission risk associated with aging equipment. Sustainment of capabilities will also require continued training and development of subject matter experts to produce components and resolve technical issues.

HEU processing is required for other missions, including surveillance of the stockpile, fuel for naval reactors for submarines and aircraft carriers, and nuclear nonproliferation. Nondestructive and destructive testing is performed on HEU components in full assembly and part form as part of critical data collection for ensuring confidence in the stockpile. Production of fuel for the Navy requires reprocessing HEU into a form that is usable in naval reactors. HEU-related nuclear nonproliferation activities involve downblending weapons-grade materials to a lower enrichment level for safe and secure use in domestic and foreign nuclear reactors.

3.3.1.2.1.2 Challenges and Strategies

Table 3–2 provides a high-level summary of HEU challenges and the strategies to address them.

Table 3–2. Summary of Highly Enriched Uranium Handling, Packaging, and Processing challenges and strategies

Challenges	*Strategies*
Transitioning enriched uranium capabilities from 70+ year-old facilities that do not meet current safety standards into existing and new facilities to phase out mission dependency.	Implement the Transition Strategy, which entails complex activities to shut down production processes, drain and isolate systems, and facilitate post-operations clean-out of the facility.
Extending the operational lifetime of existing enriched uranium processing facilities.	Sustain existing enriched uranium capabilities through enhanced facility and equipment maintenance and the purchase of critical spare parts to improve the availability and reliability of production systems.
Constructing the Uranium Processing Facility by the end of 2025 to house processes currently performed in older facilities that cannot be transferred to another operating facility.	Execute capability relocations into existing facilities through the Process Technology Development projects. Construct the Uranium Processing Facility to provide new floor space for the high-hazard, high-security operations currently located in older buildings that cannot viably be relocated to existing facilities. Prepare for increased work scope by increasing staff in several areas, including hiring additional craftspeople to execute the construction work.
Maintaining subject matter expertise at the national laboratories in base R&D capabilities to support HEU production.	Continue two-way communications between the nuclear weapon production facilities and the national security laboratories to meet increased production needs. Recommend improvements that can be applied to HEU production.

HEU = highly enriched uranium

3.3.1.2.2 Depleted Uranium

Depleted uranium, a byproduct of the HEU enrichment process, has a lower concentration of the fissile isotope uranium-235 and a higher concentration of the fissionable isotope uranium-238 than natural uranium. DOE/NNSA has a long-term requirement for high-purity depleted uranium metal feedstock to meet national security mission needs.

Depleted uranium is required for nuclear component production to maintain and modernize the stockpile through life extension, modification, and limited life component (LLC) exchange programs. Depleted uranium is processed into precision components through complex processes that must meet stringent requirements. Key processes include casting, rolling, swaging, forming, forging, machining, assembly, and inspection.

Depleted uranium is also required for surveillance of the stockpile. Nondestructive and destructive testing is performed for depleted uranium components in full assembly and part forms as part of surveillance data collection for ensuring confidence in the stockpile. The demand for depleted uranium continues to increase based on the needs of the stockpile.

3.3.1.2.2.1 Status

DOE/NNSA's Manhattan Project-era facilities continue to experience failures that represent significant risk to mission delivery and personnel safety. Restarting and sustaining depleted uranium processing capabilities requires targeted resources to address risk associated with aging equipment. Sustainment of these capabilities also requires continued training and development of subject matter experts to produce components and resolve technical issues associated with the complex processes. DOE/NNSA has developed an integrated strategy to restore lapsed capabilities; invest in new technologies that simplify processes and increase safety and efficiency of depleted uranium operations; and is evaluating infrastructure needs to meet mission requirements.

DOE/NNSA intends to restart and modernize depleted uranium capabilities to meet imminent mission requirements, including feedstock procurement, alloying and manufacturing capabilities, and investments in key new technologies for maturation. The capability to produce, process, and handle depleted uranium supports a number of key missions within the nuclear security enterprise.

DOE/NNSA has a large quantity of depleted uranium in the form of depleted uranium hexafluoride (DUF_6) gas, a byproduct of enriching uranium. At present, DOE/NNSA do not have the capability to convert this gas to a usable form of depleted uranium. DOE/NNSA began efforts to reestablish depleted uranium feedstock capability through material recycle and recovery in FY 2019. As part of that program, DOE/NNSA is working with DOE's Office of Environmental Management to initiate design work for construction, installation, and operation of equipment at the Portsmouth DUF_6 Conversion Facility to meet nuclear stockpile requirements.

A key element of DOE/NNSA's depleted uranium strategy is to restart and maintain capabilities for depleted uranium and depleted uranium alloying. In order to restart casting, forming, heat-treating, machining, and metalworking, DOE/NNSA will need to restart the Vacuum Induction Melt – Vacuum Arc Melt production process, as well as establishing capability for machining, training operators, developing procedures, and assisting with process qualification activities.

3.3.1.2.2.2 Challenges and Strategies

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

Table 3–3. Summary of Depleted Uranium Handling, Packaging, and Processing challenges and strategies

Challenges	*Strategies*
Determining a path forward to mitigate the issue of limited supplies of depleted uranium for the future.	Continue efforts to reestablish the depleted uranium supply. Investigate alternate processes and technology improvements that can increase the efficiency of traditional manufacturing processes.
Creating innovative new sources for depleted uranium metal production beyond the current limited vendor base.	Increase supply and more closely interface with DoD by exploring the capability for recycling depleted uranium resulting from processing of byproducts and waste. Provide an alternate source for the remainder of the demand. Work with DoD counterparts to establish a clear understanding of the shared need for this material.
Achieving and maintaining steady-state production of depleted uranium alloy production in existing aging equipment and other infrastructure.	Target resources and address risks associated with aging equipment and infrastructure to restart the equipment in a timely manner.
Meeting stockpile requirements to support warhead modernization in the face of potential single-point process equipment failures.	Pursue multiple alternative technologies concurrently. Invest in upgrades to recapitalize the aging physical infrastructure to reduce risk and the ability to produce strategic materials and components.

3.3.1.2.3 Domestic Uranium Enrichment

Enriched uranium contains higher concentrations of the fissile uranium-235 isotope than natural uranium. Enriched uranium is required at various levels of enrichment and forms for national security and nuclear nonproliferation missions, including but not limited to nuclear weapon components and fuel for naval reactors, power reactors (tritium production), and research reactors (medical isotope production). DOE/NNSA is currently executing an analysis of alternatives (AoA) to determine the best approach to meet the mission need for enriched uranium. The selected option to provide domestic uranium enrichment will provide a reliable supply of enriched uranium to support all of the mission needs mentioned above.

Longstanding policy and international agreements require that LEU used for tritium production be free of peaceful use restrictions. The United States currently has no domestic uranium enrichment capability that could produce such material. At present, mission needs for enriched uranium are currently fulfilled using the United States' existing HEU stockpile, which is a finite source. To meet future needs, DOE/NNSA will require a U.S.-origin enrichment capability for a long-term supply of LEU for tritium production and naval nuclear propulsion.

3.3.1.2.3.1 Status

DOE/NNSA is executing a three-pronged strategy towards reestablishment of a Domestic Uranium Enrichment capability. First, DOE/NNSA is downblending HEU to LEU through 2025, which will extend the need date for LEU fuel for tritium production to 2042.[6] Second, DOE/NNSA is preserving and advancing enrichment technology by funding centrifuge R&D at Oak Ridge National Laboratory. Third, DOE/NNSA is pursuing a capital acquisition to deploy a domestic uranium enrichment capability in time for need.

The Domestic Uranium Enrichment program formally obtained approval of mission need for reestablishment of a domestic uranium enrichment capability, and is currently executing the AoA. The AoA will inform NNSA's strategy to establish a source of unobligated uranium in time for need. Depending on the outcome of the AoA, NNSA may need to deploy an enrichment pilot plant in the mid-2020s, which will demonstrate the selected enrichment technology at a smaller scale, identify any remaining technical issues within sufficient time to develop remedies, and begin training operators ahead of full-scale plant operation. The full-scale capability, if selected following the AoA, will be established in time to meet the 2042 need for tritium production.

3.3.1.2.3.2 Challenges and Strategies

Table 3–4 provides a high-level summary of Domestic Uranium Enrichment challenges and the strategies to address them.

Table 3–4. Summary of the Domestic Uranium Enrichment Handling, Packaging, Processing, and Manufacturing challenges and strategies

Challenges	*Strategies*
Deploying complex enrichment technologies at production scale.	Consider deployment of an enrichment pilot plant, which would identify technical issues and further R&D to remedy any issues.

3.3.2 Tritium Production, Handling, and Processing

Tritium, a strategic material used for national security purposes, is placed in gas transfer system (GTS) reservoirs and used to meet weapon system military specifications, increase system margins, and support weapon system reliability. Due to the rate of radioactive decay, tritium must be replenished periodically in these components. DOE/NNSA produces tritium for this and other purposes using tritium-producing burnable absorber rods (TPBARs) that are irradiated in the Watts Bar Unit 1 reactor operated by the Tennessee Valley Authority (TVA), using unencumbered and unobligated LEU as fuel, i.e., LEU that is free of peaceful use restrictions, as discussed in more detail in Section 3.3.1.2.3. Once the TPBARs are

[6] In FY 2020, DOE/NNSA's need date for LEU for tritium production has shifted one year from 2041 to 2042. This is the result of the program identifying additional quantities of LEU free of peaceful use restrictions within DOE's inventory. DOE/NNSA has executed the necessary contracting actions to secure this material and make it available, providing an additional year of tritium production.

irradiated, the bars are transported to SRS, where the tritium is extracted, stored, and loaded into GTS reservoirs. In addition to tritium production at TVA, tritium supplies from previously filled reservoirs are recycled to maintain required inventories. Most of DOE/NNSA's tritium capability activities focus on stockpile requirements, but activities also include tritium gas processing R&D, GTS life storage, helium-3 recovery, and stockpile surveillance.

3.3.2.1 Status

The demand for tritium is increasing, and DOE/NNSA continues to deliver the requisite supply through the use of TVA's Watts Bar Unit 1 and eventually Watts Bar Unit 2 reactors at TVA. The goal to reach maximum tritium production in each of the two Watts Bar reactors by FY 2024 is on schedule. Extraction of tritium from irradiated TPBARs at SRS is ongoing and is expected to increase to meet future tritium demand.

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

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

Examples of these required smaller projects include:

- Replacement of large, obsolete distributed control systems for the gas processing equipment
- Replacement and electronic refurbishment of mass spectrometers to analyze gas associated with processing equipment
- Replacement of the GTS tracking system that is no longer supported by the software vendor
- Installation of a hydrogen/tritium separation capability in the Tritium Extraction Facility
- Replacement of the deuterium/tritium separation equipment, including support systems and valves
- Several minor construction projects to address safety, space, and parking requirements

The scope described above will require significant production downtime. The equipment replacement sequence and timing will be critical to ensuring the shortest possible GTS loading outage during construction and installation periods.

3.3.2.2 Challenges and Strategies

Table 3–5 provides a high-level summary of Tritium Production, Handling, and Processing challenges and the strategies to address them.

Table 3–5. Summary of the Tritium Production, Handling, and Processing challenges and strategies

Challenges	*Strategies*
Maintaining a reliable tritium supply chain to meet tritium inventory and availability requirements to load GTSs on schedule.	Implement recommendations from the Tritium Sustainment Strategic Efficiency Enhancement study to improve supply chain reliability, manage facility health and availability, increase proficiency and implement process system modernization capabilities, procure spare parts or equipment, and evaluate options for increasing tritium production.
Maintaining tritium production in the face of pending license renewals in 2055 for The Watts Bar Unit 1 and 2.	Monitor the results of studies underway regarding potential current and emerging replacement methods and technologies as risk mitigation for long-term tritium production.
Maintaining facilities and equipment to support stockpile deliverables and future Alts, Mods and LEPs and reduce GTS delivery risks.	Construct the modern Tritium Finishing Facility on schedule to replace infrastructure critical to stockpile deliverables at SRS by 2031.
Developing technologies that further enhance stockpile maintenance and evaluation and increase efficiency of processes throughout the tritium production life cycle.	Continue scientific research into the material properties and behaviors of TPBARs, GTSs and tritium gas processing technologies. Develop a strategy to acquire dedicated radiological tritium R&D to address future technology needs without compromising mission schedule.
Planning for long (~2-year) lead times to hire, clear, and train personnel.	Examine multi-year staffing needs appropriate to ensure a continuous pipeline of knowledge, skills, and abilities to sustain capabilities.

GTS = gas transfer system
TPBAR = tritium producing burnable absorber rod

3.3.3 Energetic and Hazardous Material Handling, Packaging, Processing, and Manufacturing (High Explosives and Lithium)

Across the enterprise, DOE/NNSA laboratories and production sites handle energetic and hazardous material as a part of the nuclear weapon sustainment and warhead modernization missions. The nuclear security enterprise must maintain reliable production, integrated infrastructure, a reliable domestic supplier base, and logistics (handling, storage, and delivery) for raw materials and War Reserve products.

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

This capability depends on the High Explosives and Energetics Science and Engineering capability (Section 3.7.10) for support and is synergistic with its companion capability, special nuclear materials handling, packaging, and processing (plutonium and uranium) (Section 3.3.1).

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

3.3.3.1 Status

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

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

3.3.3.2 Challenges and Strategies

Table 3–6 provides a high-level summary of Energetic and Hazardous Materials Handling, Packaging, Processing, and Manufacturing (HE and lithium) challenges and the strategies to address them.

Table 3–6. Summary of Energetic and Hazardous Materials Handling, Packaging, Processing, and Manufacturing (HE and Lithium) challenges and strategies

Challenges	*Strategies*
Maintaining aging equipment and facilities while awaiting upgrades or replacements.	Keep aging equipment available for warhead modernization and current stockpile systems through rigorous maintenance programs. Employ creative methods to mitigate obsolescence issues, such as using additive manufacturing to produce parts.
Maintaining subject matter experts across the nuclear enterprise.	Increase hiring to plan for multi-year training and clearance requirements. Transfer knowledge from subject matter experts near retirement age to new subject matter experts. Gather and collate knowledge from subject matter experts through documentation programs targeting critical knowledge areas.
Maintaining qualified vendors for low-volume, high-quality outsourced components.	Establish clear requirements for Nuclear Enterprise Assurance. When necessary, use in-house capabilities to restore mission schedules at risk.
Continuing operations in aging facilities with increasing safety, security, and environmental requirements and maintaining them until their transition to newly deployed facilities.	Make short- to medium-term recapitalization investments where reasonable. Find creative solutions to maintain facilities past their useful life.

3.3.3.3 High Explosives and Energetics

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

DOE/NNSA uses one of two types of HE in the main charge of a nuclear weapon: insensitive high explosives can greatly improve the safety and security of the stockpile by reducing the risk of low-likelihood but high-consequence accidents from initial build through retirement and disassembly.

3.3.3.3.1 Status

DOE/NNSA is currently planning two major programmatic line-item construction projects for HE. The HE Science and Engineering Facility will consolidate 15 aging facilities into 3 new efficient facilities to conduct science, technology, engineering, and production activities in weapons assembly/disassembly and HE. The HE Synthesis, Formulation, and Production project will address challenges at the supplier's formulation facility and the difficulty meeting DOE/NNSA production requirements. Areas to be addressed include explosive and mock formulation operations to support multiple weapon programs, technology development for future programs, and support for strategic partners.

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

3.3.3.3.2 Challenges and Strategies

Table 3–7 provides a high-level summary of High Explosives Handling, Packaging, Processing, and Manufacturing challenges and the strategies to address them.

Table 3–7. Summary of the High Explosives Handling, Packaging, Processing, and Manufacturing challenges and strategies

Challenges	*Strategies*
Developing sufficient supply chain capacity for energetic materials in current and future LEPs and Alts.	Exercise initiatives for Energetic Materials. Refresh HE formulation, synthesis, and machining capabilities at Pantex. Maintain a robust R&D capability within the national laboratories.
Maintaining a viable and reliable domestic supplier base.	Exercise suppliers to maintain proficiency on a more frequent schedule between procurements and continue technical exchanges.
Ensuring that requirements for energetic materials are preserved and documented.	Document the detailed processes necessary for the synthesis and formulation of energetic materials for a repeatable material specification that yields the required engineering and performance requirements.
Planning for material shortfalls for legacy War Reserve 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 formulation of energetic materials. Preserve and enhance in-house production for items such as War Reserve detonator powder production.
Controlling risks posed by aging HE facilities across the nuclear security enterprise needed to support warhead modernization and emerging weapons program needs.	Coordinate with the Infrastructure and Operations Program and the Programmatic Recapitalization Working Group to improve energetic readiness. Construct the HE Synthesis, Formulation, and Production building, the High Explosives Science and Engineering Facility, and the Energetic Materials Characterization Facility.
Forecasting future needs in both legacy inventories and new procurements and formulations for HE.	Charter the NNSA Energetics Coordinating Committee and establish an HE sustainment program (both completed).

HE = high explosives

3.3.3.4 Lithium

Lithium is a subset of the Energetic and Hazardous Material Handling, Packaging, Processing, and Manufacturing capability that is key to the nuclear weapon production mission. It has recently come into increased focus due to supply, production, and infrastructure issues. DOE/NNSA requires specialized, weapon-specific forms of lithium for stockpile sustainment and is the sole source provider for these materials. DOE/NNSA manufactures lithium materials into precision nuclear weapon components that meet stringent specifications to support warhead modernization programs and joint test assembly (JTA) requirements, as well as to support TPBAR production for tritium modernization.

Lithium metal from technology maturation efforts

3.3.3.4.1 Status

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

DOE/NNSA is actively pursuing alternate, advanced lithium purification techniques. In addition, DOE/NNSA established a technology development laboratory to support and expand lithium technology maturation. Technology Readiness Assessments will be conducted as needed to assess the strengths and weaknesses of identified technologies.

Hydriding reactor vessels, restarted in 2019

DOE/NNSA will continue to work with operating partners to develop tailored, long-term staffing plans that anticipate critical skills shortfalls within this capability and properly forecast staffing levels based on the current program of record. Sustainment of capabilities will require continued training and development of subject matter experts to produce lithium components and resolve technical issues associated with these complex production processes.

Currently, aging infrastructure and antiquated equipment present risks to mission delivery that could affect the ability to meet stockpile requirements. The current 75-year-old lithium facility has structural issues due to chemical contamination that poses safety and environmental concerns and must be replaced. To meet near- and long-term requirements, DOE/NNSA put in place a lithium strategy for the availability of sufficient lithium processing capabilities (from raw materials to finished assemblies). The strategy includes the design and construction of a new Lithium Processing Facility by 2031 to house modernized lithium processing capabilities.

3.3.3.4.2 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

Challenges	*Strategies*
Meeting manufacturing deliverables using existing aging and degraded facilities.	Sustain current operations in the legacy lithium facility to meet near-term stockpile needs. Monitor and optimize weapons dismantlement schedule to provide feedstock as needed. Reestablish a small purification capability and restart some legacy processing capabilities to supplement recycling activities. Plan and prioritize recapitalization projects and risk reduction activities to keep facilities and process equipment functional until the Lithium Processing Facility is operational. Design and construct the Lithium Processing Facility.
Sustaining lithium production with current inefficient processes.	Develop and mature lithium process technologies to introduce efficiencies into the current process and prepare for insertion of these new technologies into the Lithium Processing Facility.
Sustaining the supply of recycled lithium in the face of potential shortages from the Weapons Dismantlement Program.	Restart a small purification capability and legacy processing capabilities in the legacy lithium facility to provide additional feedstock material. Deploy a new material recycle cleaning station to provide additional capacity. Monitor and optimize weapons dismantlement schedule to provide feedstock as needed.

3.3.4 Metal and Organic Material Fabrication, Processing, and Manufacturing

DOE/NNSA uses a variety of metals and organic materials to manufacture precision components that meet tight specifications to support life extension, modification, and JTA programs. More detail on this capability is provided in the classified Annex.

3.4 Weapon Component Production Portfolio

The Weapon Component Production portfolio includes the capabilities for producing all the non-nuclear components and systems for weaponization of the nuclear explosive package. These functions are for the weapons to arm, fuze, fire, for the designed function when needed. This capability includes both internal and external manufacturing and a broad supply base. It also includes identification and verification of trusted suppliers to provide materials and parts within the weapon product realization process.

3.4.1 Non-Nuclear Component Production

The Non-Nuclear Component Production capability includes activities associated with the design, development, qualification, manufacture, assembly, and inspection of all non-nuclear weapon components. Many non-nuclear weapon components require special manufacturing and inspection protocols. The design, development, qualification, and fabrication of non-nuclear components and subsystems used in the stockpile amounts to more than half the cost of each warhead modernization. This capability incorporates innovative technologies from both the commercial and government sectors. The weapon components include power sources, radiation-hardened microelectronics, neutron generators, GTSs, arming, fuzing, and firing (AF&F) assemblies, environmental sensing devices, structural parts, cushions, pads, spacers, engineered polymeric components, detonator cable assemblies, and other specialized electro-mechanical components.

Subject matter experts at the nuclear weapons production facilities work with the national security laboratories early in the design phase for producibility of components. The national security laboratories define the component testing needed for acceptance through a variety of specialized procedures to ensure that (1) materials meet design specifications; (2) parts are manufactured within acceptable tolerances; and (3) assemblies function as intended.

3.4.1.1 Status of Non-Nuclear Component Production

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

Production sites face capacity constraints that affect both production and development of components due to increased weapon modernization requirements and scope. As an example, the Kansas City National Security Campus (KCNSC) management and operating (M&O) workforce has increased from 2,200 to more than 4,500 employees since 2014, resulting in a lack of office space, production space, and parking. Additional production capacity is being sought through bridging leases at KCNSC, as well as shifting production to other DOE/NNSA sites while simultaneously increasing the vendor base for commercial component production. DOE/NNSA is considering both short- and long-term solutions as part of an ongoing study.

Sandia National Laboratories (SNL) is the Nation's sole resource for nuclear weapon power sources research, development, testing, and evaluation. Current stockpile stewardship plans are forecasting a fourfold increase in workload for power sources production during the next decade. The primary SNL power sources research and production facility is a shipping/receiving warehouse converted in 1949. Severe degradation of this facility has led to an AoA for a long-term replacement while exploring use of other SNL facilities on a temporary basis. Similar issues hold true for radiation-hardened microelectronics at SNL's Microsystems Engineering, Science, and Applications (MESA) complex. The MESA facilities and existing equipment face obsolescence and are becoming less suitable for mission use. MESA has an ongoing extended life program to sustain MESA's capabilities through 2040. In addition, plans are being developed for sourcing and manufacturing these microelectronics well past 2040.

Aging equipment poses reliability and obsolescence issues, resulting in greater risk to continuity of operations. DOE/NNSA is pursuing efforts to better understand current and future equipment needs across the nuclear security enterprise for all aspects of the nuclear weapons mission, including non-nuclear production, through the Programmatic Recapitalization Working Group. This working group is a combination of participants from the Office of Defense Programs and the Office of Safety, Infrastructure, and Operations, as well full participation from each of the DOE/NNSA sites.

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

3.4.1.2 Challenges and Strategies

Table 3–9 provides a high-level summary of Non-Nuclear Component Production challenges and the strategies to address them.

Table 3–9. Summary of Non-Nuclear Component Production challenges and strategies

Challenges	*Strategies*
Sustaining unreliable, obsolete equipment and inadequately sized and aging facilities, which poses risks to manufacture of non-nuclear components.	Plan and execute major investments in facilities, infrastructure, and equipment for key production sites. Optimize Capabilities-Based Investments funding to provide interim relief for some of the critical equipment needs related to these key product lines.
Meeting increased weapon program requirements on schedule with current production capacity limitations across all production sites.	Established the new Non-Nuclear Components program office with renewed focus on the design, development, and manufacturing of these critical components and funding the associated modernization of equipment and facilities to improve production yields and capacity, including necessary long-term modernization needs at Pantex. Develop options for additional space or more efficient use of existing space. KCNSC is pursuing an interim solution to lease additional manufacturing space and is considering long-term solutions for manufacturing needs. DOE/NNSA is conducting an AoA for Power Sources. Gather and use industrial best management practices for application across key component production areas.
Developing domestic external supplier options to supplement internal production capacities to meet mission requirements and balance R&D needs with production.	Evaluate and develop new suppliers and implement new, more-efficient supplier qualification practices. Use baseline capabilities at nuclear security enterprise sites to quickly fulfill unexpected needs and expand surge capability.

AoA = analysis of alternatives

3.4.2 Weapon Component and Material Process Development

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

Weapon Component and Material Process Development capabilities must include the ability to rapidly develop and mature manufacturing processes and technologies. Advanced manufacturing technologies and digital-based processes are needed to reduce cost and support mission success. Historically, the maturation of these processes and technologies has been conducted 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 develops innovative manufacturing processes, technologies, and materials that are necessary to address obsolescence due to sunset availability, regulatory safety or security requirements, and to reduce schedule and cost risks.

3.4.2.1 Status of Weapon Component and Material Process Development

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

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

Advances in the Weapon Component and Material Process Development capability are currently constrained by aging infrastructure and associated reliability risks. Aging manufacturing equipment is leading to increased downtime and reduced product yield. At the same time, sustaining or restarting legacy processes is affected by equipment and material obsolescence. DOE/NNSA must also address facility capacity issues due to the increased production demand from multiple concurrent modernization programs. DOE/NNSA is performing AoA studies to seek ways to mitigate any potentially adverse effects to existing and future programs caused by insufficient facility capacity and emerging production needs, as described in Section 3.8.3.

3.4.2.2 Challenges and Strategies

Table 3–10 provides a high-level summary of Weapon Component and Material Process Development challenges and the strategies to address them.

Table 3–10. Summary of Weapon Component and Material Process Development challenges and strategies

Challenges	*Strategies*
Conducting rapid design, production, testing, and qualification of new equipment and technologies to meet modernization needs using inadequate processes, capabilities, and facilities.	Pursue common test capabilities and advanced manufacturing technologies and infrastructure for cost-effective, rapid-prototype iteration, and faster transition from design to production. Increase understanding of properties and performance of additive manufacturing materials and components.
Reducing risks to meeting the mission due to aging infrastructure and legacy processes.	Implement predictive maintenance to determine when failure might occur and to prevent the occurrence of the failure; sustaining facilities and infrastructure, to include strategies for managing substandard facilities that house mission-critical functions or operations.
Increasing responsiveness and innovation with inadequate equipment, facilities, and computational capabilities.	Establish joint projects and milestones between multiple sites, programs, suppliers and agencies for early prototyping and technology development and maturation and encourage collaboration.
Dealing with attrition and attendant loss of experienced critical personnel needed to bring the manufacturing capability up to an appropriate level.	Provide design staff with the flexibility to develop and implement modern concepts by means of advanced manufacturing. Increased efforts in training and improved collation and transfer of knowledge.

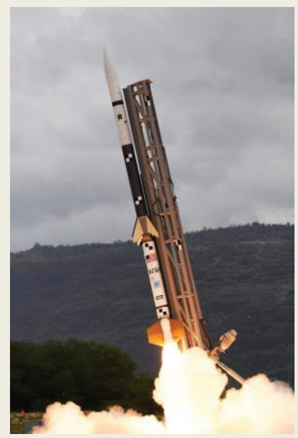
3.4.3 Weapon Component and System Prototyping

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 evidence that a component can function with DoD delivery systems in realistic environments. Identifying, developing, and sustaining process expertise and prototyping is crucial to scientific understanding, production agility, responsiveness, and efficiency in the ever-changing threat environment.

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

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

- Developing technology insertion options to prepare the nuclear stockpile for changing global security environments, such as design of advanced hardware for nuclear explosive packages, energetics, microelectronics/microprocessors, mechanisms, GTSs, initiation systems, and neutron generators
- Partnering with DoD's Science and Technology community to mature and demonstrate integrated system architectures to accelerate innovation and reduce risks in the nuclear weapons development life cycle



High Operational Tempo Sounding Rocket Flight Test (HOT SHOT) Launch

The first HOT SHOT from the Kauai Test Facility in Hawaii in May 2018 supported seven experiments on component technologies, additive manufacturing processes, model validation, and data communications. The HOT SHOT program provides an agile, risk-tolerant technology maturation platform to deepen scientific understanding by testing in relevant environments at a lower cost than operational system flight tests.

3.4.3.1 Status of Weapon Component and System Prototyping

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

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

3.4.3.2 Challenges and Strategies

Table 3–11 provides a high-level summary of Weapon Component and System Prototyping challenges and the strategies to address them.

Table 3–11. Summary of Weapon Component and System Prototyping challenges and strategies

Challenges	*Strategies*
Improving rapid learning cycles to support evaluation of emerging capabilities and reduce risks associated with insertion into future systems.	Employ a high-tempo flight test capability to influence innovative design practices for new technologies to gain the necessary flight pedigree to mitigate risk in a systems context.
Using inadequate processes and capabilities for fast design, production, testing, and qualification of new equipment and technologies to meet modernization needs.	Pursue common test methodologies, advanced manufacturing technologies, and infrastructure that together support cost-effective, rapid-prototype iteration; faster transition from design to production; and understanding and assuring the properties and performance of additive manufacturing materials and components.
Conducting prototyping activities with inadequate investments in equipment, facilities, and computational capabilities.	Establish joint projects and milestones among multiple sites, suppliers, programs, and agencies for support of early prototyping and technology development and maturation. This approach will facilitate a collaborative scope, joint priorities, integrated systems, and leveraging of resources. Continue development of commercial vendors for component piece-parts for responsive testing and evaluation.
Dealing with loss of experienced, critical personnel.	Increase efforts to provide additional training and improve the collation and transfer of knowledge to mitigate the consequences of attrition.

3.4.4 Advanced Manufacturing

The Advanced Manufacturing capability uses innovative techniques from industry, academia, or enterprise-wide R&D to reduce costs, reduce component development and production time, improve safety and performance, and control waste streams. Examples include additive manufacturing, use of micro-reactors, augmented reality, microwave casting, and electrorefining.

This capability provides the nuclear security enterprise the ability to respond to emerging issues with the current stockpile and adapt new processes for follow-on use to gain production efficiencies. The stockpile of the future depends on innovation, agility, and responsiveness in advanced manufacturing in order to reduce defects, increase yields, and develop new and improved production techniques for future weapons requirements.

3.4.4.1 Status of Advanced Manufacturing

All advanced manufacturing technologies require rigorous scientific testing and development to ensure the components produced can meet requirements and perform throughout the entire life cycle of the weapon systems. To implement this, DOE/NNSA created a long-term Advanced Manufacturing Strategic Program Plan linked to 2018 *Nuclear Posture Review* objectives, the Nuclear Weapons Council strategic guidance, and the Technology Development Strategic Plan.

The themes of this plan are laid out in **Figure 3–3** and cover additive manufacturing, automation, intelligent production systems, and manufacturing processes to reduce production time, waste, and floor space requirements. Efforts across these themes will directly affect the agility and responsiveness of DOE/NNSA's manufacturing infrastructure and will continue to develop the required manufacturing capabilities prior to the development engineering phase of a future weapon program, producing confidence in the schedules and cost estimates for those programs.

Figure 3–3. DOE/NNSA will pursue advanced manufacturing areas for investments across capabilities that support a robust and resilient manufacturing capability

Emerging advanced technology solutions will include an evolving, digital-based enterprise that will use a common set of trusted models throughout the entire product life cycle. Benefits include elimination of waste and errors, ability to simulate and predict outcomes for critical manufacturing processes, more rapid incorporation and propagation of requirements changes, and enhanced producibility, agility, and responsiveness.

The DOE/NNSA sites are working collectively to rapidly advance additive manufacturing technology for nuclear deterrence applications. DOE/NNSA has established a multi-site Additive Manufacturing Coordinating Team to coordinate activities across the enterprise. Additive manufacturing is an emerging technology that requires additional work to apply and qualify additive manufacturing for weapon applications.

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.

3.4.4.2 Challenges and Strategies

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

Table 3–12. Summary of Advanced Manufacturing challenges and strategies

Challenges	*Strategies*
Improving responsiveness to assess and qualify new manufacturing technologies for the stockpile.	Continue investments in process and materials R&D, equipment, and infrastructure and partner with domestic industrial manufacturing to improve collaboration with national security laboratories and nuclear weapons production sites. Implement a "design for manufacture" philosophy to accelerate the qualification process. Include qualification planning as part of requirements mapping for technology insertion.
Achieving faster development of advanced manufacturing expertise, equipment, technologies, and processes for component certification and qualification.	Advance the manufacturing development activities at all sites.
Pursuing more integrated systems across the nuclear security enterprise to reduce costs and improve design and technology development in the lead-up to production.	Implementation of common, connected platforms for efficient design development and definition, effective technology and process maturation, common digital model and component libraries, and multi-site integrated scheduling.

3.5 Weapon Simulation and Computing Portfolio

The Weapon Simulation and Computing portfolio 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. The Weapon Simulation and Computing portfolio is closely coupled with the Weapon Design and Integration portfolio (Section 3.6) and Weapon Science and Engineering portfolio (Section 3.7) in an iterative fashion, such that capabilities in all three portfolios are routinely supporting efforts in the other two.

***Sierra,** DOE/NNSA's latest high performance computing system, provides computational resources that are essential for nuclear weapon scientists to fulfill the stockpile stewardship mission through simulation in lieu of underground testing. DOE/NNSA scientists and engineers use the integrated codes on Sierra to assess the performance of nuclear weapon systems and carry out the advanced nuclear weapon science and engineering calculations needed to understand key issues of weapon physics. In turn, this knowledge in turn informs the integrated codes used for weapon component design.*

Partnership between High Performance Computing and Simulation Codes

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

Advanced computer codes, models, and data analytics used to simulate and assess the behavior of nuclear weapons and their components form another important part of the Weapon Simulation and Computing portfolio. Codes range in application from design of systems to fundamental scientific processes. DOE/NNSA codes operate on computers ranging from desktop machines to the world's largest supercomputers. Simulation codes and models must accurately reflect and predict the physical phenomena and behaviors of nuclear weapon functionality, ranging from atomistic nuclear processes to integrated nuclear performance. These codes must be sufficiently flexible and adaptable to run on a variety of the latest HPC platforms.

Application to the Stockpile

Together, HPC and simulation codes are important to enabling weapons designers to sustain and certify the stockpile in the absence of underground nuclear tests. These capabilities support accelerated nuclear weapons design, manufacturing process development, and prediction of weapon response to hostile environments. Simulation and HPC play a central role in assessing both the performance and safety of the nuclear explosive package and the reliability of the full warhead system in the stockpile-to-target sequence (STS) environments.

These capabilities underpin DOE/NNSA's ability to resolve challenging stockpile problems using codes that take advantage of increased spatial and temporal resolution, higher dimensionality, and higher-fidelity physical models. Code improvements lead to more predictive simulations that are less reliant on empirical calibration to experimental data. These capabilities are essential to address issues associated with an aging stockpile and modernize the stockpile with new materials in different configurations without a strong underground test history. 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.

3.5.1 Status of Weapon Simulation and Computing Portfolio

This portfolio has three major interdependent components (**Figure 3–4**) that must evolve together to support Weapons Activities and other DOE/NNSA missions (codes, computing platforms, and facilities). Each component depends on versatile, highly qualified and skilled staff for vital work on and with the capabilities in this portfolio. Evolution of these components must be managed in an integrated and consistent manner, while balancing program efforts to continuously support current missions and be prepared for future requirements.

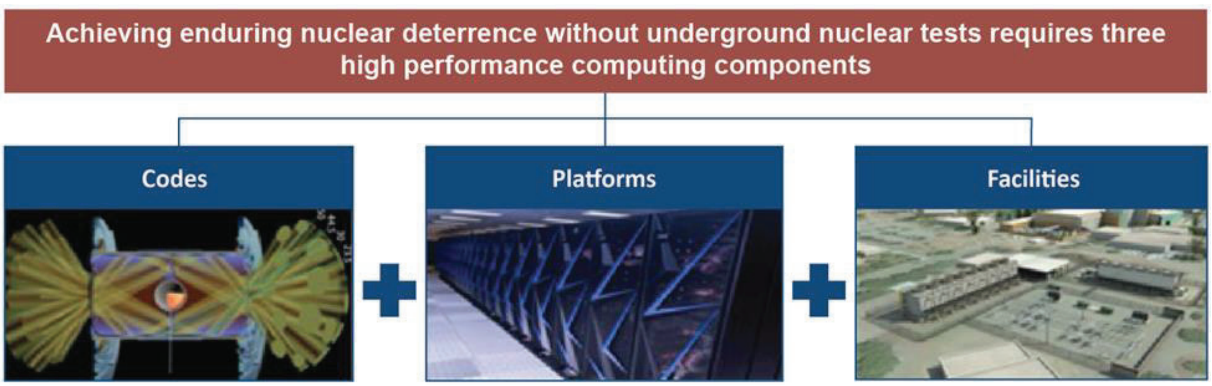


Figure 3–4. Interdependent components of the Weapon Modeling and Simulation portfolio

Simulation codes include integrated design codes (IDCs) that perform large-scale, multi-physics simulations in direct support of the assessment mission, and weapons science codes that model specific phenomena in more detail and inform the models in the IDCs where experiments are lacking. Improved physical models are needed to address response to hostile environments and analyses of manufacturing, production, and disassembly processes to reduce cost and waste. Newer generations of IDCs and supporting codes are being designed to respond to evolving requirements. Future rewrites to accommodate new technologies will be expedited through careful modular design and adaptable programming models.

Just as the science codes support the IDCs, both types of codes are supported by experimental activities designed through close cooperation between the simulation and experimental communities. Simulations, especially those resolving 3D features, currently require an extended time to complete on petascale machines. As the simulation detail increases into the mesoscale, exascale-class computing will be required to resolve these simulations in a responsive timeframe to support experimental needs (see Appendix B for detailed information on the Exascale Computing Initiative).

HPC platforms are evolving in response to the computer industry's movement toward increasing computing cores on each node or with different processor and accelerator technologies in a system. As recently as 2015, IDCs used homogeneous systems with a moderate number of cores. At the time, NNSA recognized that these IDCs would run with degraded efficiency on emerging heterogeneous HPC platforms. In response, DOE/NNSA initiated development of a new generation of IDCs, requiring new capabilities in numerical methods, software design, and programming models to optimize the use of these emerging HPC technologies. This work continues in preparation for NNSA's first exascale system, El Capitan, to be deployed at LLNL in FY 2023. DOE/NNSA continues to collaborate with the U.S. HPC technology sector to manage the effect of technological disruptions while delivering productive advances in computing for inherent missions.

DOE/NNSA has a clearly defined strategy of upgrading HPC platforms at regular intervals to meet mission need. Evolution of these platforms also creates increased demand on supporting infrastructure. Power, cooling, and mechanical requirements have grown dramatically and are being addressed through minor construction projects and construction line items. The Exascale Computing Facility Modernization (ECFM) project is an example of a construction line item that will upgrade the LLNL computing facility with increased power and cooling capability in preparation of the El Capitan system. The nuclear security enterprise will continue to manage and coordinate code development and facility upgrades with system acquisitions to assure the use of HPC platforms for DOE/NNSA as the technology progresses into the exascale era.

An integrated approach is also key to incorporating advanced technology innovations to support the future mission. Artificial intelligence technologies, for example, have the potential to transform all aspects of this portfolio through coordinated evolutions of both codes and platforms. Quantum computing, which is even more forward-looking, could have a similar effect but will require more focused attention from DOE/NNSA to explore the potential benefits these new technologies could provide to the weapons missions.

3.5.2 Challenges and Strategies

Table 3–13 provides a high-level summary of Weapon Simulation and Computing portfolio challenges and the strategies to address them.

Table 3–13. Summary of Weapon Simulation and Computing portfolio challenges and strategies

Challenges	*Strategies*
Improving the rate at which new modeling and simulation capabilities are provided to the Stockpile Major Modernization and Stockpile Sustainment programs	Develop and implement a broader range of tools to support rapid design, evaluation, and qualification of new materials for a range of mission applications while keeping costs manageable.
Enhancing the ability to simulate the effects of weapons effects, aging, and manufacturing changes.	Develop the needed models and databases in conjunction with experiments to improve the performance, reliability, and safety of weapons. Adapt weapon science codes to the most advanced computing architectures to reach time and spatial scales of greatest interest. Run IDCs and supporting codes on more powerful platforms for quicker time-to-solution for applications of the above simulation enhancements.
Performing rapid evaluations of new materials and modeling additive manufacturing techniques requires advanced simulations.	Continue current efforts to model additive manufacturing processes and couple these more closely with molecular dynamics and mesoscale modeling to enhance the utility of these models. Develop machine learning techniques that can use these effects efficiently for routine use in part scale simulations.
Working with less effective IDCs that are not effectively using advances which have emerged in commercial HPC architectures.	Short-term: Optimize current codes for advanced technology hardware. Longer-term: Evolve HPC tools for a next generation of IDCs to achieve new levels of capability through sophisticated programming models, software designs, and numerical algorithms. This will produce a more responsive simulation capability that is able to respond more rapidly to new challenges and more efficiently search for possible solutions.

Challenges	*Strategies*
Supporting exascale platforms with inadequately structured and sized facilities and supporting infrastructure (space, power, and cooling).	Continue to execute the Advanced Simulation and Computing Platform Strategy. Continually survey HPC vendors' facility requirements, identify gaps, and proceed with modernization or new infrastructure solutions to meet demands of HPC solutions. Aggressively pursue power and cooling efficiencies while building on recent programmatic planning and execution successes to deliver large-scale power and cooling infrastructure.

HPC = high performance computing
IDC = integrated design codes

3.6 Weapon Design and Integration Portfolio

The Weapon Design and Integration portfolio 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. The Weapons Design and Integration portfolio is closely coupled with the Weapons Science and Engineering and Weapons Modeling and Simulation portfolios in an iterative fashion, such that capabilities in all three portfolios are routinely supporting efforts in the other two.

3.6.1 Weapons Physics Design and Analysis

Design and analysis of the nuclear explosive package is required to assess U.S. nuclear weapons, qualify and certify changes to the stockpile (such as with life extensions and modernization), evaluate proliferant nuclear weapon programs, and respond to emerging threats, unanticipated events, and technological innovation. This capability includes concept exploration, conceptual design, requirements satisfaction, detailed design and development, production process development, certification, and qualification. It also encompasses evaluation of weapon effects.

Weapons Physics Design and Analysis efforts are predicated on codes developed through the Weapon Modeling and Simulation portfolio, as well as the nuclear data and material properties that underpin simulation tools. These tools also require data and knowledge acquired through hydrodynamic, subcritical, and high energy density (HED) experimental facilities, as well as legacy data from nuclear explosive testing, to validate and improve the models. Advances in diagnostics and experimental capabilities are required to obtain data of suitably high fidelity. All of these related capabilities underpin and are critical for the Weapons Physics Design and Analysis capability.

3.6.1.1 Status of Weapons Physics Design and Analysis

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

Requirements for DOE/NNSA's current systems will evolve in the future due to component aging or remanufacture, the changing threat environment, or the need to transition to alternate materials and technologies. In these future scenarios, Weapons Physics Design and Analysis tools will require expanded predictive capabilities to assess and certify system performance that was never demonstrated through nuclear explosive testing. The planned warhead modernization requirements over the next decade also have expanded. The ability to provide timely analysis to support warhead development timelines is critical.

DOE/NNSA must develop new, highly capable methods for certifying designs beyond the nuclear explosive test history, and the national security laboratories are developing potential non-nuclear experimental capabilities and evaluation metrics that can quantify performance without an underground nuclear test.

3.6.1.2 Challenges and Strategies

Table 3–14 provides a high-level summary of Weapons Physics Design and Analysis challenges and the strategies to address them.

Table 3–14. Summary of Weapons Physics Design and Analysis challenges and strategies

Challenges	*Strategies*
Developing and exercising design (rather than assessment) skills in physics, engineering, chemistry, and materials science personnel.	Short-term: Implement activities called out under Stockpile Responsiveness in the 2016 *National Defense Authorization Act*, Certification Readiness Exercises, design practicums, and other design studies. Longer-term: Enhance design experience through the 2018 *Nuclear Posture Review*-tasked design studies and Stockpile Responsiveness exercises, as well as warhead modernization.
Developing and exercising certification methodologies using recently-developed physics performance metrics on device designs for which there is no underground test data.	Short-term: Develop metrics and the methodologies for applying them. Longer-term: 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.	Short-term: Rely on current simulation capabilities (validated by aboveground experiments and non-nuclear testing) to model reuse design options. Longer-term: Develop certification methodologies for reuse and replacement designs. Close the capability gap regarding evaluation of plutonium response in integrated weapons experiments as part of the Enhanced Capabilities for Subcritical Experiments program.
Mitigating emerging adversary threats to deterrence.	Short-term: Rely on current simulation capabilities (validated by experiments). Longer-term: Develop design skills to take advantage of advanced manufacturing and testing capabilities.
Applying machine learning to weapon physics design problems for current system confidence, future system certification, and increased responsiveness.	Short-term: Develop capabilities to shorten the design loop through workflow enhancement and development of surrogate models for faster parameter space exploration. Long-term: Use machine learning as an accelerant capability for data interpretation, simulation results implementation, certification, design, evaluating discrepancies, detecting anomalies, and enhancing current solutions.

HED = high energy density

3.6.2 Weapons Engineering Design, Analysis, and Integration

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

This capability affects several phases of the weapons life cycle, including concept exploration, design, development, and production. It also encompasses systems integration, which includes working with DoD to define the functional, physical, performance and interface requirements between the DOE/NNSA and

DoD systems. DOE/NNSA uses that understanding to develop the subsystem-level requirements among the non-nuclear subsystems and the requirements between the non-nuclear components and the nuclear explosives package.

3.6.2.1 Status of Weapons Engineering Design, Analysis, and Integration

While much of the Weapons Engineering Design, Analysis, and Integration capability is being exercised by multiple concurrent LEPs, Alts, and stockpile sustainment, some elements are not being adequately exercised. Because recent modernization activities have been focused on extending the life of current stockpile weapons, there also has been a decline in capacity to develop warhead concepts to address military requirements that differ from those addressed by current stockpile systems. These gaps will be closed through activities supporting the Stockpile Responsiveness Program (50 U.S.C. 2538b) by exercising the technical capabilities required for all stages of the design, testing, and production of nuclear weapons, as well as working in concert with DoD to recruit, train, and retain the next generation of weapon designers and engineers.

DOE/NNSA is addressing challenges within digital engineering through Headquarters and site-level initiatives to (1) define where specific digital transformation opportunities provide value over time and (2) determine where and how changes should be made in policy and business processes for the use of digital product definition and associated data. Any transformation will require investment decisions in software and information technology (IT) infrastructure.

3.6.2.2 Challenges and Strategies

Table 3–15 provides a high-level summary of Weapons Engineering Design, Analysis, and Integration challenges and the strategies to address them.

Table 3–15. Summary of Weapons Engineering Design, Analysis, and Integration challenges and strategies

Challenges	*Strategies*
Responding in a timely manner to emerging threats under current lengthy weapon development cycles.	Seek ways to accelerate the development cycle, respond more quickly to emerging threats, and invest in technology development and process improvements to increase the speed at which weapon systems are updated and recertified.
Certifying and qualifying required new processes or materials needed for weapon design, engineering, and production, especially as weapons design moves further away from the underground tested design.	Engage the Material Science and Engineering capability early in the design process to inform process development and material choices. Perform system trade analyses to develop new materials that can support warhead modernization programs. Seek earlier collaboration with nuclear weapons production facilities in the design process.
Enabling digital engineering capabilities to reduce material and labor waste.	Develop a high-level understanding of digital engineering challenges within the nuclear security enterprise and pilot potential solutions through focused efforts (e.g., Production Operations and Product Realization Integrated Digital Enterprise) and using potential warhead modernization challenges as opportunities. Once acceptable solutions are identified, develop information technology infrastructure investment requirements and implement policy and process changes to allow the official use of digital product definition.
Ensuring a responsive and resilient nuclear security enterprise using aging, Cold War-era facilities that need to be refurbished and/or replaced.	Pursue facility recapitalization, including laboratory space and equipment replacements, through a carefully planned, prioritized, and executed investment program.

3.6.3 Environmental Effects Analysis, Testing, and Engineering Sciences

The Environmental Effects Analysis, Testing, and Engineering Sciences capability uses an array of test equipment, tools, and techniques to simulate STS environments and measure the 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, hydrodynamics, radiation transport and disposition, and electromagnetics. This capability influences the design and qualification of planned and future weapon programs, as well as surveillance activities supporting assessment of the safety, security, and reliability of the stockpile.

3.6.3.1 Status of Environmental Effects Analysis, Testing, and Engineering Sciences

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

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

3.6.3.2 Challenges and Strategies

Table 3–16 provides a high-level summary of Environmental Effects Analysis, Testing, and Engineering Sciences challenges and the strategies to address them.

Table 3–16. Summary of Environmental Effects Analysis, Testing, and Engineering Sciences challenges and strategies

Challenges	*Strategies*
Conducting higher-tempo testing in aging facilities, equipment, and structures that support this capability across the DOE/NNSA nuclear security enterprise. Higher risk of single-point failures due to breakdown of programmatic equipment.	Develop a plan for systematic maintenance, replacement, and recapitalization of programmatic capital equipment and test facilities to reduce the risk of the unavailability of test capabilities that could delay qualification and physics experiments.
Acquiring the capability to experiments in combined mechanical, thermal, radiation, and electromagnetic radiation environments.	Pursue enhanced combined hostile, normal, and abnormal environment testing capabilities to meet evolving and future mission requirements. Consider building a new reactor facility to address part of the need for a combined environment capability. Complete the CREST line-item construction project.

3.6.4 Weapons Surety Design, Testing, Analysis, and Manufacturing

The Weapons Surety Design, Testing, Analysis, and Manufacturing capability includes development, analysis, integration, and manufacture of safety and use control systems to prevent accidental nuclear detonation and unauthorized use of nuclear weapons, all of which are necessary for a safe and secure stockpile. All aspects of this capability require elevated classification control, as well as secure facilities and equipment for surety feature design and manufacturing. National requirements from Presidential Directives have been implemented through DOE Orders, and new performance-based use control requirements were introduced by the Deputy Administrator for Defense Programs to further establish high surety standards for the stockpile.

DOE/NNSA performs assessments that integrate both weapon and venue security and control capabilities to understand the best allocation of resources to meet evolving threats. This includes partnerships across DOE/NNSA and the Government with stockpile and modernization programs, nuclear counterterrorism and incident response personnel, and other national assets. The Integrated Security Architecture Program is one example program that incorporates surety technology to meet transportation and shipping requirements.

3.6.4.1 Status of Weapons Surety Design, Testing, Analysis, and Manufacturing

A variety of surety technologies and approaches have been or are currently under development to improve the safety and security of nuclear weapons. Technologies that improve safety and security have recently been applied to stockpiled weapons.

3.6.4.2 Challenges and Strategies

Table 3–17 provides a high-level summary of Weapons Surety Design, Testing, Analysis, and Manufacturing challenges and the strategies to address them.

Table 3–17. Summary of Weapons Surety Design, Testing, Analysis, and Manufacturing challenges and strategies

Challenges	*Strategies*
Sustaining technology maturation activities of advanced surety technology development.	Use planned investments in this capability to support the ST&E base needed for maturing advanced technologies to increase weapons surety and reduce the risk associated with insertion of advanced technologies into system LEPs, Mods, and Alts.
Continuously creating and evolving highly advanced surety technologies that are independent of specific weapon types or insertion opportunities and can result in major surety improvements.	Establish a balanced program for weapon surety within DOE/NNSA for creating and evolving highly advanced, cost-effective surety technologies that are independent of specific weapon types and minimize effects to warhead performance, safety, and reliability.

ST&E = science, technology, and engineering

3.6.5 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 ranging from radiation within the weapon to cosmic rays and hostile sources external to the weapon.

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

DOE/NNSA has developed a Microelectronics Capability Development Roadmap that was informed by DOE/NNSA's continued coordination with the Department of Defense. DOE/NNSA is engaged with the Strategic Radiation Hardened Electronics Council (SRHEC), including multiple SHREC working groups such as the Test and Evaluation, Recruitment and Retention, and Advanced Packaging working groups and is the co-lead for the Science and Technology Needs working group.

3.6.5.1 Status of Radiation-Hardened Microelectronics Design and Manufacturing

The MESA complex is the enduring lead institution for trusted, strategic radiation-hardened microelectronics. DOE/NNSA is committed to sustaining this capability through 2040 via implementation of the Microsystems Extended Life Program, which includes equipment upgrades to maintain and advance capabilities for all active weapons systems, to include the W87-1 Modification program. 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 post-2040 capability sustainment.

3.6.5.2 Challenges and Strategies

Table 3–18 summarizes the Radiation-Hardened Microelectronics Design and Manufacturing challenges and the strategies to address them.

Table 3–18. Summary of Radiation-Hardened Microelectronics Design and Manufacturing challenges and strategies

Challenges	*Strategies*
Balancing LEP, Alt, and Mod production requirements with development and maturation of new engineering- and science-based microelectronics capabilities.	Implement the NNSA Microelectronics Capability Development Roadmap, which outlines an agreed-upon 20-year prioritization of R&D to be matured in parallel with production.
Sustaining microelectronics capabilities' aging infrastructure and equipment through upgrades and replacements to sustain the existing capability until 2040.	Incorporate the results of an independent risk assessment, as well as an internal evaluation of tools and equipment, into the MESA Extended Life Program – a detailed review of maintenance required to sustain the status quo R&D and production capability through 2040 (completed).
Finding and maintaining trusted U.S. suppliers for radiation-hardened microelectronics that meet national security requirements.	Evaluate future options for procuring or producing microelectronics that take this difficulty into account.

3.7 Weapon Science and Engineering Portfolio

The Weapon Science and Engineering portfolio includes the suite of physical sciences and engineering disciplines that comprise the theoretical and experimental capabilities necessary to assess the current nuclear stockpile and certify future stockpile weapons. This portfolio of capabilities is closely coupled with the Weapon Simulation and Computing portfolio (Section 3.5) and the Weapon Design and Integration portfolio (Section 3.6) in an iterative fashion, such that capabilities in all three portfolios are routinely supporting efforts in the other two. All three portfolios of capabilities are needed to achieve stockpile mission priorities.

3.7.1 Nuclear Physics and Engineering

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 such as fission and fusion.

Measuring nuclear properties relevant to weapons is critical to enhancing predictive capability and designing validation experiments that enhance and provide confidence in simulation models. Obtaining new measurements and evaluations of nuclear data on weapon properties can reduce uncertainties in predictive simulations and to improve reassessments of historic diagnostic data to validate and constrain the simulations. Reducing uncertainty is critical to the certification and assessment processes as weapons age.

3.7.1.1 Status of Nuclear Physics and Engineering

Over the past decade, nuclear physics experiments for stockpile stewardship have increased in precision and complexity. New detector systems that use new materials are enabling unprecedented data precision. Coupling nuclear theory to experiments is also opening up new predictive methods to determine nuclear properties for radioactive materials and other properties that are difficult to measure.

Nuclear data evaluation is an established methodology that requires high-quality measurements coupled with computer codes to improve predictive simulations. Evaluators reconcile newly acquired measurements with existing data and physics models to determine “best value” quantities. Presently, the United States has a shortage of well-trained evaluators, resulting in a substantial backlog of work. Significant investment in training new evaluators is essential to support the nuclear data pipeline in the long term.

3.7.1.2 Challenges and Strategies

Table 3–19 provides a high-level summary of Nuclear Physics and Engineering challenges and the strategies to address them.

Table 3–19. Summary of Nuclear Physics and Engineering challenges and strategies

Challenges	*Strategies*
Maintaining a highly competent workforce in the face of a diminishing supply of U.S. trained nuclear theorists and evaluators.	Implement Weapons Activities programs that develop workforce skills, knowledge, and abilities, and implement strategic alliances and fellowship programs in critical skills areas.
Conducting experiments in aging experimental facilities, resulting in increasingly unreliable operations.	Reduce deferred maintenance and develop conceptual plans for future experimental facilities.
Maintaining reliable operations in facilities where capital equipment is becoming difficult to repair or replace due to obsolescence.	Prioritize strategic investments in key equipment.
Mitigating the negative consequences of merging computer architectures on theory, process, and transport software.	Maintain close coupling with simulation, codes, and HPC capabilities to build on investments and efforts in code migration to advanced architectures.

HPC = high performance computing

3.7.2 Radiochemistry

Radiochemistry is the study of radioactive materials and their interactions and is the basis of DOE/NNSA’s modern connection to legacy underground nuclear test data. Radiochemical data from the United States’ extensive underground nuclear test history database are used to inform modern-day assessments of weapon performance as part of stockpile stewardship. Explosion debris from past tests is analyzed for reaction products, and the results are used to benchmark models of events. These data are directly integrated into the computer simulations used by the design community; the simulations are modified if disagreement is noted between calculated and measured radiochemical reaction products. Radiochemistry is also an important element of the diagnostic capabilities used by HED experiments. DOE/NNSA is the nuclear forensics[7] lead for the U.S. Government and employs radiochemistry tools to address national security problems.

3.7.2.1 Status of Radiochemistry

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

Many personnel in this specialized field have retired, resulting in knowledge gaps about historical methods. Qualified radiochemists must have both 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.

3.7.2.2 Challenges and Strategies

Table 3–20 provides a high-level summary of Radiochemistry challenges and the strategies to address them.

Table 3–20. Summary of Radiochemistry challenges and strategies

Challenges	*Strategies*
Adequately preserving and cataloguing radiochemical data from historical nuclear tests to improve access; creating adequately searchable databases that are easily accessible across weapon laboratories.	Scan and catalogue all data and improve function and access of data management systems.
Meeting the high demand for work in aging radiochemical facilities.	Perform incremental initial infrastructure improvements. Revitalize radiochemistry facilities and equipment.
Finding and training enough radiochemists with direct nuclear test experience.	Conduct workshops and other similar mechanisms to facilitate knowledge transfer and close gaps caused by the absence of ongoing underground nuclear tests. Address the specialized knowledge and experimental skill sets required for the modern workforce through focused training programs.

3.7.3 Atomic and Plasma Physics

Atomic physics is the study of interactions among positively charged atomic nuclei, the surrounding negatively charged electrons, and photons, particularly X-rays. Plasma physics is the study of systems containing separate ions and electrons that can exhibit collective behavior. Plasmas (highly charged ions with complex electronic structure) and X-rays are generated at the extremely high temperatures of functioning nuclear weapons and on flagship experimental facilities such as the National Ignition Facility, Z pulsed power facility (Z), and Omega Laser Facility.

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

3.7.3.1 Status of Atomic and Plasma Physics

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

The workforce of scientists with training in atomic and plasma physics has become stronger over the last decade. A concern for future workforce development and growth is that only a small number of university programs offer directly relevant training.

3.7.3.2 Challenges and Strategies

Table 3–21 provides a high-level summary of Atomic and Plasma Physics challenges and the strategies to address them.

Table 3–21. Summary of Atomic and Plasma Physics challenges and strategies

Challenges	*Strategies*
Addressing uncertainty in the behavior of matter in warm and hot regimes, as well as high-magnetic field regimes to enhance certainty in simulated outputs.	Conduct fundamental theoretical and experimental research at universities and national laboratories to reduce uncertainties.
Generating sufficient benchmark data for verification of certain phenomena to increase certainty in simulated outputs.	Develop and maintain 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).
Addressing inconsistency among tabulated data for certain properties of materials of interest to increase certainty in simulated outputs.	Extend state-of-the art complex models to produce complete data sets and increase model accuracy.
Increasing availability of computational capacity and capability to run complex radiation models.	Develop new computational tools and exploit new computing architectures, leveraging simulation, codes, and HPC capabilities.
Increasing numbers of atomic and plasma physicists trained to work beyond academia and basic research.	Provide opportunities specific to atomic and plasma physics for graduate students; build and maintain academic alliances with materials science, plasma physics, and astrophysics departments.

HPC = high performance computing

3.7.4 High Energy Density Physics

High Energy Density Physics includes the study of matter and radiation under extreme conditions (e.g., the conditions produced in a functioning nuclear weapon). HED experiments provide data required to validate weapon designs and physics models and help evaluate the survivability of weapons in hostile environments. Both focused and integrated HED experiments provide the proficiency needed to support warhead certification for legacy and new weapon systems.

HED experiments also support the development of HED physicists and promote the development of skills in experimentation, design work, fabrication, instrumentation, and other related areas.

3.7.4.1 Status of High Energy Density Physics

Across all three major HED facilities, the experimental platforms have produced data relevant to the performance of nuclear weapons. DOE/NNSA has made advances in determining plutonium properties at relevant pressures and addressing key questions on aging and remanufacturing using this material. These advances provide immediate mission support in predictive nuclear weapon performance and survivability assessments, and are crucial to advancing simulation capabilities in energy densities of interest.

One challenge facing the HED Physics capability is achieving a robust burning plasma, which would demonstrate continued progress in shrinking the gap between experimental radiation and weapons environments. DOE/NNSA has also set incremental goals toward achieving a burning plasma state[8] at the National Ignition Facility. The understanding developed through each stage of experimental performance provides key knowledge and constraining data input for simulations, as well as access to material properties and outputs unachievable anywhere else in the world. A focused effort on the understanding and scaling of all the major inertial confinement fusion (ICF) platforms will establish a foundation for next-step decisions on investments and program balance needed to realize the long-term goals of the ICF program.

3.7.4.2 Challenges and Strategies

Table 3–22 provides a high-level summary of High Energy Density Physics challenges and the strategies to address them.

Table 3–22. Summary of High Energy Density Physics challenges and strategies

Challenges	*Strategies*
Maintaining world-class experimental capabilities in support of high operational tempos as facilities age.	Perform long-term capital planning for facility upgrades and replacements. Form a National Diagnostics group to plan and develop transformational, high-fidelity diagnostics. Develop advanced experimental platforms and predictive capabilities to acquire needed high-fidelity HED data coupled to simulations.
Using HED experimental data to better understand evolving hostile environments and survivability.	Develop relevant X-ray, neutron, and gamma sources on NNSA's HED facilities and use these sources to test relevant materials and components.
Confidently predicting the performance of ICF targets to achieve fusion ignition, followed by developing a high-yield platform.	Implement a program of experiments at the HED facilities to characterize fusion phenomena; then use the results to enhance predictive modeling capabilities. Acquire high-fidelity data and improve physics and modeling fidelity to validate 3D models. Investigate models and codes. Understand the physics and scaling for the balanced development of next-generation capabilities leading to future high-yield platforms.

HED = high energy density
ICF = inertial confinement fusion

3.7.5 Laser and Optical Science, Technology, and Engineering

Lasers deliver intense beams of energy to localized regions. Within the nuclear security enterprise, these laser capabilities are used to generate and probe HED conditions similar to those produced during the detonation of a nuclear weapon. Lasers support studies that affect enhancement of design codes, qualification of new components and systems, and improvement of weapon performance assessments. Experiments on laser facilities directly inform material choices for warhead modernizations and resolve stockpile questions.

Laser-driven devices such as the National Ignition Facility and Omega Laser Facility are complemented by pulsed-power machines, generating unique HED conditions with distinct characteristics. The combination of capabilities from these two approaches to producing HED conditions work together to cover the spectrum of material and physics regimes needed to generate and study the environments produced by nuclear weapons upon detonation.

[8] A burning plasma—in which at least 50 percent of the energy to drive the fusion reaction is generated internally—is an essential step to reach the goal of fusion power generation. (A Strategic Plan for U.S. Burning Plasma Research, National Academies, 201)

3.7.5.1 Status of Laser and Optical Science, Technology, and Engineering

Over the past decade, U.S. laser facilities for HED science have achieved unprecedented levels of performance and efficiency. Maintaining and enhancing this capability as equipment and facilities reach midlife is a challenge. The National Ignition Facility and other flagship facilities were designed approximately 20 years ago, and many subsystems and components are reaching obsolescence and becoming increasingly challenging to maintain. Recapitalization of these facilities and equipment with minimal pause in operations will be necessary to sustain a key role in maintaining a strong deterrent.

3.7.5.2 Challenges and Strategies

Table 3–23 provides a high-level summary of Laser and Optical Science, Technology, and Engineering challenges and the strategies to address them.

Table 3–23. Summary of Laser and Optical Science, Technology, and Engineering challenges and strategies

Challenges	*Strategies*
Maintaining effective experimental operations and mission-required experimental tempos in the face of aging and increasingly obsolete subsystems and components.	Develop and implement comprehensive sustainment plans to refurbish, recapitalize and incorporate modest enhancements to existing facility capabilities.
Losing U.S. preeminence in laser and optical science, which expands the potential for other nations to generate materials in extreme conditions beyond U.S. capabilities.	Implement research plans for domestic development of the next generation of laser technology, including advanced probe and radiography techniques and alternate light sources, to maintain U.S. leadership in this discipline. Develop flexible designs for new facilities geared toward increased mission capabilities.
Generating certain experimental conditions using current facilities to validate weapons codes for the full nuclear weapon life cycle.	Sustain RDT&E efforts to understand experimental performance gaps and implement plans to mitigate identified gaps by extending the capabilities of current facilities.

RDT&E = research, development, test and evaluation

3.7.6 Accelerator and Pulsed Power Science, Technology, and Engineering

Accelerators use high-voltage pulses 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 are used as a radiographic source for dynamic imaging diagnostics.

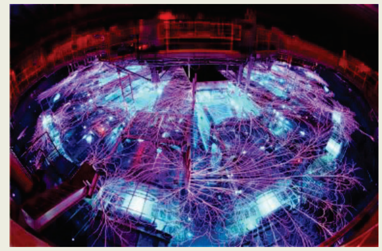
Pulsed power experiments, which complement laser-driven experiments, provide data on HED materials under compression (e.g., densities, temperatures, and radiative properties). Such data are used to study aging of components and materials, performance of weapon–relevant materials under hostile environments, and survivability of components and systems.

DOE/NNSA uses accelerator and pulsed power capabilities to support the stockpile in several ways:

- Generating stockpile-relevant environments to qualify nuclear and non-nuclear materials, components, systems, and hardened electronics in hostile environments
- Providing static and dynamic material information for weapon assemblies and components
- Generating data to explore and implement new options for the stockpile as external threats evolve

3.7.6.1 Status of Accelerator and Pulsed Power Science, Technology, and Engineering

Pulsed power technology is vital for laboratory-scale experiments at several large-scale facilities such as the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility, Los Alamos Neutron Science Center (LANSCE), High-Energy Radiation Megavolt Electron Source (HERMES), Z, and Saturn to generate pressures, temperatures, and radiation that approach levels found in nuclear weapons. Such experiments produce data to qualify weapon components and assess weapon performance, which was formerly only possible via underground nuclear tests. At present, the Nation's accelerator and pulsed power facilities are aging and cannot provide the full range of test capabilities needed to assure the future viability and reliability of the stockpile, including within a combination of the environments that weapons may experience during use. A new, more capable accelerator is being developed for the Enhanced Capabilities for Subcritical Experiments (ECSE) project to deliver images of the final implosion stages of plutonium; that is not currently possible using existing radiography capabilities. Neutron diagnostic capabilities are also being developed for deployment in underground subcritical tests.



Pulsed Power Technology is used to simulate the extreme temperatures and pressures created by the detonation of the nuclear weapon. The Z pulsed power facility is the world's most powerful and efficient laboratory radiation source. It uses high magnetic fields associated with high electrical currents to produce high temperatures, high pressures, and powerful X-rays for research in HED science.

Z is crucial to DOE/NNSA's mission to ensure the reliability and safety of the Nation's nuclear stockpile as it ages. It produces key data used to validate physics models in computer simulations.

3.7.6.2 Challenges and Strategies

Table 3–24 provides a high-level summary of Accelerator and Pulsed Power Science, Technology, and Engineering challenges and the strategies to address them.

Table 3–24. Summary of Accelerator and Pulsed Power Science, Technology, and Engineering challenges and strategies

Challenges	***Strategies***
Generating environments that will validate models and simulation capability across the full nuclear weapon life cycle.	Sustain driver and accelerator technology R&D to extend the capability of existing facilities and design new facilities to produce higher-fidelity, weapons-relevant environments.
Advancing the capability in pulsed power technology to retain the U.S. pre-eminence in HED/ICF science and other related technologies.	Advance the state of the art in fundamental science and technology to determine the feasibility of next-generation demonstration systems that extend the capabilities of current facilities. Develop feasible, practical designs geared to increased outputs and mission capability.
Providing time-evolution data for experiments of interest.	Develop advanced, potentially multiple-pulse technologies that support diagnostic techniques that can probe for data at higher spatial and temporal resolutions.
Increasing the reliability and availability of experimental facilities and equipment.	Modernize facilities and equipment. Increase the resilience and capability of aging facilities. Use technology advancements developed for ECSE in sustaining enduring experimental facilities.
Recruiting and training the next generation of accelerator and pulsed power stewards.	Make DOE/NNSA facilities available to academic partners for use by students and professors; develop small-scale technology demonstration systems as platforms to engage and recruit the next generation of stockpile stewards.

ECSE = Enhanced Capabilities for Subcritical Experiments
ICF = inertial confinement fusion
HED = high energy density

3.7.7 Advanced Experimental Diagnostics and Sensors

The Advanced Experimental Diagnostics and Sensors capability provides detailed measurements of materials, objects, and dynamic processes that are critical to weapon performance, other national security applications, and HED science. For dynamic material experiments, new diagnostics provide data vital to understanding material behavior in the extreme conditions reached in nuclear weapons. In the HED field, advanced diagnostics are necessary to understand scaling of current capabilities to much larger yields.

Diagnostic development activities are linked closely to other enterprise mission needs, and individual diagnostic requirements can vary drastically. Time scales can vary from microseconds to picoseconds and length scales can vary from meters to microns. Different technologies need to be developed to probe this wide range of parameters.

3.7.7.1 Status of Advanced Experimental Diagnostics and Sensors

Working across the accelerator/pulsed power science and HED science capabilities, DOE/NNSA has developed transformative, next-generation diagnostics for flagship radiographic and HED capabilities. To drive down simulation uncertainties, diagnostic measurements and techniques need to be improved to obtain higher spatial resolution, additional time resolution/evolution of the data, and improved sensitivity at higher energies.

Several new diagnostic capabilities now contribute to a better understanding of weapon performance and the dynamic behavior and response of materials and components in relevant weapon environments. Data from experiments that explore the effects of plutonium aging on dynamic material properties are used to improve models to inform lifetime assessments of plutonium.

Recent experiments have been conducted to determine the effects of using additively manufactured components that may be added to future warhead modernization programs. With advanced diagnostic techniques, uncertainties can be decreased when changes to the stockpile are needed.

Higher-fidelity measurements lead to a greater understanding of HED and stockpile science. Experimental diagnostics push the boundary of what is possible and create concepts for future experimental advances. To support this, DOE/NNSA must make investments in three areas:

- Infrastructure to support the continued health of existing capability in advanced diagnostics
- Hiring and training the next generation of diagnostic scientists who will push the frontier of measurement science
- Development of advanced and transformational diagnostics

3.7.7.2 Challenges and Strategies

Table 3–25 provides a high-level summary of Advanced Experimental Diagnostics and Sensors challenges and the strategies to address them.

Table 3–25. Summary of Advanced Experimental Diagnostics and Sensors challenges and strategies

Challenges	Strategies
Driving down simulation uncertainties, developing better diagnostic measurements and techniques, and obtaining higher spatial resolution, additional time resolution/evolution of the data, and improved sensitivity at higher energies.	Provide world-class radiographic and neutron diagnostic systems for ECSE. Deliver world-class diagnostic capabilities, including proton radiography at LANSCE, X-ray diffraction, and advanced temperature diagnostics. 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. Develop and execute an Integrated Plan for experimental diagnostics.

ECSE = Enhanced Capabilities for Subcritical Experiments
LANSCE = Los Alamos Neutron Science Center
ICF = inertial confinement fusion

3.7.8 Hydrodynamic and Subcritical Experiments

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

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

3.7.8.1 Status of Hydrodynamic and Subcritical Experiments

The National Hydrodynamic Testing Complex operates as a user facility; it supports base operations while the sponsors of individual experiments provide experiment-specific support. This complex is aging, and the demand for a higher cadence of experimental data collection required by multiple DOE/NNSA programs stresses both the workforce and the specialized facilities that are operating at near capacity. To meet a greater demand, additional investments are necessary to maintain the equipment, facilities, and people underpinning this capability.

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

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

3.7.8.2 Challenges and Strategies

Table 3–26 provides a high-level summary of Hydrodynamic and Subcritical Experiments challenges and the strategies to address them.

Table 3–26. Summary of Hydrodynamic and Subcritical Experiments challenges and strategies

Challenges	*Strategies*
Enhance the ability to obtain multi-frame penetrating radiographs on hydrodynamic experiments with plutonium pits.	Implement the ECSE program, which is installing a radiographic capability in the U1a Complex to close these capability gaps in the mid-2020s.
Measuring reactivity of subcritical assemblies on the experiments.	Implement neutron diagnosed subcritical experiments in the early to mid-2020s to address this need.
Increasing the physical capacity to generate more experimental data from hydrodynamic and subcritical experiments.	Increase staffing and investments in facility enhancements to provide increased experimental capacity and operational efficiency.
Designing and procuring new confinement vessels at all firing facilities as existing vessels exceed useful life.	Establish an enduring vessel capability and procurement funding strategy with the intention to reestablish a domestic fabrication and manufacturing capability for vessels.
Dealing with increased operational issues due to aging infrastructure at firing sites, as well as at upstream and downstream support facilities.	Invest in baseline capability (facilities, infrastructure, and equipment) to sustain and enhance the hydrodynamic capabilities at firing sites.

ECSE = Enhanced Capabilities for Subcritical Experiments

3.7.9 Chemistry and Chemical Engineering

The Chemistry and Chemical Engineering capability encompasses the study of the fundamental composition, structure, bonding, and reactivity of matter in a given state and under processing conditions. Chemistry and chemical engineering are essential for synthesizing, purifying, processing, and fabricating all of the materials that are currently fielded in stockpile warheads, proposed for near-term warhead modernizations, or to be deployed to meet future system requirements. Chemical knowledge and assessment are key to ensuring quality, performance, and safety of the current stockpile.

Chemistry and Chemical Engineering plays a key role in the design and improvement of manufacturing processes for weapon components, as well as in resolving stockpile production and surveillance issues and developing and qualifying new materials and diagnostics. Chemistry supports materials and compatibility testing to mitigate material aging, while computational chemistry and material science tools help to understand the chemical reactions that control material creation and the mechanisms and effects of aging and degradation.

3.7.9.1 Status of Chemistry and Chemical Engineering

The breadth of the current capability is extensive and presents challenges in maintaining an expert workforce and sustaining modern facilities. Developing a sustainable workforce requires active partnering with academic institutions and onboarding that allows significant training time in specialized areas. Some facilities have received major capital investments; e.g., the Plutonium Facility upgrades, the new Uranium Processing Facility, and renovated radiological space to replace the existing facilities. Future investments are needed for modernized laboratory space to house radiological and general chemical synthesis.

3.7.9.2 Challenges and Strategies

Table 3–27 provides a high-level summary of Chemistry and Chemical Engineering challenges and the strategies to address them.

Table 3–27. Summary of Chemistry and Chemical Engineering challenges and strategies

Challenges	*Strategies*
Predicting chemical compatibility in new systems to reduce the need for expensive core-stack and shelf life units.	Develop validated computational chemistry models that span length and time scales and address reactivity at interfaces.
Eliminating capability gaps in weapons analytical chemistry as DOE/NNSA increases pit production activities.	Simultaneously execute War Reserve qualification of analytical techniques and the Chemistry and Metallurgy Research facility exit strategy.
Scaling up of new material formulations from the laboratory to industry to provide commercial material sources of required materials.	Partner across the nuclear security enterprise to transition from large numbers of small-scale experiments to fewer informed pilot-scale tests.
Improving the ability to predict the effects of age on components.	Advance multiscale, validated predictive models of material aging, including the kinetic and thermodynamically aware degradation models of organics, inorganics, energetics, and corrosion of metals. Improve the use of data informatics and artificial intelligence to aid the interpretation of large data sets (e.g., mass spectrum data from compatibility and surveillance testing). Develop and deploy nondestructive tools to assess the state of materials in service.
Understanding the effects of processing conditions on production consistency and device performance.	Provide advanced inline analytical and diagnostic tools combined with process modeling to introduce efficiencies in manufacturing.
Developing validated predictive models of material aging that incorporate material microstructure, including degradation of organics and energetics and corrosion of metals.	Improve the use of data informatics and artificial intelligence to aid the interpretation of large data sets (e.g., mass spectrum data from compatibility and surveillance testing) and incorporate reaction kinetics.
Improving flexibility in the current and future stockpile through accelerated qualification methodologies using advanced and additive manufacturing techniques.	Synthesize new formulations that expand material possibilities for the design of new composite, multifunctional materials. Build confidence in a prediction capability of the stability over time of materials made by new processes. Successfully collaborate with design and production agencies to design for manufacturing.
Improving throughput, reducing waste, and limiting worker exposure to hazards.	Explore improvements in automated synthesis, advanced shielding, and compatibility testing and prediction for waste streams.
Conducting activities in aging chemistry infrastructure.	Modernize chemistry facilities across the nuclear security enterprise to support analytical and physical chemistry, as well as new feedstock synthesis and process scale-up needs, including radiological space.
Developing and maintaining a pipeline of specialized chemists and chemical engineers required to meet current and future staffing needs.	Develop a hiring pipeline by forming strategic alliances with specific universities that are strong in areas that are relevant to the nuclear security enterprise.

3.7.10 High Explosives and Energetic Science and Engineering

The High Explosives and Energetic Science and Engineering capability encompasses the study of detonation and deflagration physics, shock wave propagation, and reaction initiation. It includes the design, synthesis, formulation, manufacturability, inspection, testing and evaluation of HE and other energetic materials and components for specific applications. Knowledge of the characteristics and behavior of energetic materials is necessary to understand nuclear weapon performance and can contribute more-efficient weapons design and production.

DOE/NNSA mission priorities are critical for making available energetic materials and products to meet production base and capability objectives and other commitments. DOE/NNSA organizes energetic materials efforts to meet weapon delivery schedules and address challenges through strategic planning. The energetic materials mission covers three broad areas:

- Surveillance, maintenance, and LLC replacement of existing stockpile material
- Development of new materials for modernization
- R&D, diagnostics, and safety studies of novel materials and processes

3.7.10.1 Status of High Explosives and Energetic Science and Engineering

Meeting current and future challenges requires continued investments in sustaining DOE/NNSA's existing infrastructure and capabilities while transforming relevant infrastructure to be responsive and agile. To that end, DOE/NNSA has a project underway for energetic materials characterization, and plans to recapitalize additional HE facilities, including the High Explosives Applications Facility, Site 300, and the National Energetic and Engineering Weapons Campus including the Detonator Production Facility.

3.7.10.2 Challenges and Strategies

Table 3–28 provides a high-level summary of High Explosives and Energetic Science and Engineering challenges and the strategies to address them.

Table 3–28. Summary of High Explosives and Energetic Science and Engineering challenges and strategies

Challenges	*Strategies*
Supporting science and engineering programs and responding to emerging weapons program needs in aging HE facilities.	Develop and implement plans for modernization of HE/energetic materials design infrastructure to meet immediate programmatic needs, while maintaining the technological capacity to support the long-term HE mission. Coordinate with the Infrastructure and Operations Program and the Programmatic Recapitalization Working Group to improve energetic capability readiness. Implement the Energetic Materials Characterization Facility.
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 in conjunction with goals reflecting future program requirements.
Developing the next generation of HE scientists and engineers to continue to maintain the stockpile into the future.	Develop training and knowledge transfer programs to retain current HE scientists and engineers; develop partnerships with key universities to increase available pool of candidates.
Improving HE safety by bringing the state of the prediction capability in line with HE performance prediction.	Understand and predict HE deflagration through a combination of bench- and full-scale experimentation.
Finding a sufficient number of competent, qualified commercial vendors that are willing and able to meet stringent specifications and produce a diversity of energetic materials for commercial vendors to improve existing processes.	Collaborate with DoD and industrial partners to produce HE and preserve in-house production authority, such as for War Reserve detonator powder production.

HE = high explosives

3.7.11 Materials Science and Engineering

The Materials Science and Engineering capability aids in understanding how all the materials in a nuclear weapon system perform in diverse and extreme environments throughout the entire life cycle.

This capability plays a key role in resolving stockpile and production issues, validating computational models, and developing new materials (e.g., materials produced through advanced manufacturing). Materials Science and Engineering experiments also contribute to surveillance, where the effects of aging materials must be detected and evaluated to support annual assessment of the stockpile. When materials used in the stockpile must be replaced due to aging issues or obsolescence, new materials are studied and developed for insertion into the stockpile and are integral to extending the life of weapon systems. This reduces risks and may improve the overall safety and reliability of the stockpile. Dynamic material studies investigate the structural transformations, deformation, fracture, and chemical reactions that contribute to a confident prediction of weapon performance.

3.7.11.1 Status of Materials Science and Engineering

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

DOE/NNSA performs thousands of materials science and engineering experiments using a broad range of R&D, testing, and evaluation facilities. Capabilities for probing material properties in extreme conditions have been advanced by using light sources and HED physics facilities. However, a number of new materials and increased scrutiny of how legacy materials change with age are putting significant strain on throughput at existing facilities.

3.7.11.2 Challenges and Strategies

Table 3–29 provides a high-level summary of Materials Science and Engineering challenges and the strategies to address them.

Table 3–29. Summary of Materials Science and Engineering challenges and strategies

Challenges	*Strategies*
Maintaining and enhancing the ability to assess material changes due to aging, obsolescence, replacement for hazard mitigation in a timely and cost-effective manner for qualification.	Develop 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. Expand experimental and computational abilities to study these material changes through partnerships between national security laboratories and nuclear weapons production facilities and deliver solutions to emerging materials issues.
Maintaining capabilities to develop new materials and perform advanced evaluation and assessment of materials behavior in aging facilities, using aging equipment, in support of development, design, production, and surveillance activities.	Execute capital reinvestment in key facilities and equipment for Materials Science and Engineering capabilities to support nuclear weapons throughout life cycles.
Maintaining a reliable, sustainable and predictable material supply chain for nuclear weapons components.	Develop strategic partnerships with U.S. industries to understand the effects of material process or property changes on performance.
Maintaining the ability to perform rapid design and qualification of replacement materials in the face of the loss of vendor supply.	Understand the key material parameters affecting the performance of legacy materials and control them in the production of replacements materials.

Challenges	*Strategies*
Performing rapid design and qualification of new materials needed to meet future requirements.	Use advanced manufacturing techniques to design new materials with controlled and tailored performance.
Establishing a capability to quantify mesoscale[a] material performance and micron-scale performance in bulk materials in dynamic environments.	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.
Meeting the high demand for dynamic materials properties data to support warhead modernizations and Science programs and in situ diagnostics.	Develop and implement modern and cutting-edge material science and engineering tools that will attract the next generation of nuclear security enterprise workforce. Build and sustain pipeline networks with U.S. academic institutes. Use cross-functional teams of experts to prioritize the use of unique capabilities such as plutonium-capable gun facilities.

[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.

3.8 Weapon Assembly, Storage, Testing, and Disposition Portfolio

After weapon components are produced, each requires assembly into complete warheads and temporary storage before delivery to DoD. Some of these warheads are removed from the stockpile on a yearly basis for surveillance to provide data to evaluate the 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. This portfolio covers all of these capabilities.

3.8.1 Weapon Assembly, Storage, and Disposition

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

3.8.1.1 Status of Weapon Assembly, Storage, and Disposition

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

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

3.8.1.2 Challenges and Strategies

Table 3–30 provides a high-level summary of Weapon Assembly, Storage, and Disposition challenges and the strategies to address them.

Table 3–30. Summary of Weapon Assembly, Storage, and Disposition challenges and strategies

Challenges	*Strategies*
Sustaining aging equipment and facilities that support this capability due to age and condition.	Implement a strategy for major facilities, infrastructure, and equipment projects that includes refurbishments and replacements to support weapon assembly and disassembly operations.
Mitigating the shortage of staging area for pits from dismantled weapons.	Develop a strategy to address future staging capacity issues.

3.8.2 Testing Equipment Design and Fabrication

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

3.8.2.1 Status of Testing Equipment Design and Fabrication

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 both production and surveillance. Furthermore, the quantity and complexity of data that must be collected and processed has challenged the sites' ability to handle, analyze, store, and transfer data. Examples of equipment to address these digital data needs include digitized waveforms, high-speed video, centrifuge, higher frequency and shock, and simultaneous multi-environment requirements. Efforts continue to enhance the common tester architecture and develop the next-generation foundation bus that will improve connectivity, interchangeability, and multi-use compatibility with components and systems in the future.

Many items of test equipment in this capability are one-of-a-kind, custom-designed, and custom-built apparatuses that test classified assemblies. While some external vendors support a few test equipment capabilities, currently none can handle DOE/NNSA's unique requirements for combining test article classification, hazardous materials (including HE) testing, and stringent diagnostic or performance data collection and processing. Consequently, much of the tester design and fabrication remains in-house, which requires the retention of certain specialized technical expertise among staff.

3.8.2.2 Challenges and Strategies

Table 3–31 provides a high-level summary of Testing Equipment Design and Fabrication challenges and the strategies to address them.

Table 3–31. Summary of Testing Equipment Design and Fabrication challenges and strategies

Challenges	*Strategies*
Acquiring replacement parts, software upgrades, maintenance for test equipment, and test-specific hardware.	Develop a modular approach to system testers that supports more commonality and flexibility across systems to provide more cost-effective spares management, upgrade or repair frequencies, and operations, as well as a reduced footprint.
Establishing the capability to test hardware performance under more realistic environmental conditions, such as combinations of stimuli.	Obtain a design and fabricating test capability that will stress components and systems under multiple concurrent environments.
Recapitalizing one-of-a-kind testing equipment that is nearing or beyond end of life and subject to single-point failures (e.g., system-level acceptance testers, unique centrifuges).	Develop and implement a strategy to replace or modernize existing facilities and recapitalize programmatic equipment to prevent technical obsolescence.
Improving testers' capacities and capabilities to handle, store, transport, retrieve, and search for relevant data within large data sets.	Work with a larger consortium on developing solutions for handling, storage, transport, retrieval, and searching large amounts of data.
Attracting and retaining staff with requisite skills.	Partner with nuclear security enterprise sites to enhance processes for acquisition and retention of critical skills such as digital signal processing, field programmable gate arrays, and environmental testing. Partner with universities to identify and develop a pipeline of qualified candidates in critical fields.
Maintaining a balance between in-house design and manufacturing capability with industry engagement and procurement.	Continue to maintain critical capabilities in house, while using industry standards, hardware, and software as appropriate.

3.8.3 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 take place through inspections, laboratory and flight tests, destructive and nondestructive tests, and component and material appraisals. Comparing surveillance results over time provides the ability to detect, assess, and resolve aging trends and anomalous changes in the stockpile; potentially predict phenomena before the stockpile is affected; and address or mitigate issues or concerns.

X-rays from a 9-megaelectronvolt linear accelerator (far right) travel through three tungsten collimators to the heavily shielded CoLOSSIS (far left). CoLOSSIS supports nondestructive evaluations, providing 3D images of components that help identify flaws or defects in materials without damaging them.

Figure 3–5. Confined Large Optical Scintillator Screen and Imaging System (CoLOSSIS)

3.8.3.1 Status of Weapon Component and System Surveillance and Assessment

The Weapon Component and System Surveillance and Assessment capability is essential to surveillance and assessment activities, and depends on a broad array of specialized equipment. It is becoming increasingly difficult to maintain test equipment, gauges, and other analytical equipment and techniques to support surveillance needs. Efforts continue to obtain replacement parts and software upgrades to maintain test equipment and identify needs for gauges and other acceptance equipment to maintain capabilities.

3.8.3.2 Challenges and Strategies

Table 3–32 provides a high-level summary of Weapon Component and System Surveillance and Assessment challenges and the strategies to address them.

Table 3–32. Summary of Weapon Component and System Surveillance and Assessment challenges and strategies

Challenges	*Strategies*
Managing the additional strain on aging facilities and equipment due to increased workload throughout the enterprise.	DOE/NNSA is deploying innovative management tools to facilitate a data-driven, risk-informed planning process that will guide investment decisions. Furthermore, multiple capabilities will come on line and be available for use in FY 2020 that will improve capacity for planned warhead modernizations and related activities.
Performing adequate surveillance with a decrease in the overall size of the stockpile, which limits the availability of test assets to pull from inventory for surveillance.	Improve and adjust surveillance, including an increased emphasis on nondestructive diagnostics to optimize, and potentially reduce, destructive testing of major components.
Performing adequate surveillance in the face of deterioration of supporting capabilities.	Coordinate the programs that maintain these capabilities to develop risk-driven plans for recapitalization of capabilities as needed to sustain performance of the Surveillance program. Bring multiple capabilities on line for use in FY 2020 that will improve capacity and/or data quality, including: • Graded collimation/computed tomography and built-in glovebox microscopy capabilities at Y-12 • Pit nondestructive evaluations (increased gas sampling, assessment of weigh and leak capabilities; CoLOSSIS computed tomography maintenance and upgrades)

CoLOSSIS = Confined Large Optical Scintillator Screen and Imaging System

3.9 Transportation and Security Portfolio

The Transportation and Security portfolio involves DOE/NNSA’s capabilities for protecting the people, places, information, and other aspects that are critical to the function of the nuclear security enterprise. The Secure Transportation capability provides safe, secure transport of the Nation’s nuclear weapons, weapon components, and SNM throughout the nuclear security enterprise to meet nuclear security requirements and support DOE/NNSA operations. The Physical Security capability protects all nuclear materials, infrastructure assets, and the workforce at DOE/NNSA sites that are 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.

3.9.1 Secure Transportation

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

Mobile Guardian Transporter (Test Article)

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

The Secure Transportation Asset program (STA), 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 Government owned and operated due to the control and coordination required and the potential security consequences of material loss or compromise.

3.9.1.1 Status of Secure Transportation

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

The process of identifying, designing, procuring, and manufacturing vehicles takes several years. The Safeguards Transporter (SGT) fleet vehicles began reaching the end of their projected design life cycle in 2018. DOE/NNSA is sustaining this capability by implementing a risk-reduction initiative to extend the life of the SGT until a replacement, known as the Mobile Guardian Transporter (MGT), becomes operational. The MGT is critical for the safety and security of weapon related cargo, protect the public, and meet nuclear explosive safety standards. Without an effective MGT, future mission transportation needs will be at risk.

DOE/NNSA maintains the Secure Transportation capability by sustaining its vehicle fleet with replacement armored tractors, escort, and support vehicles. In 2021, DOE/NNSA will design and begin production of the next-generation Armored Tractor (T4) and Escort Vehicle (EV4).

A business case analysis to review options for replacing DOE/NNSA's aging DC-9 supported the planned purchase of an aircraft in FY 2021. The business case also supports a long-range replacement plan for the two 737 aircraft. DOE/NNSA currently plans to replace the first 737 in 2025 and the second in 2029.

As with other capabilities, DOE/NNSA 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 takes into account the many years it takes to achieve substantial growth in the Federal Agent workforce due to the stringent hiring process, security clearances, and attrition.

3.9.1.2 Challenges and Strategies

Table 3–33 provides a high-level summary of Secure Transportation challenges and the strategies to address them.

Table 3–33. Summary of Secure Transportation challenges and strategies

Challenges	*Strategies*
Sustaining the SGT fleet beyond the design life in the face of difficulties replacing obsolete parts, finding new manufacturers, and meeting Nuclear Explosive Safety Study requirements.	Develop the MGT to replace the aging SGT. Work with partners to identify mitigation strategies, address Nuclear Safety Study requirements, and sustain the SGT capability. Implement an SGT risk-reduction program.
Sustaining the aging Tractor Control Unit communications hardware/software, which provides critical communication functionality in vehicles.	Redesign the Tractor Control Unit to accommodate updated communications and security for the SGT and MGT.
Supporting DOE/NNSA missions in the face of aircraft performance issues and payload restrictions.	Support a charter aircraft contract. Procure a DC-9 replacement aircraft.
Maintaining and operating aging facilities and infrastructure safely and securely.	Repair, upgrade, and enhance STA facilities to meet safety, security, and mission requirements.

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

3.9.2 Physical Security

The Physical Security capability protects the Nation's nuclear materials, infrastructure assets, and the workforce at DOE/NNSA sites involved in Weapons Activities from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile or noncompliant acts that may adversely affect national security; assures program continuity; and provides employee security. The Physical Security capability includes the protection, control, and accounting of materials, physical security, and information for all facilities within the nuclear security enterprise. These physical measures are deployed to mitigate a broad range of threats to DOE/NNSA at all locations. The current growth in Weapons Activities programs mandates increases to the physical security capabilities necessary to support ongoing modernization efforts, including the addition of personnel in each of the safeguards and security functional areas and commensurate increases in the ongoing security infrastructure modernization effort.

Physical security technology management at the various DOE/NNSA sites includes alarm management and control, intrusion detection and assessment, access controls, contraband detection, barriers and locks, material accountability, technical surveillance countermeasures, tactical systems, remotely operated weapon systems, and countering unmanned aircraft systems. For specific system and site information refer to the SSMP classified Annex.

3.9.2.1 Status of Physical Security

DOE/NNSA deploys state of-the-art technologies to manage various aspects of physical security to execute a single, resilient, world-class security program across the nuclear security enterprise. Key aspects of these technologies are illustrated in **Figure 3–6**, and the current status is described in **Table 3–34**.

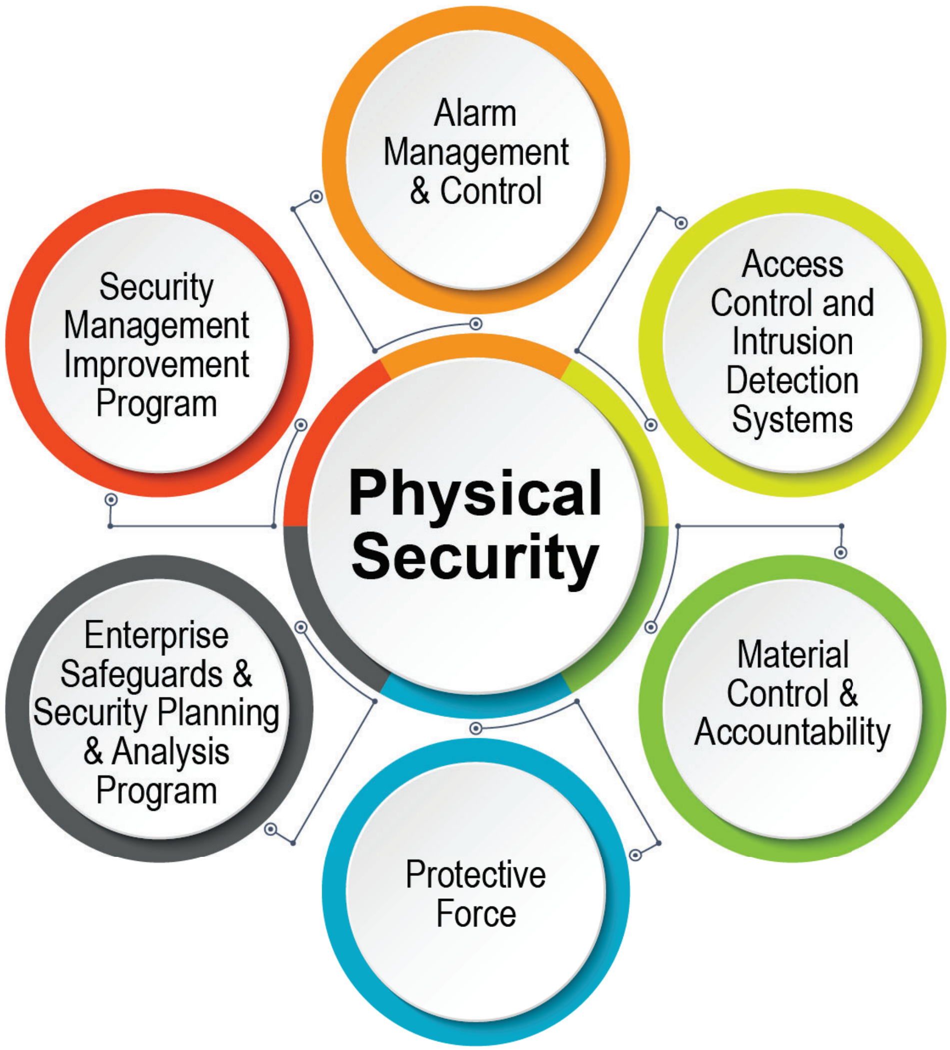


Figure 3–6. Physical security composition

Table 3–34. Physical Security status

Physical Security Component	*Status*
Alarm Management and Control Systems	Employing a proprietary physical security system to protect assets at Security Category I/II sites. The system is deployed at three sites; deployment of the system at the fourth site is scheduled to be completed in FY 2020.
Intrusion Detection Systems/Access Control Systems	Collaborating with DoD to develop a reliable, rapidly deployable, portable perimeter security system for the temporary protection of high-value assets. Developing a standardized security systems training program for operators and system maintainers. DOE/NNSA's proprietary security system is being installed at the last SNM Category I facility.
Material Control and Accountability	DOE/NNSA completed its modernization of the standardized accounting software in 2019. Currently, all but one site uses this accounting software; the remaining site will transition to this standardized accounting system software by 2023.

Physical Security Component	***Status***
Protective Force	Developed Tactical Casualty Care initiative. Phase I, Train-the-Trainer, was completed in 2019. Phase II, Procurement of Equipment, is ongoing and is scheduled to be completed in FY 2020. Used an existing DoD contract to acquire standardized, enterprise-wide primary individual weapons: • Reduces need for multiple weapon parts stockpiles • Supports bulk supply orders to reduce overall cost and provide seamless mutual support initiatives among the DOE/NNSA sites • Initial delivery of new individual weapons is expected in the fourth quarter of FY 2020 Through the Enterprise Mission Essential Task List, DOE/NNSA has restructured training with a primary focus on critical tasks that directly contribute to mission success.
Enterprise Safeguards and Security Planning and Analysis Program	Continuing to conduct standardized vulnerability assessments of DOE/NNSA facilities, providing risk acceptance authorities' critical program information to help guide/manage the safeguards and security program.
Security Management Improvement Program (SMIP)	The SMIP Pilot was conducted and completed at the Nevada National Security Site in November 2019.

SNM = special nuclear material

Note: A complete breakdown of physical security technology management at each NNSA site is available in the SSMP classified Annex.

3.9.2.2 Physical Security Challenges

Aging security infrastructure, with some physical security systems older than 30 years, drove DOE/NNSA to develop a standardized approach for prioritizing critical physical security system upgrades and life-cycle management at each DOE/NNSA site, plant, and laboratory. The 10-Year Security Infrastructure Revitalization Program Plan provides a prioritized, cost-effective schedule of recommended physical security system investments, *assuming* appropriate funding is provided. Failure to maintain the schedule will increase the risk to security and could affect critical weapons program production activities.

Table 3–35 provides a high-level summary of Physical Security challenges and the strategies to address them.

Table 3–35. Summary of Physical Security challenges and strategies

Challenges	***Strategies***
Identifying emerging threats and ensuring capabilities are developed and implemented to counter threats.	Collaborate with numerous internal and external entities.
Assessing and addressing the full range of threats, from protestor incursions to active, violent insiders or intruders.	Participate in executing the DOE Insider Threat Program through local Insider Threat Working Groups at each DOE/NNSA site. Operate a Security Analysis Cell to analyze and disseminate external threat information and interface with the intelligence community and law enforcement agencies.
Ensuring security requirements are factored into NNSA mission planning efforts (i.e., production capabilities, infrastructure modernization, etc.) and appropriate resources are provided to support those requirements.	Coordinate with NNSA stakeholders to integrate security requirements into NNSA mission planning efforts.
Ensuring all security-related projects (i.e., line items, General Plant Projects, and other minor construction projects) are executed on time, within budget, and to specification.	Track project implementation through recurring Annual Operating Plan updates, field-based Program Execution Reviews, and supplementary, monthly project reports as necessary.

3.9.3 Information Technology and Cybersecurity

The IT and Cybersecurity capability provides infrastructure and protection for both classified and unclassified computing networks, secure communications, applications, systems, and logical environments. Efficient and effective operations and protection of unauthorized access and malicious acts that would adversely affect national and economic security of electronic information and information assets is vital for the DOE/NNSA. DOE/NNSA directs the design, development, and maintenance of all aspects of DOE/NNSA computing and provides DOE/NNSA staff with the IT resources necessary to achieve mission goals and objectives. Core components and functions of the IT and Cybersecurity capability are influenced and supported by Policy and Governance, as illustrated in **Figure 3–7**.

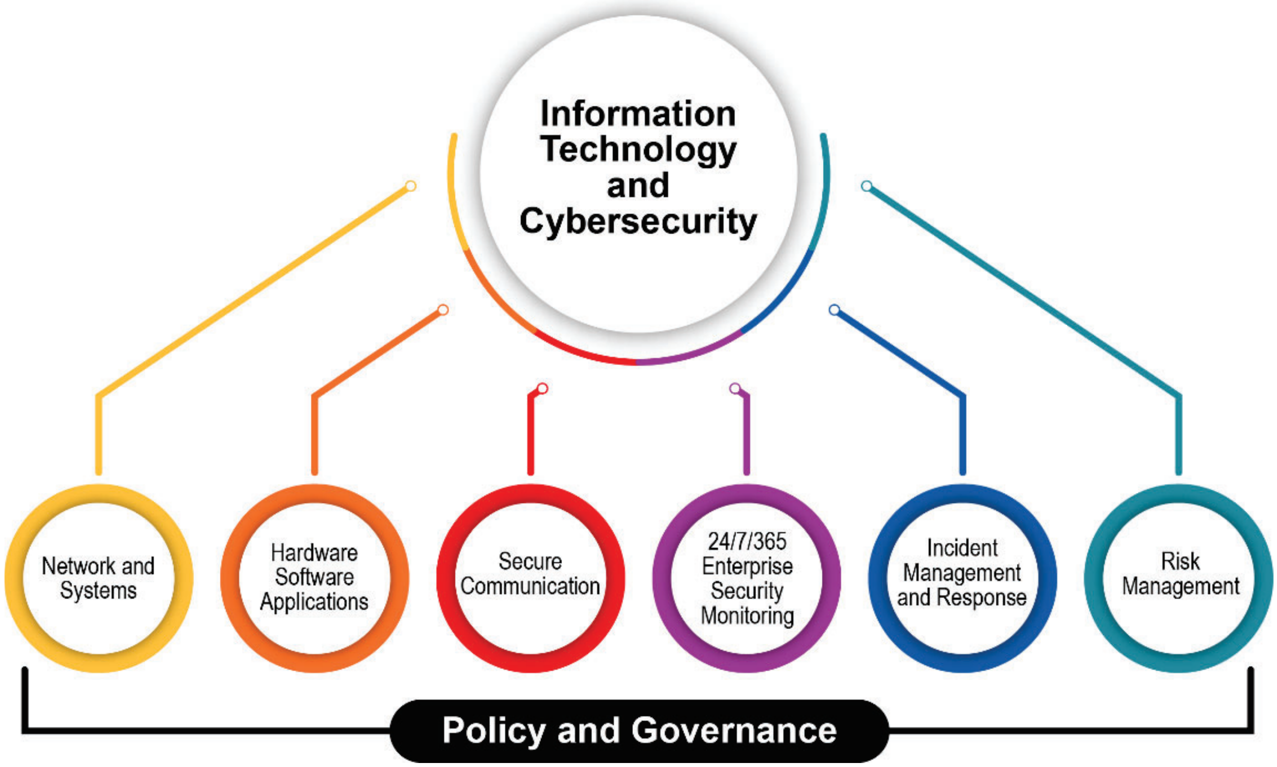


Figure 3–7. Information Technology and Cybersecurity Capability core functions

Efficient and effective management of IT and Cybersecurity is one of the most crucial factors in supporting the DOE/NNSA enterprise; every capability in the nuclear security enterprise depends on IT and Cybersecurity to keep information and related assets securely protected and well managed. The highly complex nature of the DOE/NNSA enterprise, coupled with resource priorities, requires information and information assets to be secured, managed, and protected using a risk-management approach. DOE/NNSA makes well-informed management decisions based on a systematic understanding of the risks inherent in the use of information systems to properly protect assets and information.

3.9.3.1 Status of the Information Technology and Cybersecurity

DOE/NNSA's IT and Cybersecurity capability supports and underpins the DOE/NNSA mission and provides secure, reliable, well-managed, and accessible IT solutions critical to executing DOE/NNSA's missions. **Table 3–36** describes key aspects of the IT and Cybersecurity capability and the current status.

Table 3–36. Information Technology and Cybersecurity status

IT/Cyber Component	*Status*
Information Technology Modernization	Implemented Phase 1 of the IT Modernization effort. Continuing to work with DOE to complete modernization of the current IT infrastructure provided to Departmental elements and the move to a managed service model.
Enterprise Secure Computing	Continuing to pursue a strategic initiative as part of the larger Enterprise Secure Computing program, which will directly increase the capability, capacity, and responsiveness of the DOE classified infrastructure. This will directly support the DOE/NNSA mission and statutory requirements governing classified data protections and information assurance.
Restricted Data	Continuing to work with external partners (including other Government agencies and the intelligence community) to identify interagency needs and opportunities for accessing, sharing, leveraging, and protecting Restricted Data (RD) by: • Providing a list of current cyber protection requirements and methodologies for RD • Explaining the current congressional statutes that control dissemination of RD outside the DOE/DoD environment • Assessing the current state of the Federal Bureau of Investigation cybersecurity controls in correlation with RD protection requirements and assisting in the formulation of an official memorandum from the Associate Director of the Render Safe Program to the NNSA Office of the Chief Information Officer, requesting access to host RD • Developing and integrating an RD overlay for external partners to enforce protection across environments that are outside of DOE/NNSA's direct control and oversight
Technologies Deployed to Address Cybersecurity Threats	Maintaining management, operations, and technical security safeguards throughout the nuclear security enterprise for adequate protection of information assets. Developed, deployed, and used security tools to provide the first lines of defense against known adversaries and emerging threats.

3.9.3.2 Challenges and Strategies

The cyber threat landscape constantly evolves, with the most sophisticated threats adapting rapidly to deterrents. DOE/NNSA is committed to providing an IT infrastructure to protect the stockpile stewardship and management missions using a collaborative, intelligence-informed approach to cyber operations and a response that employs the full capabilities of the nuclear security enterprise, DOE, and the Federal Government. **Table 3–37** provides a high-level summary of the IT and Cybersecurity challenges and the strategies developed to address them.

Table 3–37. Summary of Information Technology and Cybersecurity challenges and strategies

Challenges	*Strategies*
Addressing current supply chain and software assurance issues.	Move toward centralized purchasing and equipment review before issuing equipment to the field.
Developing a more robust Insider Threat program for emerging threats.	Work with counterintelligence on implementation of an insider threat program.
Managing aging computing infrastructure.	Improve network infrastructure by updating and enhancing networking equipment through public/private cloud services, managed services, software, and hardware enhancements. Mature capabilities of aging infrastructures enterprise-wide to identify and alert concerning emerging threats. Implement faster development and application of these capabilities to counter such threats.
Addressing limitations of current network monitoring services.	Upgrade sites across the enterprise through deployment of new cybersecurity solutions.
Supporting scientific computing and increased reliance on computers across the DOE/NNSA complex.	Work with the Office of Infrastructure, Operations, and Modernization to optimize infrastructure and the Office of Advanced Simulation and Computing and Institutional R&D to perform capacity planning for DOE/NNSA.
Addressing new requirements from the 2018 *Nuclear Posture Review*.	Assess methods for IT and Cybersecurity programs are poised to support new and emerging mission requirements.
Filling critical cybersecurity and IT vacancies across the enterprise.	Hire a workforce that has the required skills per DOE/NNSA strategic plans. Invest in employee development to cultivate a high-performing workforce that will support DOE/NNSA's mission today and into the future. Incorporate student participation in the DOE/NNSA Cyber Summit.
Fulfilling Office of Management and Budget guidance to consider and use cloud solutions in a secure manner.	Modernize current services by capitalizing on cloud technology to increase performance and strengthen security.
Managing operational technology cybersecurity.	Establish an effective methodology to accurately baseline present and future operational technology (OT) devices in use across both the NNSA Production Office and the nuclear security enterprise. Work with external partners on a path forward and partner with the Office of Defense Programs to determine toolsets that are necessary to develop and support a strategic approach. Implement recommendations identified in the OT/IT study performed by the JASON independent advisory group.
Managing software assurance.	Work with strategic DoD partner to increase awareness, capabilities and tools, and consistent approaches to effectively detect evidence of malicious features.

Chapter 4
Infrastructure and Workforce

> *"Previous de-emphasis on our nuclear deterrent and the infrastructure that supports it…coupled with adversaries that are modernizing and creating increasingly capable forces, has led us to the point where we must modernize now to continue to maintain a viable deterrent in the future."*
>
> *Charles A. Richard, Commander, United States Strategic Command, 2020*

The *National Nuclear Security Administration Strategic Vision* recognizes infrastructure and workforce as two of the seven strategic management challenges that requires immediate attention. DOE/NNSA is committed to making concerted investments in infrastructure and workforce initiatives to support increasing scope and address the state of decline across the nuclear security enterprise. As detailed in the beginning of Chapter 3, infrastructure and workforce represent two of the four elements that comprise every Weapons Activities capability. The status of these elements, as well as challenges associated with them, are described in detail throughout Chapter 3. Many of the individual capability descriptions identified challenges specific to aging infrastructure and the need to recruit and retain a highly-skilled workforce, as well as strategies to mitigate those challenges. This chapter describes DOE/NNSA's overall strategy to strengthen these elements from an enterprise-wide perspective.

4.1 Infrastructure

> ***Key Changes Affecting Nuclear Security Enterprise Infrastructure***
>
> - *Increases in near-term investments in specialized facilities for weapon material production and processing*
>   - *A two-site solution for Pit Modernization*
>   - *High Explosives Synthesis, Formulation and Production Facility*
>   - *Lithium Processing Facility*
>   - *Tritium Finishing Facility*
>   - *Physical security and IT enterprise investments*
> - *Increased planning resources for major programmatic construction investment*

Infrastructure modernization efforts across the nuclear security enterprise are necessary to mitigate risks and implement the 25-year program of record described in the Nuclear Weapons Council Strategic Plan for Fiscal Years 2019–2044 and in this SSMP. Efforts include investments in major programmatic and mission-enabling construction projects, as well as risk-informed, time-sensitive recapitalization efforts across every DOE/NNSA site. These complementary investments support DOE/NNSA in meeting the most pressing mission needs while also addressing the issues of an aging infrastructure across the nuclear security enterprise.

Major infrastructure investments require additional scrutiny and follow defined acquisition methodology. DOE/NNSA manages line-item capital acquisition projects through DOE's acquisition process with five critical decision (CD) points (detailed in **Figure 4–1**) that serve as major milestones approved by a Project Management Executive. Each CD marks further certainty in project scope and requires successful completion of the preceding phase. DOE/NNSA will sometimes combine CD-2 (Approve Performance Baseline) and CD-3 (Approve Start of Construction) to reduce acquisition time while maintaining program management requirements.

CD-0	CD-1	CD-2	CD-3	CD-4
Approve Mission Need	Approve Alternative Selection and Cost Range	Approve Performance Baseline	Approve Start of Construction	Approve Start of Operations or Project Completion

CD-0 documents that a mission need, such as a scientific goal or a new capability, requiring material investment exists.

CD-1 serves as a determination that the selected alternative and approach is optimized to meet the mission need defined at CD-0. Key elements of the evaluation are the project's conceptual design, cost and schedule range, and general acquisition approach. The cost range allows for uncertainty in the estimates and scope options such as a range of capabilities.

CD-2 is an approval of the preliminary design of the project and the baseline scope, cost, and schedule. The baseline is the definitive plan that the project will be measured against using Earned Value metrics for cost and schedule and Key Performance Parameters for technical performance.

CD-3 is an approval of the project's final design and authorizes release of funds for construction.

CD-4 provides recognition that the project's objectives have been met.

Figure 4–1. Critical Decision overview

4.1.1 Overall State of DOE/NNSA Physical Assets

DOE/NNSA's infrastructure is a $121 billion enterprise composed of programmatic research and production facilities, support facilities, and service facilities that are of critical importance for mission work. More than half of all DOE/NNSA facilities are more than 40 years old. Excess facilities (i.e., facilities that are no longer usable for mission needs) account for 10 percent of enterprise infrastructure, and hundreds of additional assets are expected to become excess in the next decade. These excess facilities must be maintained in a safe standby condition as they await decommissioning and disposition.

Simultaneously, DOE/NNSA is addressing the declining state of infrastructure by optimizing the application of resources across its portfolio. DOE/NNSA has undertaken a comprehensive strategic capital acquisition planning effort to identify, scope, and prioritize capital investment needs across all capabilities, including office and laboratory space, utilities, equipment, and other supporting infrastructure. DOE/NNSA has established priorities based on mission needs and optimization of costs and risk reduction. DOE/NNSA has also deployed innovative management tools to facilitate data-driven, risk-informed planning that will guide integrated short- and long-term investment decisions. In addition, streamlined acquisition and execution techniques will standardize and deliver assets more efficiently by applying more commercial standards.

4.1.2 Major Investments in Programmatic Infrastructure

DOE/NNSA's programmatic facilities are facing increased user demand due to multiple concurrent warhead modernization activities that have dramatically increased production workload as well as critical science, technology, and engineering activities related to stockpile stewardship. Production facilities in particular are facing safety, capacity, and reliability challenges. Revitalization of the pit production capability and continuing missions in uranium, tritium, high explosives, lithium, and non-nuclear component production will require significant investments in modernization of aging infrastructure and systems, as well as some improvements or expansions to meet increased capacity requirements. Special initiatives such as Exascale Computing Initiative and Enhanced Capabilities for Subcritical Experiments also require dedicated equipment and facilities investments. Existing facilities require additional funding for maintenance costs and extended bridging strategies until major programmatic construction projects are completed.

DOE/NNSA developed the Capital Acquisition Planning (CAP) process to prioritize programmatic infrastructure investments as part of overall planning, programming, budgeting, and evaluation activities.[1]

[1] CAP replaces the Capital Acquisition Process (CapAx) described in the FY 2020 SSMP.

This effort, consistent with the planning for DOE/NNSA's Stockpile Major Modernization programs, is conducted in collaboration with the laboratories, plants, and sites to identify and prioritize major programmatic construction projects for Weapons Activities within the FYNSP and projected out for a 25-year period. The CAP process uses site expertise, programmatic requirements reviews, and Federal cost and schedule planning estimates to develop long-term plans for major projects. The final 25-year schedule of major projects is determined by DOE/NNSA leadership. Integrated planning for infrastructure across the enterprise is detailed in the annually updated DOE/NNSA Master Asset Plan. Current planning estimates and schedule dates for major programmatic construction projects that are included in the FY 2021 President's Budget Request are listed in **Figure 4–2**.[2] Proposed major programmatic construction projects that are planned for after FY 2025 are listed in **Figure 4–3**.

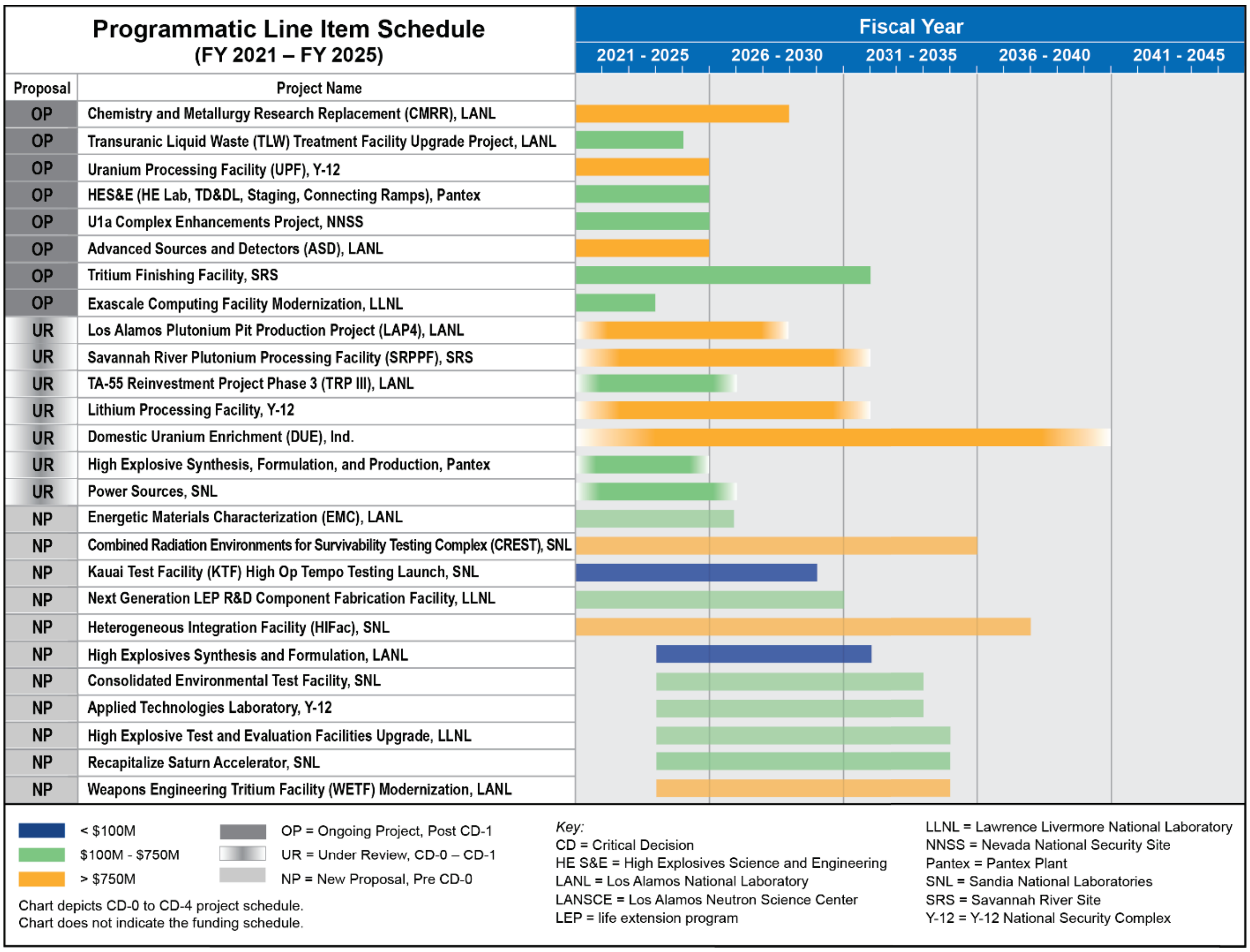


Figure 4–2. DOE/NNSA 25-year programmatic line-item schedule for projects included in the FY 2021 President's Budget Request (FY 2021–FY 2025)[3]

[2] Figure 4–2 includes construction projects that DOE/NNSA has requested planning funding (pre-CD-1) for within the FY 2021 President's Budget Request.

[3] DOE/NNSA obtained CD-0, Achieve Mission Need, approval for the Power Sources Capability facility in FY 2019 and for the Energetic Materials Characterization facility in FY 2020. DOE/NNSA is working toward CD-4 (Approve Start of Operations or Project Completion) approval for both projects in FY 2026 based on the clearly defined capability gap and mission need. The analysis of alternatives process for the Energetic Materials Characterization, Conceptual Design for the Power Sources Capability, and subsequent cost estimates for both will inform future budget planning profiles.

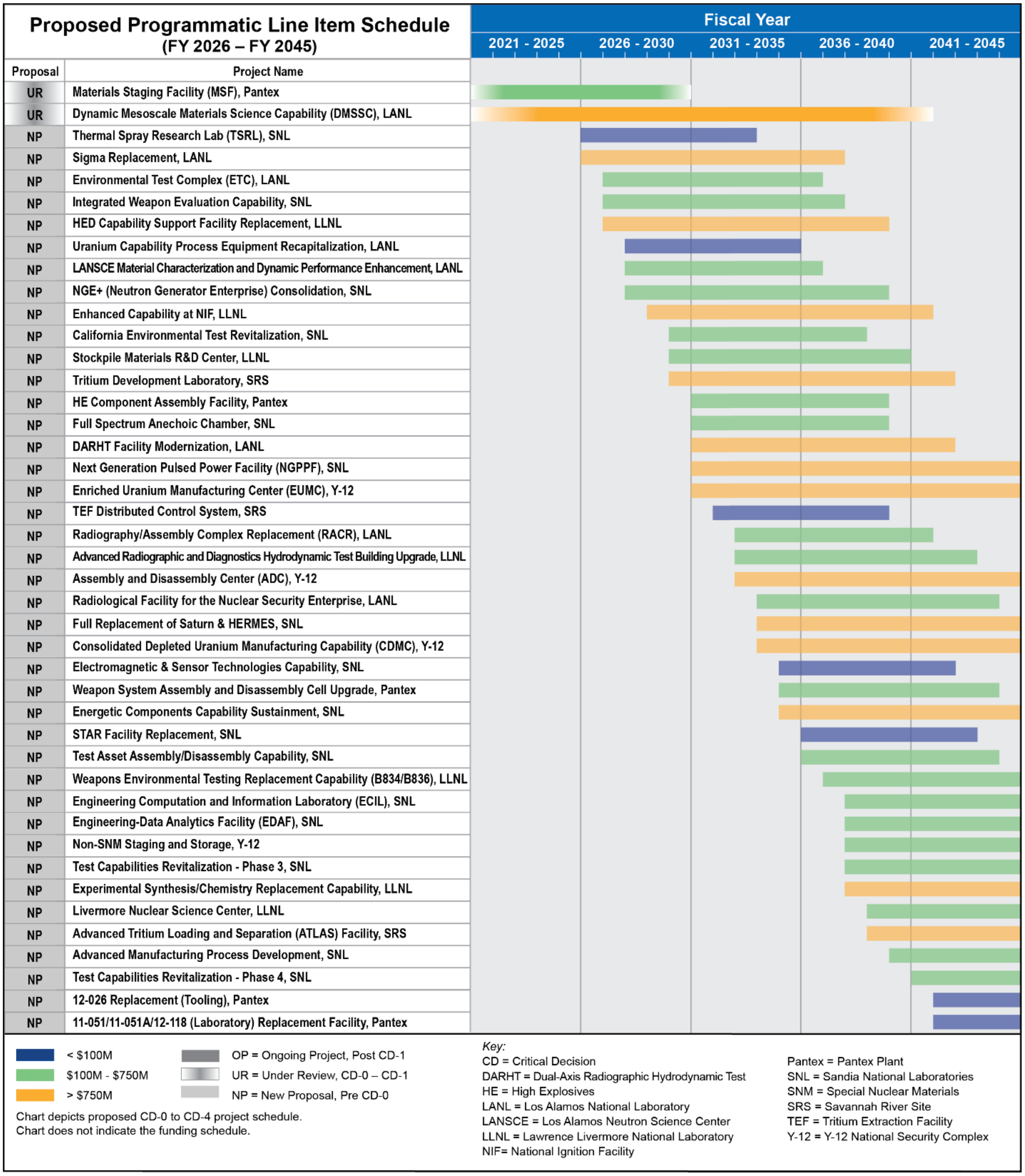


Figure 4–3. DOE/NNSA 25-year programmatic line-item schedule for proposed projects (FY 2026–FY 2045)

The projects presented in Figures 4–2 and 4–3 are intended to reduce risk to mission by consolidating and replacing unreliable facilities and infrastructure that have exceeded life-cycle expectations and pose safety and program risks to people, the environment, and the mission. Near-term projects have higher-fidelity cost and schedule data associated with them. As a result, the planned start and end dates for the "ongoing projects" are more certain than those in the "under review" and "new proposals" categories.

DOE/NNSA will continue to update this schedule annually based on revised and new mission needs assessments, cost estimates, programmatic prioritization, and the availability of funding. There will be a number of planned acquisitions that may convert to alternate strategies upon conduct and completion of an analysis of alternatives.

4.1.3 Major Investments in Mission-Enabling Infrastructure

In addition to a suite of programmatic facilities, DOE/NNSA is dependent on hundreds of office and laboratory buildings, power systems, water systems, emergency response, and other supporting assets for programs to function. Similar to the situation with direct mission assets, increases in workload and associated staffing are creating a shortage of mission-enabling facilities such as office and laboratory space. These aging facilities and systems require maintenance, updating, refurbishment, or replacement.

Regular investments in power transmission and distribution systems are necessary to avoid safety, security, and productivity issues that stem from age and obsolescence. Growth in high performance computing requires increased electrical capacity at some sites, while more efficient manufacturing technologies and processes at other sites have reduced power requirements. Efforts are underway to improve the reliability, capacity, sustainability, and coverage of electrical infrastructure across the enterprise.

Regular investments are also needed to maintain a viable water supply and distribution system, sewers, tanks, and other water infrastructure. Activities are underway to mitigate the risk of single point failures for the water supply throughout the enterprise. Strategic investments in mission-enabling infrastructure are prioritized to address increased program requirements and reduce infrastructure risks to capabilities. DOE/NNSA is using the major capital acquisition construction process to address capacity issues and safety concerns in utilities, office and laboratory space, and emergency response, as illustrated in the 25-year mission-enabling infrastructure line-item schedule in **Figure 4–4**.

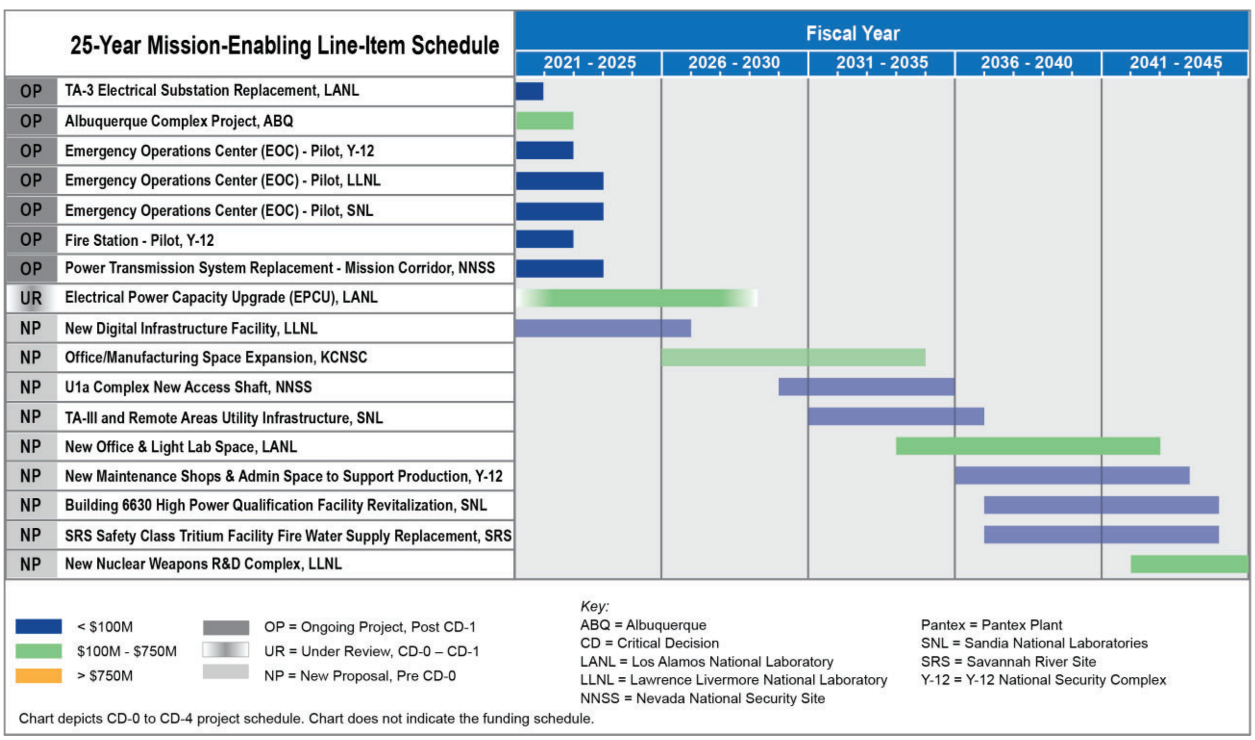


Figure 4–4. DOE/NNSA 25-year mission-enabling infrastructure line-item schedule

4.2 Workforce

DOE/NNSA's greatest asset is the highly qualified and skilled world-class scientific and engineering workforce, without which DOE/NNSA could not meet its vital national security missions. One of DOE/NNSA's top mission enabling priorities is to strengthen key science, technology, and engineering capabilities, including recruiting, training, and retaining the next generation of DOE/NNSA's scientists, engineers, project and program managers and technicians. This section emphasizes the overall importance of staffing to maintaining capability qualifications, expertise, and competencies, and the approach DOE/NNSA is using to address these issues at a strategic, enterprise level.

Over one-third of the workforce is now retirement-eligible, posing a challenge to DOE/NNSA in bringing new hires up to speed while the expertise and experience is still available. Maintaining a DOE "Q"-cleared, qualified, and technically-trained workforce requires transferring knowledge, skills, and direct experience with respect to all stockpile technologies and processes. Because the expertise required to fulfill DOE/NNSA's mission is often learned on-the-job over a significant period of time, retention of the workforce is critical to the development, growth, and maintenance of the workforce's scientific, engineering, technical, and project/program management competencies.

DOE/NNSA's approach to addressing its workforce challenges recognizes five keys characteristics necessary to attract and retain a high-quality workforce:

- Owning a place in the mission
- Working with state-of-the-art experimental, computational, and manufacturing capabilities
- Employing modern business and operating systems
- Working in modern workspaces
- Providing ample career development opportunities

On an enterprise level, DOE/NNSA is focused on retaining and preparing the workforce for the future through succession planning, knowledge preservation, training, retention, and workforce development. Each management and operating (M&O) partner site has a variety of established programs to improve retention:

- Critical skill retention programs that provide pay incentives for hard-to-fill critical positions
- Employee leadership development programs
- Increased employee engagement through career conversations, career development tools, workshops, and mentoring
- Educational opportunities and assistance to encourage career growth
- Flexible work schedules and other family-friendly workplace options
- Rotational assignments to diversify experience

The M&O partner sites have placed increased emphasis on career development opportunities and strong employee engagement and are committed to attracting and retaining top talent.

For FY 2019, the M&O partner sites collectively reported a headcount of 44,444 employees.[4] This is an increase of 3,926 employees from the reported 40,518 in the FY 2020 SSMP. This increase is reflected across all job categories as depicted in **Figure 4–5**. Despite attrition, the nuclear security enterprise experienced a positive net gain.

The M&O partners reported 2,192 separations during FY 2019, as depicted in **Figure 4–6**. Broken down by reason for separation, the data in **Figures 4–7** and **4–8** identify two very noticeable issues. One is that most voluntary separations occur within 0-5 years of service, and the second is that the voluntary separations are concentrated in age groups that would ideally learn from and replace retirees. These voluntary separations amount to six percent of the workforce. Overall, site attrition rates have compared favorably to the estimated industry average.

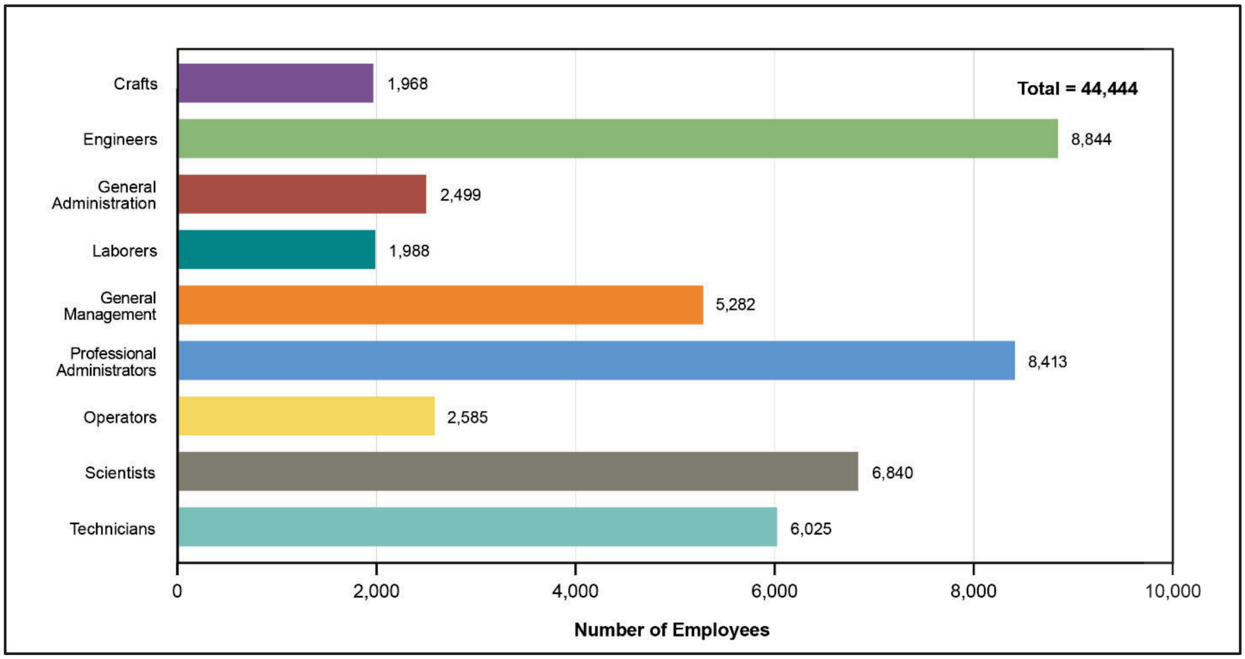


Figure 4–5. Total M&O workforce by Common Occupational Classification System

[4] This total is not all-inclusive for the entire nuclear security enterprise workforce of over 50,000 personnel. For reporting purposes, the SSMP collects data in headcount form for M&O **permanent** career employees based on categories from the *Common Occupational Classification System*. This data does not include Naval Reactors or Federal workforces, and exclude part-time or other personnel that fall outside one of these categories. Comprehensive Federal data is presented to Congress outside of the SSMP. At the time of data collection (9/30/19), DOE/NNSA had around 1,700 Federal FTEs (not counting Office of Secure Transportation couriers); DOE/NNSA, to fulfill its growing workload, was authorized to increase its desired end-strength FTE cap to 1,890, as opposed to the 1,690 stated in previous SSMPs. DOE/NNSA also has several support-service contractors in Federal program offices providing crucial advisory and programmatic services.

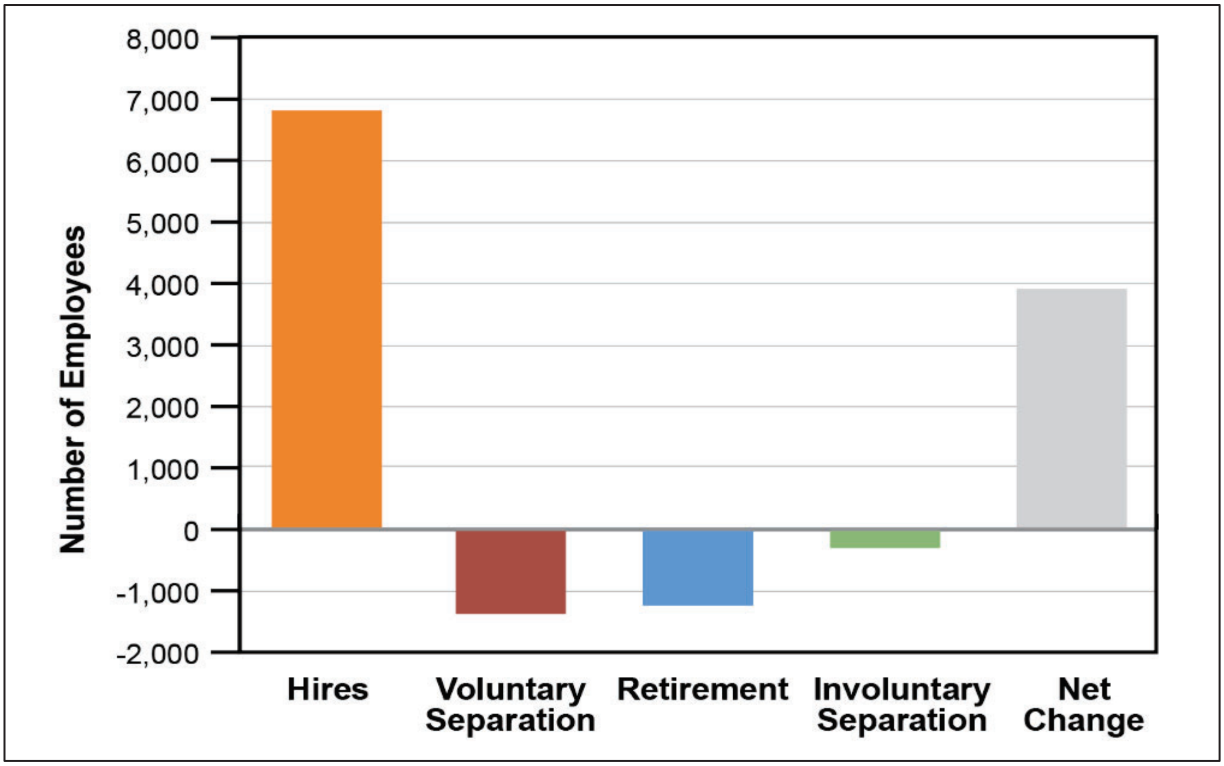


Figure 4–6. M&O separations in FY 2018 and FY 2019

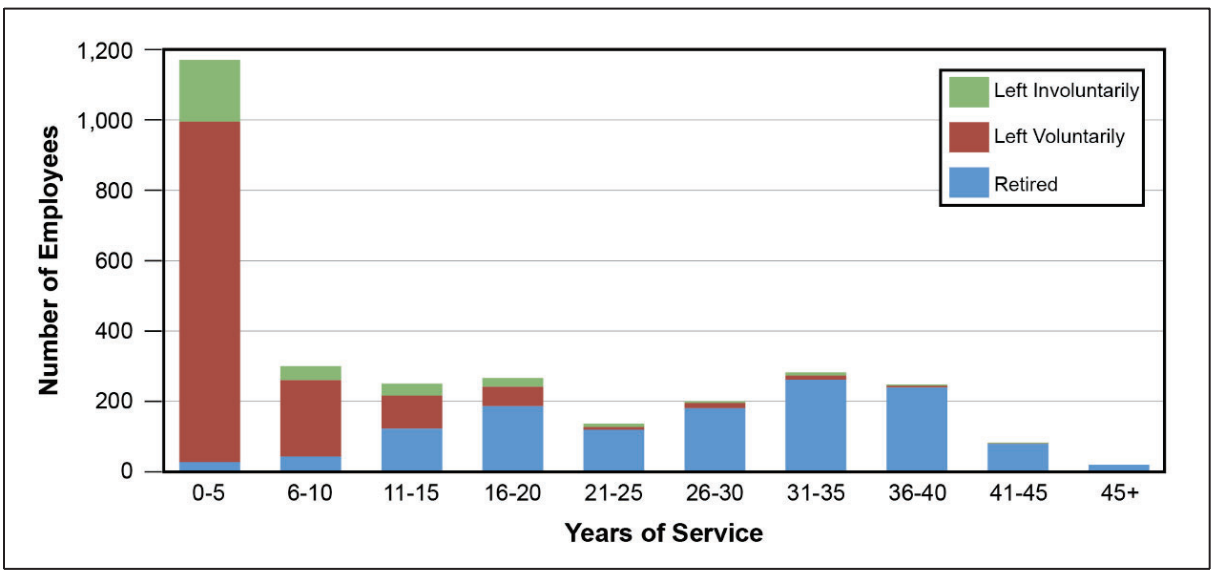


Figure 4–7. M&O separations by years of service

Figure 4–8. M&O separations by age

Chapter 5
Budget and Fiscal Estimates

The FY 2021 President's Budget Request for Weapons Activities seeks appropriations from Congress needed to support the Administration's nuclear deterrent modernization program as described in the 2018 *Nuclear Posture Review*. The FY 2021 President's Budget Request provides an increase of 19 percent for DOE/NNSA, and 25 percent for Weapons Activities above the FY 2020 enacted appropriation. These robust increases are needed to support the warhead modernization programs and the infrastructure modernization projects required to deliver these warheads on schedule.

DOE/NNSA developed the FY 2021 Future Years Nuclear Security Program (FYNSP) budget request for Weapons Activities using a detailed, bottom-up assessment of DOE/NNSA's capabilities and a thorough alignment of warhead programs to DOE/NNSA requirements. The assumptions encompassed by this request meet the timeline for DOE/NNSA's warhead deliveries to be fully synchronized with the modernization of DoD delivery platforms.

The first half of this chapter displays budgetary information based on the FYNSP request, which includes programming for FY 2021 through FY 2025. The FY 2021 budget request makes use of a new budget structure for Weapons Activities that better accounts for the full scope of activities undertaken in this area. Each programmatic section in this chapter compares the FY 2021 budget request to the FY 2020 enacted budget (comparable) and presents key milestones representing progress toward program goals. The second half of the chapter describes cost projections for selected programs beyond the FYNSP, and the basis of those cost projections used to estimate the potential long-term cost of the DOE/NNSA Weapons Activities program. Cost-estimating techniques supporting the budget request are consistent with Government Accountability Office (GAO) best practices and have been updated with current requirements for each weapon system. The chapter concludes with an overview of this 25-year program and an analysis of the affordability of the Weapons Activities program.

5.1 Future Years Nuclear Security Program Budget

5.1.1 FY 2021 Budget Structure Change

The FY 2021 FYNSP budget request for Weapons Activities reflects an updated structure that better aligns with current and future Weapons Activities programming; production modernization programming; and research, technology, and engineering efforts. It also improves alignment with the current and future scope, consolidates similar activities, and facilitates improved program execution by grouping activities by how they are managed. A high-level overview of these changes is presented in **Figure 5–1**. Additional details about the budget request are provided in the ensuing sections and can be found in the *Department of Energy FY 2021 Congressional Budget Request*. As a result of the budget structure change, all references to the FY 2020 enacted budget in this chapter are provided as comparable numbers to the new budget structure for FY 2021.[1]

[1] The complete budget crosswalk from the FY 2020 enacted budget structure to the FY 2021 requested budget structure can be found in the *Department of Energy FY 2021 Congressional Budget Request*.

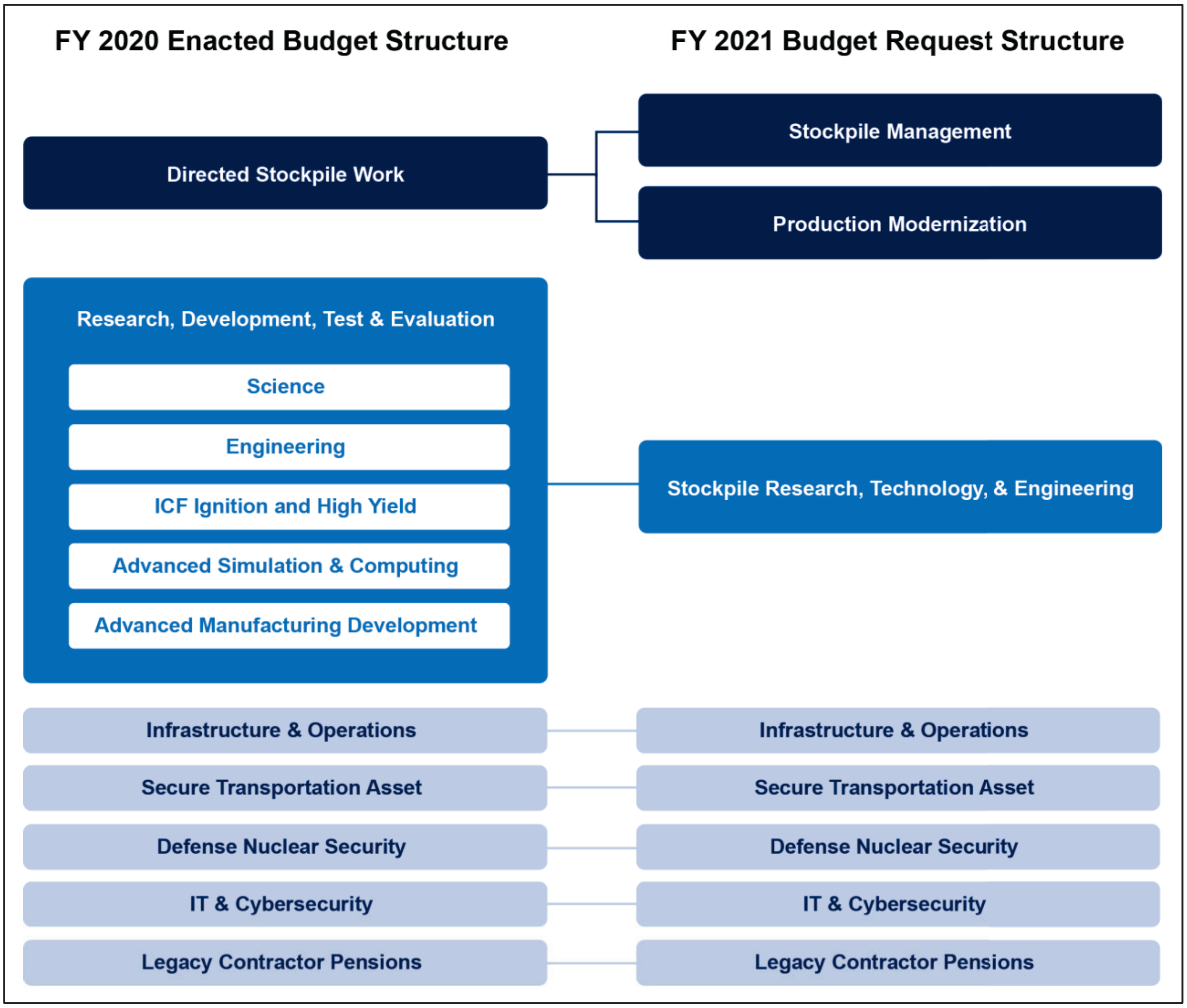


Figure 5–1. FY 2020 – FY 2021 Weapons Activities Budget Structure Comparison

5.1.2 FY 2021 Future Years Nuclear Security Program Request

Weapons Activities provides for maintenance and refurbishment of nuclear weapons to sustain confidence in their safety, reliability, and military effectiveness; investment in scientific and engineering capabilities for certification of the nuclear weapons stockpile; and increased manufacturing capabilities to produce nuclear weapon components. Weapons Activities also provides for maintenance and investment in DOE/NNSA's infrastructure.

The FY 2021 FYNSP budget request supports the current stockpile, warhead modernization activities, recapitalization and modernization programs for infrastructure, and filling gaps in DOE/NNSA's reestablishment of necessary production capabilities. It also supports R&D efforts and personnel growth in operations, physical security, and information technology (IT) and cyber security to support expanding program needs.

DOE/NNSA must continue to meet DoD requirements to accomplish warhead modernization programs, as well as meet the highest standards of safety, security, and effectiveness while remaining aligned and integrated with DoD's delivery platform modernization. DOE/NNSA will continue to work with DoD through the Nuclear Weapons Council to evaluate, maintain, and assure the safety, security, and control of the nuclear weapons stockpile, as well as develop nuclear weapons stockpile and integrated platform delivery system options.

Table 5–1 displays the FY 2020 enacted budget and program budget requests for Weapons Activities for FY 2021–FY 2025. The figures and narrative that follow describe the FY 2021 budget request in more detail.

Table 5–1. Overview of Future Years Nuclear Security Program budget request for Weapons Activities in FY 2020 – FY 2025[a]

	Fiscal Year (dollars in millions)					
Activity	***2020 Enacted (Comp)***	***2021 Request***	***2022 Request***	***2023 Request***	***2024 Request***	***2025 Request***
Stockpile Management	3,680.1	4,284.2	4,562.5	4,612.6	4,723.3	5,182.2
Production Modernization	1,565.5	2,457.9	2,999.5	3,504.0	3,393.3	3,172.8
Stockpile Research, Technology, and Engineering	2,553.1	2,782.1	2,746.3	2,778.7	2,940.2	2,961.7
Infrastructure and Operations	3,199.5	4,383.6	3,944.8	3,674.6	3,784.8	3,839.8
Secure Transportation Asset	292.7	390.1	336.8	345.3	354.7	381.0
Defense Nuclear Security	775.0	826.9	916.5	880.1	939.9	932.8
Information Technology and Cybersecurity	300.0	375.5	387.3	394.0	403.4	415.2
Legacy Contractor Pensions	91.2	101.7	43.4	81.6	73.5	77.6
Adjustments	0.0	0.0	0.0	0.0	0.0	0.0
Weapons Activities Total	**12,457.1**	**15,602.0**	**15,937.0**	**16,271.0**	**16,613.0**	**16,963.0**

[a] Totals may not add because of rounding.

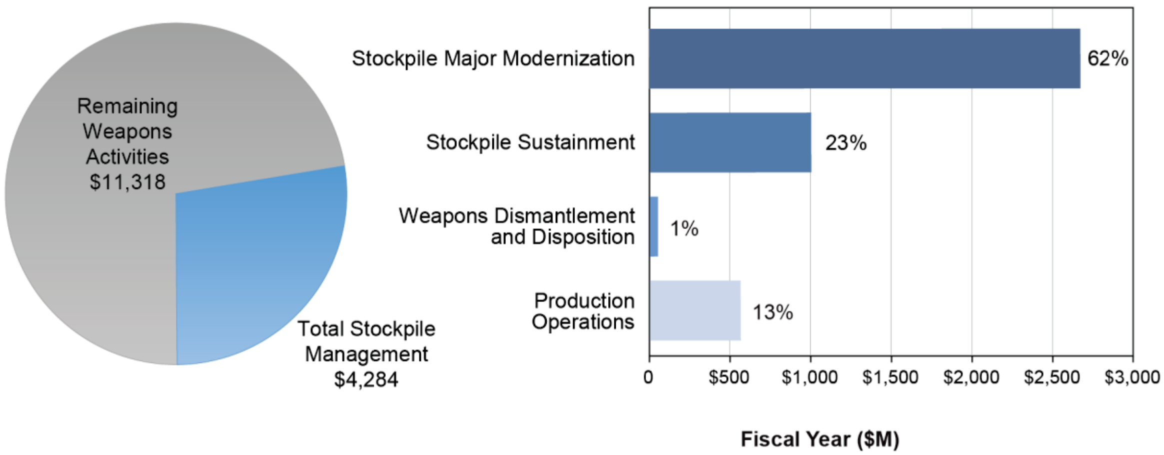
5.2 Stockpile Management

Stockpile Management encompasses four major subprograms that directly support the Nation's nuclear weapons stockpile: (1) Stockpile Major Modernization; (2) Stockpile Sustainment; (3) Weapons Dismantlement and Disposition (WDD); and (4) Production Operations. Stockpile Major Modernization extends the lifetime of the Nation's nuclear stockpile while addressing required updates, replacing aging or obsolete components for continued service life, and enhancing security and safety features. Stockpile Sustainment performs direct tail-specific and multi-system sustainment activities for all current weapons systems in the stockpile, including maintenance, surveillance assessment, development studies/capability improvements, and weapon program planning/support for each weapon system. WDD dismantles retired weapons and properly disposes of retired components from the stockpile. Production Operations provides common manufacturing processing services; maintenance and replacement of equipment; and calibration services common to the weapon programs for manufacturing operations to meet DoD War Reserve requirements.

5.2.1 Budget

The budget request for Stockpile Management increased 16 percent from the FY 2020 enacted budget (comparable) and is illustrated in **Figure 5–2**.

Stockpile Management Funding for FY 2021
(Dollars in Millions)



	2020	2021	2022	2023	2024	2025
Stockpile Major Modernization	2,117.4	2,666.9	2,830.3	2,840.6	2,897.9	3,353.5
Stockpile Sustainment	962.7	998.4	1,084.4	1,109.5	1,166.9	1,165.5
Weapons Dismantlement and Disposition	56.0	50.0	51.0	51.0	51.0	51.4
Production Operations	544.0	568.9	596.8	611.5	607.5	611.9
Total Stockpile Management	3,680.1	4,284.2	4,562.5	4,612.6	4,723.3	5,182.2

Note: Numbers may not add due to rounding

Figure 5–2. Funding schedule for Stockpile Management, FY 2020 – FY 2025

5.2.2 FY 2021 Budget Request Compared to FY 2020 Enacted Budget

5.2.2.1 Stockpile Major Modernization (previously Life Extension Programs and Major Alterations)

Stockpile Major Modernization was renamed from the Life Extension Programs (LEPs) and Major Alterations (Alts) Program in the Directed Stockpile Work Program budget restructure and contains the subprograms of: (1) B61 LEP; (2) W88 Alteration Program; (3) W80-4 LEP; (4) W87-1 Modification Program; and (5) W93. Stockpile Major Modernization encompasses the programs necessary to meet DoD warhead modernization requirements and for the projected 20- to 30-year in-service life.

The increased budget request for Stockpile Major Modernization principally represents the planned ramp-up of the W80-4 LEP to accomplish Phase 6.3 (Development Engineering) activities, Conceptual Design Reviews, production of warhead simulators/test units, and hydrodynamic physics tests to support nuclear certification; the planned ramp-up of the W87-1 Modification Program across all areas to complete Phase 6.2 (Feasibility Study and Design Options) deliverables before entry into Phase 6.2A (Design Definition and Cost Study); and the W93 planned Phase 1 (Concept Assessment) and refinement activities.

5.2.2.2 Stockpile Sustainment (previously Stockpile Systems)

Stockpile Sustainment is responsible for accomplishing sustainment activities for the total (active and inactive) stockpile for the B61, W76, W78, W80, B83, W87, and W88 weapons. The eighth subprogram, Multi-Weapon Systems, provides multi-weapon products across the nuclear security enterprise for maintenance (e.g., military spares, transportation equipment, and handling gear), surveillance (e.g., weapon system testing, component testing, and analysis), assessments (e.g., use control and weapon operations analysis), and management (e.g., integrated digital engineering databases and tools, weapons training, and military liaison).

The budget request for Stockpile Sustainment also supports:

- Development of new joint test assembly designs for the W76 and W78
- W87 Ground-Based Strategic Deterrent qualification and integration activities with DoD
- Development of improved shipping configurations (Integrated Surety Architecture activities) for weapons in transportation mode
- Preparation activities to sustain the B61-12 in the stockpile

5.2.2.3 Weapons Dismantlement and Disposition

WDD contains weapon dismantlements, safety studies on retired systems, material characterization, and the disposal of weapon parts.

The budget request for WDD, combined with the FY 2020 carryover, represents level work activities for weapon and canned subassembly dismantlements, recycle requirements, and reduction of legacy component inventories.

5.2.2.4 Production Operations (previously Production Support)

Production Operations was renamed from Stockpile Services, Production Support, in the budget restructure. It provides a manufacturing-based program that provides individual site production base capabilities for weapon modernization; maintenance, surveillance, assembly and disassembly; and safety and reliability testing.

The increased budget request for Production Operations represents continued growth to underpin the warhead modernization workload, assuring procedures and prerequisite process equipment are in place to meet warhead modernization first production unit requirements. The program will expand production line responsiveness to better sustain workload capacity for warhead modernization activities. The funding will also provide the processes needed to certify weapons and components, and the production schedule through product qualification.

5.2.3 Key Milestones

In order to sustain and modernize the stockpile, DOE/NNSA must meet the key Stockpile Management milestones illustrated in **Figure 5–3**.[2] Significant changes from last year's plan are:[3]

- The FY 2020 milestone, *Deliver first production unit of the W88 Alt 370,* was changed to FY 2021 by the Nuclear Weapons Council
- The FY 2022 milestone, *Complete Phase 6.2 activities for the W87-1 Mod Program,* was accelerated to FY 2021 by the FY 2018 *Nuclear Posture Review* and subsequent Nuclear Weapons Council implementation to meet program requirements
- The FY 2020 milestone, *Deliver first production unit of the B61-12 LEP*, was changed to FY 2022 by the Nuclear Weapons Council

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

[3] As a result of the FY 2021 budget structure change, some milestones previously captured under Directed the Stockpile Work are now under the Stockpile Research, Technology, and Engineering.

One milestone from last year's SSMP was completed in FY 2020:

- *Complete project closeout activities for the W76-1 LEP and W76-2 Modification Program*. The W76-1 LEP completed warhead production in December 2018 and deliveries to the Navy in April 2019, ahead of schedule and within planned budgets

There were no substantive changes to the remainder of the Stockpile Management milestones included in Figure 5–3.

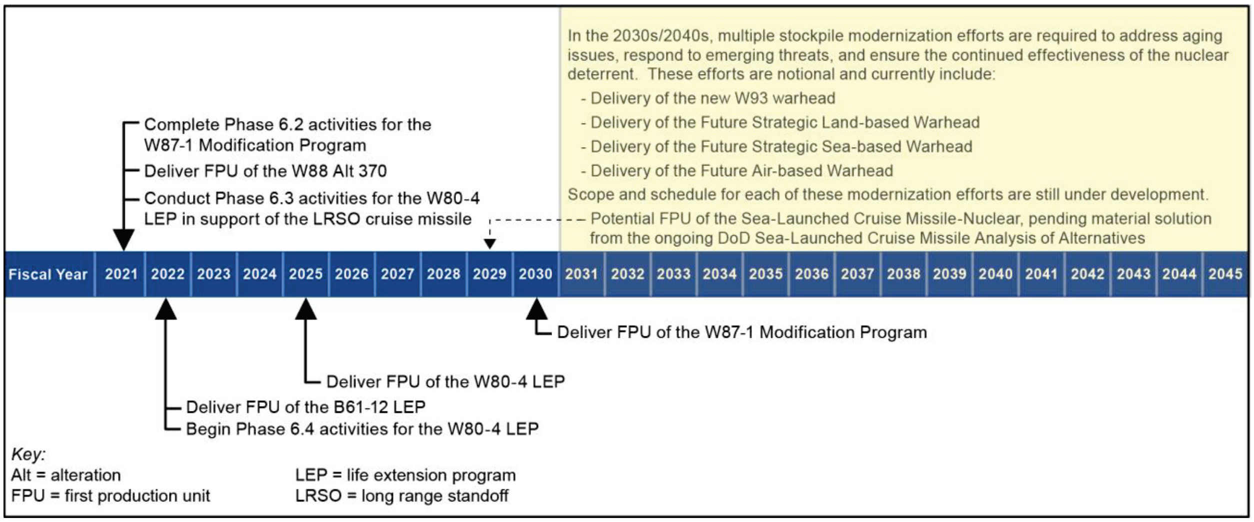


Figure 5–3. Key milestones for Stockpile Management

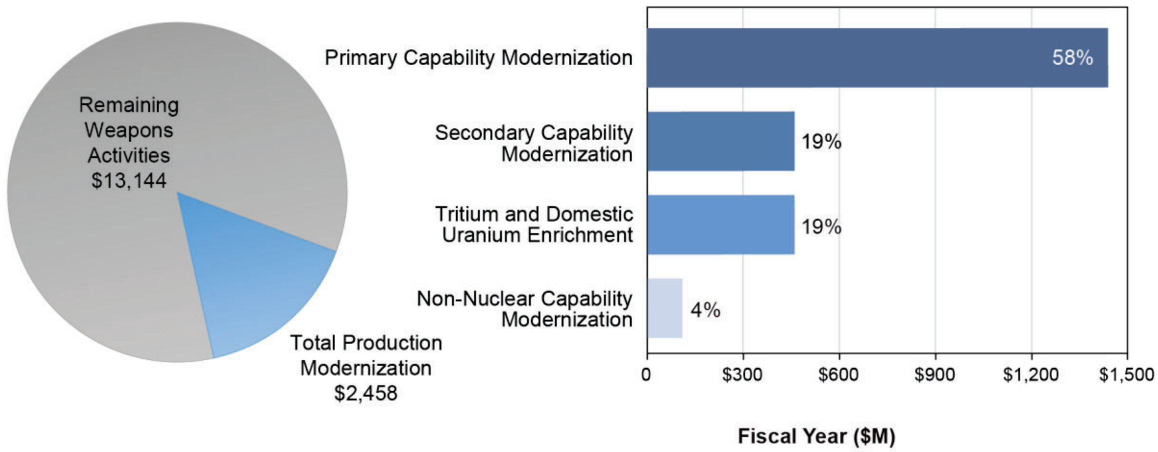
5.3 Production Modernization

Production Modernization is focused on production capabilities for nuclear weapons and consists of four major subprograms that sustain the Nation's principal nuclear weapons production capabilities: (1) Primary Capability Modernization; (2) Secondary Capability Modernization; (3) Tritium and Domestic Uranium Enrichment; and (4) Non-Nuclear Capability Modernization. Modernization efforts within this program focus on the capability to manufacture nuclear weapons components that are critical to weapon performance. The program's scope includes restoring and increasing strategic component manufacturing and processing capabilities across the national security enterprise to meet mission requirements.

5.3.1 Budget

The budget request for Production Modernization increased 57 percent from the FY 2020 enacted budget (comparable) and is illustrated in **Figure 5–4**.

Production Modernization Funding for FY 2021
(Dollars in Millions)



	2020	2021	2022	2023	2024	2025
Primary Capability Modernization	811.6	1,436.6	1,762.6	2,184.7	2,235.4	2,085.6
Secondary Capability Modernization	293.5	457.0	463.1	472.1	488.7	495.4
Tritium and Domestic Uranium Enrichment	446.5	457.1	612.3	731.7	572.0	499.4
Non-Nuclear Capability Modernization	13.9	107.1	161.6	115.5	97.2	92.4
Total Production Modernization	1,565.5	2,457.9	2,999.5	3,504.0	3,393.3	3,172.8

Note: Numbers may not add due to rounding

Figure 5–4. Funding schedule for Production Modernization, FY 2020 – FY 2025

5.3.2 FY 2021 Budget Request Compared to FY 2020 Enacted Budget

5.3.2.1 Primary Capability Modernization

Primary Capability Modernization consolidates management of nuclear material processing capabilities. The program includes (1) Plutonium Modernization (previously Plutonium Sustainment) and (2) High Explosives and Energetics. The Plutonium Modernization Program includes three subprograms: Los Alamos Plutonium Modernization, Savannah River Plutonium Modernization, and Enterprise Plutonium Support. The major construction projects for pit production at LANL (Plutonium Pit Production Project) and SRS (Savannah River Plutonium Processing Facility) are currently included under Primary Capability Modernization to encompass the full scope of the Plutonium modernization effort. These construction projects will eventually move to Infrastructure and Operations.

The budget request for this program increased to cover programmatic equipment investments and critical skills necessary to meet pit production process development and qualification activities. This increase will also provide for equipment installation at LANL to increase the pit production capability and invest in the infrastructure necessary to increase production capability to 30 pits per year during 2026. Funding for High Explosives and Energetics will support infrastructure modernization and establish a modern and robust production and manufacturing capability.

5.3.2.2 Secondary Capability Modernization

Secondary Capability Modernization is responsible for restoring and improving manufacturing capabilities for the secondary stage of nuclear weapons. The program includes three subprograms: (1) Uranium

Modernization[4] (previously Uranium Sustainment); (2) Depleted Uranium Modernization; and (3) Lithium Modernization (previously Lithium Sustainment).

The budget request for Secondary Capability Modernization increased to support new depleted uranium scope to meet near-term mission requirements and future weapon systems. This increase will also cover additional scope to supply the current stockpile with purified enriched uranium metal, and support the transition of new capabilities into modern and enduring uranium facilities. Funding for Lithium Modernization increased to process material for the B61-12 LEP and sustaining the current processing capability until the Lithium Processing Facility is operational.

5.3.2.3 Tritium and Domestic Uranium Enrichment

Tritium and Domestic Uranium Enrichment is responsible for producing tritium and supplying unobligated low enriched uranium to support DoD requirements. The program includes two subprograms: (1) Tritium Modernization (previously Tritium Sustainment) and (2) Domestic Uranium Enrichment.

The budget requests for Tritium Modernization and Domestic Uranium Enrichment increased to support ongoing activities including, but not limited to, continuing the down-blending campaign and continuing to preserve and advance uranium enrichment expertise and technology to meet current and future U.S. Government needs. Increases in Tritium Modernization will support increased tritium-producing burnable absorber rod irradiation and the ramp-up to full operations at the Tritium Extraction Facility, as well as tritium process R&D.

5.3.2.4 Non-Nuclear Capability Modernization

Non-Nuclear Capability Modernization provides funding to modernize production of non-nuclear components for use in multiple weapon systems. This program consolidates management and oversight of strategic investments in technology, equipment, infrastructure, tools, and materials. Specifically, the program focuses on improving and/or increasing the capability and capacity of the DOE/NNSA nuclear security enterprise to manufacture stockpile components in categories that include (but are not limited to) cable assembles, neutron generators, power sources, and gas transfer systems.

5.3.3 Key Milestones

To properly support the current and future nuclear deterrent mission, DOE/NNSA must invest in re-establishing production capabilities and modernizing programmatic infrastructure.[5] Key milestones for Production Modernization are in **Figure 5–5**.[6] Changes from last year's plan are:

[4] Uranium Modernization also includes the scope and funding for Process Technology Development, which was previously under Research Development, Test, and Evaluation's Advanced Manufacturing Development program.

[5] Although programmatic construction projects are funded through Infrastructure and Operations, milestones for relevant projects are included in this section for transparency. Many of the capabilities depend on the completion of programmatic construction projects to execute the mission.

[6] Key milestones beyond the FNYSP represent planned activities to meet DoD requirements and are contingent on future resource decisions.

Key milestone changes related to Production Modernization capabilities:

- The FY 2021 milestone, *Install development direct cast furnace,* was added
- The FY 2021 milestone, *Complete specification for insensitive high explosive (TATB/PBX-9502)*, was added
- The FY 2023 milestone *Obtain Critical Decision 4 (CD-4) (Approve Start of Operations or Project Completion) for the Y-12 plant electrorefiner*, was added
- The FY 2024 milestone, *Produce first War Reserve production lot of insensitive high explosive (PBX-9502)*, was added
- The FY 2024 milestone, *Produce a qualified binary ingot by restarting lapsed manufacturing processes*, was added

Key milestones changes related to production infrastructure:

- The FY 2021 milestone, *Obtain Critical Decision 3A (CD-3A; Approve Long Lead Item Procurements) for the Tritium Finishing Facility*, was added
- The FY 2021 milestone, *Provide the tooling and equipment, facility and infrastructure investments necessary to sustain the Microsystems Engineering, Science, and Applications Complex*, was added
- The FY 2021 milestone, *Obtain CD-1 (Approve Alternative Selection and Cost Range) for the Power Sources Capability Facility*, was added
- The FY 2021 milestone, *Obtain CD-1 (Approve Alternative Selection and Cost Range) for the Savannah River Plutonium Processing Facility*, was added
- The FY 2021 milestone, *Obtain CD-1 (Approve Alternative Selection and Cost Range) for the Plutonium Pit Production Project (LANL)*, was added
- The FY 2022 milestone, *Obtain Lithium Processing Facility CD-2/3 (Approve Performance Baseline/Approve Start of Construction),* was postponed to FY 2024
- The FY 2022 milestone, *Obtain CD-0 (Approve Mission Need) for the Tritium Development Laboratory*, was added
- The FY 2023 milestone, *Obtain CD-1 (Approve Alternative Selection and Cost Range) for the Domestic Uranium Enrichment production facility,* was postponed to FY 2024[7]
- The FY 2024 milestone, *Obtain CD-2/3 (Approve Performance Baseline/Approve Start of Construction) for the Tritium Finishing Facility*, was added
- The FY 2025 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for the High Explosives (HE) Science and Engineering Facility*, was added

[7] Depending on the outcome of the Analysis of Alternatives, DOE/NNSA may begin deployment of an enrichment pilot plant prior to obtaining CD-1 approval.

- The FY 2025 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for the HE Synthesis, Formulation, and Production Facility for future LEPs*, was added
- The FY 2026 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for Power Sources Capability*, was added
- The FY 2026 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for the Energetics Material Characterization,* was added[8]
- The FY 2027 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for the Lithium Processing Facility),* was postponed to FY 2031 to meet mission requirements
- The FY 2029 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for the Chemistry and Metallurgy Research Replacement Project*, was added
- The FY 2031 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for the Tritium Finishing Facility*, was added
- The FY 2037 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for the Heterogeneous Integration Facility*, was added
- The FY 2039 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for Neutron Generator Enterprise Consolidation*, was added
- The FY 2039 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for Domestic Uranium Enrichment*, was changed to FY 2040 as DOE/NNSA has identified additional quantities of material, pushing off the need date by one year

The milestones from last year's SSMP anticipated to be completed in FY 2020 are:

- *Re-establish lithium chloride conversion and purification process*
- *Complete Analysis of Alternatives for domestic uranium enrichment*
- *Obtain Technology Readiness Level 7 (TRL-7) for selected technologies for insertion into the Lithium Processing Facility* (previously scheduled in FY 2021) was accelerated to FY 2020 as the program is seeking an opportunity for TRL-6 technology insertion into the schedule with the least amount of impact

There were no substantive changes to the remainder of the Production Modernization milestones included in Figure 5–5.

[8] DOE/NNSA obtained CD-0, Achieve Mission Need, approval for the Power Sources Capability (PSC) facility in FY 2019 and for the Energetic Materials Characterization (EMC) facility in FY 2020. DOE/NNSA is working toward CD-4, Approve Start of Operations or Project Completion, approval for both projects in FY 2026 based on the clearly defined capability gap and mission need. The AoA process for EMC, Conceptual Design for PSC, and subsequent cost estimates for both will inform future budget planning profiles.

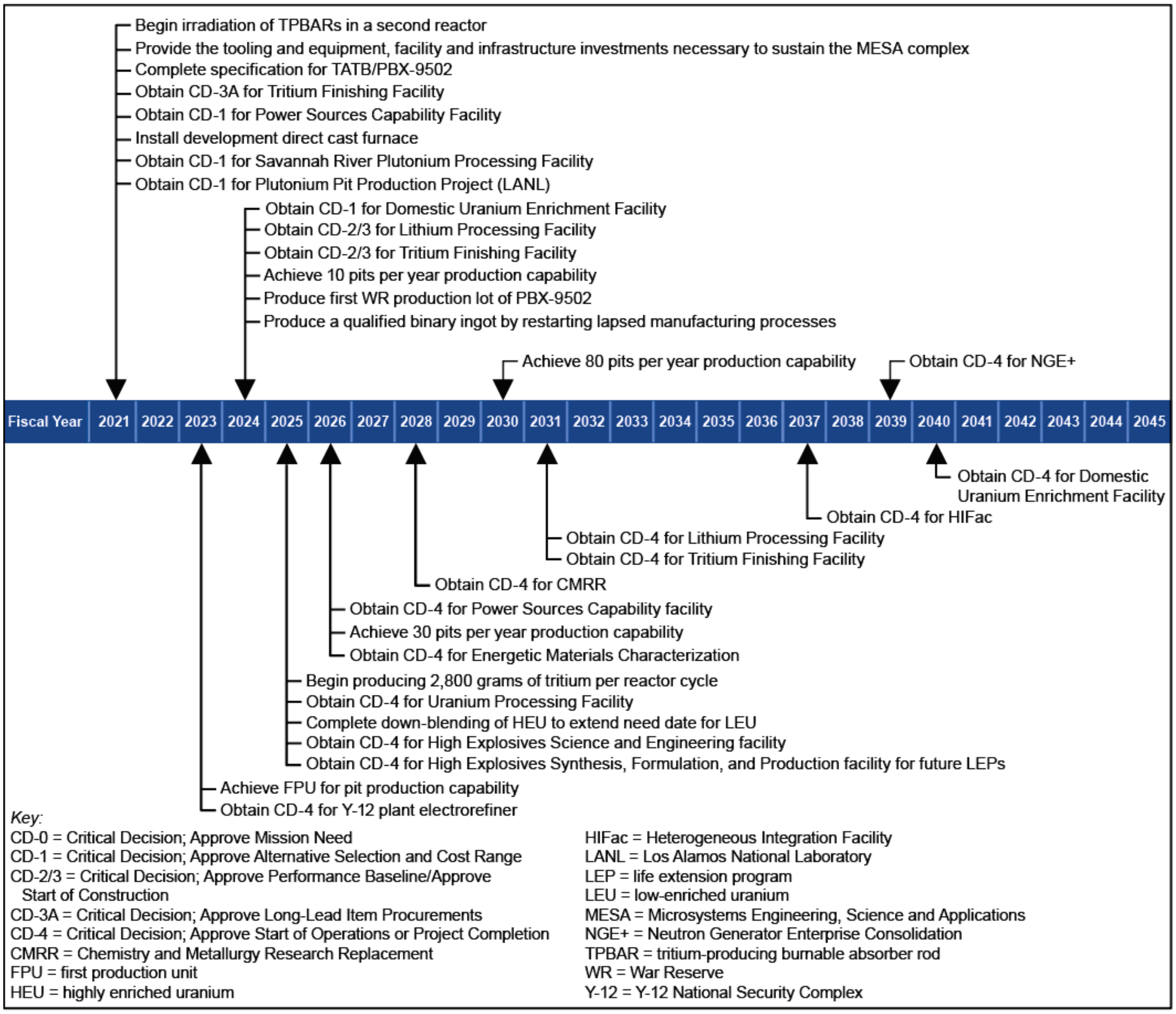


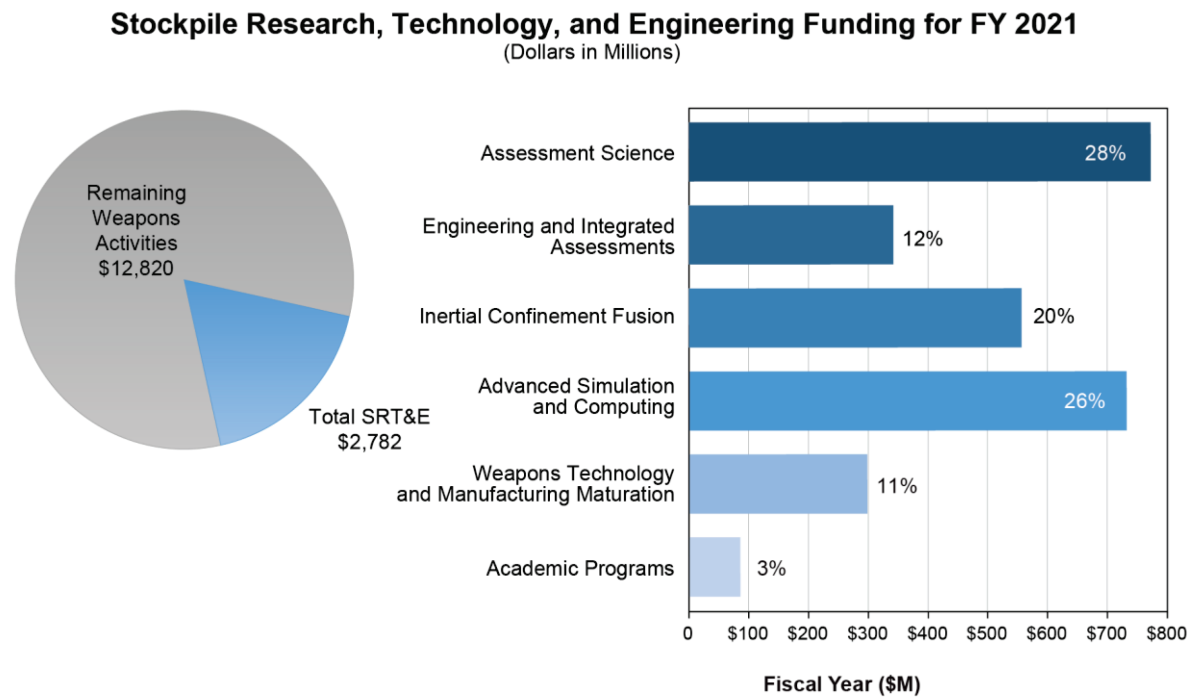
Figure 5–5. Key milestones for Production Modernization

5.4 Stockpile Research, Technology, and Engineering

Stockpile Research, Technology, and Engineering (SRT&E) provides the knowledge and expertise needed to maintain confidence in the nuclear stockpile without the need for additional nuclear explosive testing, previously within Research Development, Test, and Evaluation (RDT&E). SRT&E encompasses six major subprograms that support science-based stockpile stewardship, stockpile modernization, and continued assessment of the stockpile without additional explosive nuclear testing: (1) Assessment Science; (2) Engineering and Integrated Assessments; (3) Inertial Confinement Fusion (ICF); (4) Advanced Simulation and Computing (ASC); (5) Weapons Technology and Manufacturing Maturation; and (6) Academic Programs.

5.4.1 Budget

The budget request for SRT&E increased 9 percent from the FY 2020 enacted budget (comparable) and is illustrated in **Figure 5–6**.



	2020	2021	2022	2023	2024	2025
Assessment Science	594.8	773.1	739.9	727.5	730.1	699.4
Engineering and Integrated Assessments	325.1	337.4	348.9	362.7	373.7	381.3
Inertial Confinement Fusion	556.5	554.7	491.5	503.8	590.4	602.8
Advanced Simulation and Computing	767.8	732.0	765.3	761.2	773.3	783.9
Weapons Technology and Manufacturing Maturation	222.3	298.0	313.9	335.0	380.3	399.8
Academic Programs	86.5	86.9	86.7	88.6	92.5	94.4
Total SRT&E	2,553.1	2,782.1	2,746.3	2,778.7	2,940.2	2,961.7

Note: Numbers may not add due to rounding

Figure 5–6. Funding schedule for Stockpile Research, Technology, and Engineering, FY 2020 – FY 2025

5.4.2 FY 2021 Budget Request Compared to FY 2020 Enacted Budget

5.4.2.1 Assessment Science (previously Science)

Assessment Science provides the knowledge and expertise needed to maintain confidence in the nuclear stockpile in the absence of nuclear explosive testing. The program is comprised of six subprograms: (1) Primary Assessment Technologies; (2) Dynamic Materials Properties; (3) Advanced Diagnostics (previously Advanced Radiography); (4) Secondary Assessment Technologies; (5) Enhanced Capabilities for Subcritical Experiments (ECSE); and (6) Hydrodynamic and Subcritical Experiment Execution Support.[9] The base Subcritical Experiments (SCE) program moved from Dynamic Materials Properties to Primary Assessment Technologies to gain efficiencies and make the SCE program easier to execute.

The budget request for Assessment Science increased to address cost growth for planned FY 2025 completion of the Advanced Sources and Detectors Major Item of Equipment for the ECSE project to meet W80-4 LEP and W87-1 Modification Program needs. Funding also supports the execution of experiments for plutonium aging assessment using platforms such as the Joint Actinide Shock Physics Experimental

[9] Hydrodynamic and Subcritical Experiment Execution Support includes some scope and funding from Weapon Technology Development (previously Research & Development Certification & Safety).

Research gas gun, focused material studies in support of Plutonium Modernization, direct cast of uranium qualification, and investigations of aged canned subassemblies to aid in warhead and production modernization.

5.4.2.2 Engineering and Integrated Assessments (previously Engineering)

Engineering and Integrated Assessments supports system-agnostic survivability in present and future stockpile-to-target sequences. It also enables a responsive nuclear deterrent through collaborative partnerships, proactive integration, and assessments. This program includes seven subprograms: (1) Archiving and Support;[10] (2) Delivery Environments; (3) Weapons Survivability (previously Nuclear Survivability); (4) Studies and Assessments;[11] (5) Aging and Lifetimes (previously Enhanced Surveillance); (6) Stockpile Responsiveness; and (7) Advanced Certification and Qualification (previously Advanced Certification).

The budget request for Engineering and Integrated Assessments increased to continue development of engineering options for future weapon systems as well as supporting continued capabilities for the survivability of weapons in normal, abnormal, and hostile environments. It also provides the engineering foundation for engineering analyses in combined environments to increase safety and performance; continues investments in advanced diagnostics for non-destructive surveillance, increasing knowledge and reducing sustainment costs; studies aging effects and helps determine the lifetimes of stockpile components; accelerates the nuclear weapons life cycle; and explores new certification and qualification approaches for new and reused weapon components to reduce technical risk and time to field.

5.4.2.3 Inertial Confinement Fusion (previously Inertial Confinement Fusion Ignition and High Yield)

ICF provides expertise and capabilities in high energy density (HED) science, a key component of science-based stockpile stewardship. The program includes three subprograms: (1) HED and Ignition Science for Stockpile Applications (previously Ignition and Other Stockpile Programs and Pulsed Power ICF); (2) ICF Diagnostics and Instrumentation (previously Diagnostics, Cryogenics, and Experimental Support); and (3) Facility Operations (previously Facility Operations and Target Production).

The budget request for ICF addresses three areas:

- Support implementation of key findings from the ICF 2020 program reviews
- Focus ignition science campaigns on driving down barriers to understand necessary steps to demonstrate ignition
- Support full operations at the National Ignition Facility, the Z pulsed power facility, and the Omega Laser Facility to enable execution of the highest-priority weapons-relevant experiments

5.4.2.4 Advanced Simulation and Computing

ASC provides high-end simulation capabilities (e.g., modeling codes, computing platforms, and supporting infrastructure) to meet stockpile stewardship requirements. The program includes six subprograms: (1) Integrated Codes; (2) Physics and Engineering Models; (3) Verification and Validation; (4) Advanced

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[10] Archiving and Support includes some scope and funding from Research and Development Support, and Research and Development Certification and Safety.

[11] Studies and Assessments funds all future budget requests for pre-Phase 6.1 assessments, studies, and other activities. This new control level was directed by Congress in the *Energy and Water Development and Related Agencies Appropriations Act of 2020* with the purpose of improving oversight and visibility of all pre-Phase 6.1 activities by containing them under a single control level. It is unfunded in the FY 2021 budget request.

Technology Development and Mitigation; (5) Computational Systems and Software Environment; and (6) Facility Operations and User Support.

The budget request for ASC decreases in FY 2021 due to suspension of new development of all next-generation simulation capabilities while mature next generation code development and computing technologies are transitioned into the base program and older code and software tool packages are replaced.

5.4.2.5 Weapons Technology and Manufacturing Maturation

Weapons Technology and Manufacturing Maturation is responsible for developing agile, affordable, assured, and responsive technologies and capabilities for nuclear stockpile sustainment and modernization. It comprises three subprograms: (1) Surety Technologies (previously Enhanced Surety); (2) Weapon Technology Development;[12] and (3) Advanced Manufacturing Development (previously Additive Manufacturing and Component Manufacturing).

The budget request for Weapons Technology and Manufacturing Maturation increased to support the maturation of technologies, materials, and manufacturing processes for future weapon systems to reduce technical risk and time to field, including direct cast of uranium. The technology and production options are being developed on a timeline to ensure that they are sufficiently mature to be viable options for warhead modernization activities, with a goal of significantly reducing the time and technical risk of warhead and complex modernization. The program advances R&D of additively-manufactured (AM) feedstock and deposition processes, as well as qualification of AM parts and components. The increase also funds the next High Operational Tempo Sounding Rocket Flight Test (HOT SHOT) demonstration (see Chapter 3, Section 3.4.3.1), which will shorten the development, testing, and qualification timeline for new components and technologies and supports development of new, safer initiation technologies.

5.4.2.6 Academic Programs (previously Academic Alliances and Partnerships)

Academic Programs support students pursuing an education in science and engineering disciplines of critical importance to DOE/NNSA including: nuclear science, radiochemistry, the study of materials at extreme conditions, HED science, advanced manufacturing, and computational science. Through this support, the program facilitates a personnel pipeline for the enterprise, particularly in areas with little to no commercial interest. Academic Programs includes five subprograms: (1) Stewardship Science Academic Alliance; (2) Minority Serving Institution Partnership Program; (3) Joint Program in High Energy Density Laboratory Plasmas; (4) Computational Science Graduate Fellowships; and (5) Predictive Science Academic Alliance Program.

The budget request for Academic Programs meets growing needs to assure a strong and diverse base of national expertise and educational opportunities in specialized technical areas that uniquely contribute to modernization and stewardship of the nuclear stockpile.

5.4.3 Key Milestones

DOE/NNSA must meet key milestones in order to successfully develop and maintain the critical capabilities, tools, and processes needed to support science-based stockpile stewardship, refurbishment, and continued assessment of the stockpile without additional explosive nuclear testing. Key milestones for SRT&E are illustrated in **Figure 5–7**. As a result of the budget structure change, milestones that were previously shown separately in the former RDT&E sections have been consolidated into a single figure for

[12] Weapon Technology Development includes some of the scope and funding from Research and Development Support and Research and Development Certification and Safety.

SRT&E. Several lower-level milestones were removed for consistency with the level of detail in the other milestone sections. Major changes from last year's plan are:

- The FY 2021 milestone, *Obtain CD-3A approval for long-lead ECSE procurements,* was modified to *Obtain CD-3A (Approve Long-Lead Item Procurements) for ASD-Scorpius*
- The FY 2021 milestone, *Accept ATS-3/Crossroads computing platform,* was modified to reflect acceptance in FY 2022
- The FY 2022 milestone, *Complete Red Sage and Nimble subcritical experiment campaigns*, was added
- The FY 2023 milestone*, Design and demonstrate a light weight, modular weapon system architecture,* was added
- The FY 2024 milestone, *Provide a pulsed neutron source that supports radiographic and reactivity measures,* was modified to *Field a neutron source and detectors to obtain subcritical experiment reactivity measurements*
- The FY 2023 milestone, *Complete assembly of a 10-megaelectronvolt (MeV) neutron imaging machine at LLNL for plant installation* was modified to *Complete assembly of a 7-MeV neutron imaging machine at LLNL for plant installation* by FY 2025
- The FY 2025 milestone, *Establish sustainable ECSE capability at the Nevada National Security Site,* was modified to *Obtain CD-4 (Approve Start of Operations or Project Completion) for ASD-Scorpius*
- The FY 2026 milestone, *Conduct first test using Enhanced Capabilities for Subcritical Experiments*, was added

The milestone from the last SSMP anticipated to be completed in FY 2020 is:

- *Complete Exascale Class Computer Cooling Equipment (EC3E) project* (previously listed for completion in FY 2021)

There were no substantive changes to the remainder of the SRT&E milestones included in Figure 5–7.

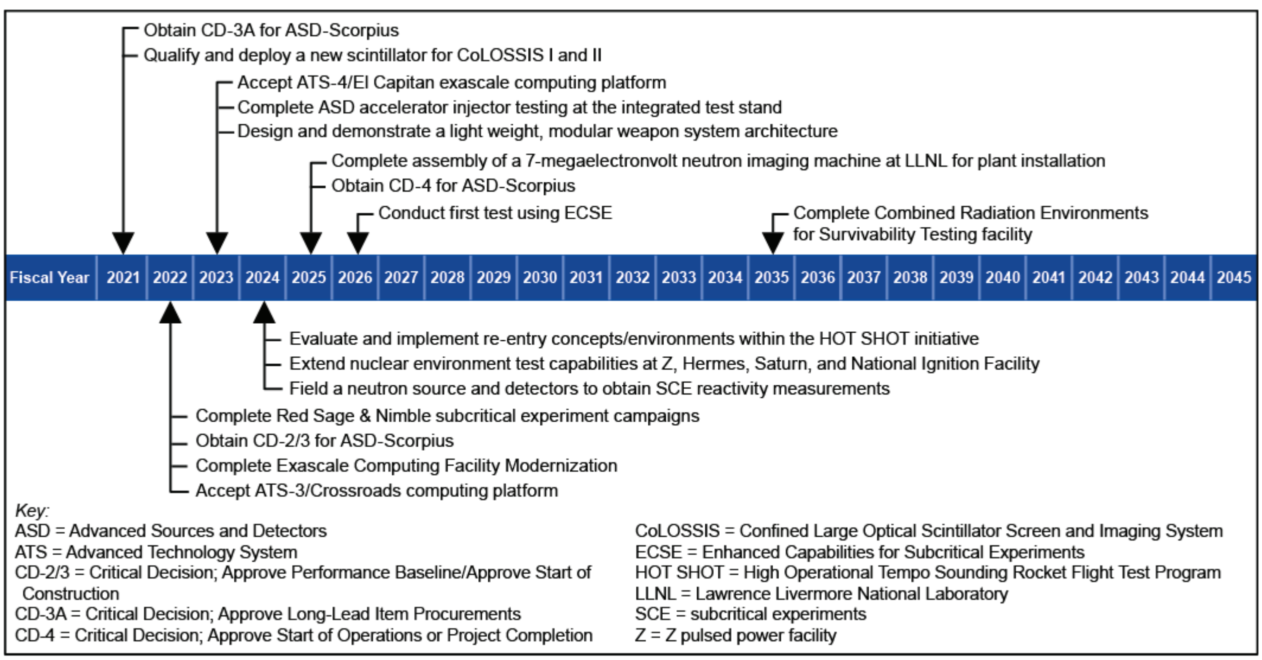


Figure 5–7. Key milestones for Stockpile Research, Technology, and Engineering

5.5 Infrastructure and Operations

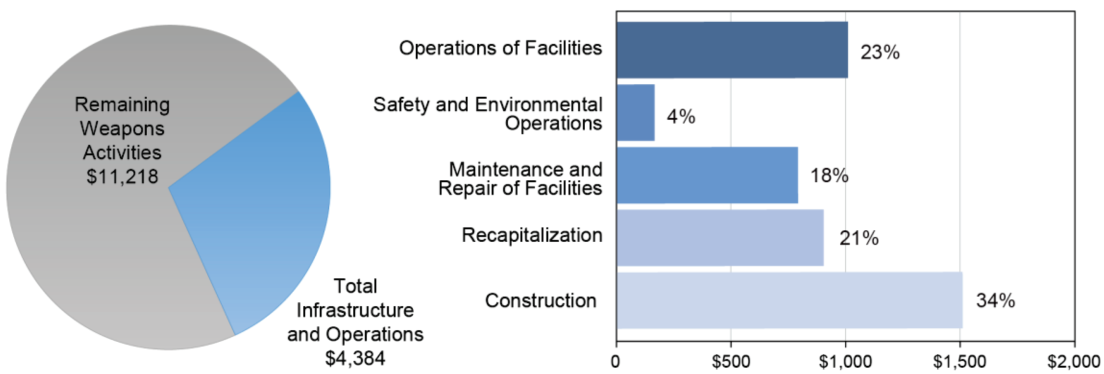
Infrastructure and Operations maintains, operates, and modernizes the DOE/NNSA infrastructure in a safe, secure, and cost-effective manner to maximize return on investment, enable program results, and reduce enterprise risk. The program also plans, prioritizes, and constructs state-of-the-art facilities, infrastructure, and scientific tools for the nuclear security enterprise. It includes: (1) Operations of Facilities; (2) Safety and Environmental Operations; (3) Maintenance and Repair of Facilities; and (4) Recapitalization.

The success of DOE/NNSA's unique national security missions is dependent upon safe, reliable, and modern infrastructure. However, the current state of DOE/NNSA's infrastructure poses increasing risk to availability, capacity, and reliability for Weapons Activities capabilities, as well as the safety of the workforce, the public, and the environment. Upgrading or replacing aging facilities will require significant and sustained investment.

5.5.1 Budget

The budget request for Infrastructure and Operations increased 37 percent from the FY 2020 enacted budget (comparable) and is illustrated in **Figure 5–8**.

Infrastructure and Operations Funding for FY 2021
(Dollars in Millions)



Fiscal Year ($M)

	2020	2021	2022	2023	2024	2025
Operations of Facilities	900.0	1,014.0	1,020.0	1,024.0	1,074.0	1,145.0
Safety and Environmental Operations	131.0	165.4	162.1	159.0	160.5	168.1
Maintenance and Repair of Facilities	456.0	792.0	795.0	798.0	800.0	803.0
Recapitalization	560.1	903.9	655.1	635.5	655.7	836.9
Construction	1,152.4	1,508.3	1,312.6	1,058.1	1,094.6	886.8
Total Infrastructure and Operations	3,199.5	4,383.6	3,944.8	3,674.6	3,784.8	3,839.8

Note: Numbers may not add due to rounding

Figure 5–8. Funding schedule for Infrastructure and Operations, FY 2020 – FY 2025

5.5.2 FY 2021 Budget Request Compared to FY 2020 Enacted Budget

5.5.2.1 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 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 30 pits per year production capability at LANL and additional leased space at KCNSC to meet warhead modernization schedules.

5.5.2.2 Safety and Environmental Operations

As a part of the FY 2021 budget request, Nuclear Materials Integration (NMI) moved from Directed Stockpile Work to Infrastructure and Operations. This realignment also includes funding realigned from the Material Recycle and Recovery program to NMI to continue support to the Material Managers at the sites currently providing NMI.

The budget request for Safety and Environmental Operations increased to support Long-Term Stewardship remedial activities associated with the Pantex groundwater contamination plume, which has migrated offsite and affected neighboring private properties. It also addresses packaging increases to support pit production efforts at LANL.

5.5.2.3 Maintenance and Repair of Facilities

The budget request for Maintenance and Repair of Facilities increased to support 30 pits per year production at LANL and to implement the *Nuclear Posture Review* infrastructure modernization plan. It supports current maintenance staffing levels to maintain and preserve facilities in a condition suitable to meet an increasing mission demand.

5.5.2.4 Recapitalization

Recapitalization is comprised of: (1) Infrastructure and Safety, (2) Capability Based Investments, and (3) Planning for Programmatic Construction (Pre-CD-1), a new subprogram. It funds minor construction projects, capital equipment, planning, Other Project Costs for Infrastructure and Operations-funded line-item construction projects, and deactivation and disposal of excess infrastructure.

The budget request for Recapitalization increased to meet 30 pits per year production capability at LANL, warhead modernization schedules at KCNSC, new office and laboratory space requirements to accommodate 9,000 additional staff, and to implement the 2018 *Nuclear Posture Review* infrastructure modernization requirements. It also funds new programmatic equipment recapitalization requirements to support the W87-1 Modification Program and W80-4 LEP. The Planning for Programmatic Construction (Pre-CD-1) subprogram consolidates funding to the planning activities necessary to approve mission need and approve alternative selection and cost range for a portfolio of mission needs and related project proposals at multiple DOE/NNSA sites: Power Sources Capability, SNL; Combined Radiation Effects Survivability Testing, SNL; Next Generation LEP Component Fabrication Facility, LLNL; Kauai Test Facility Launch Sustainment, SNL-HI; and Energetic Materials Characterization, LANL.

5.5.2.5 Construction

In the new budget structure, line-item construction projects are categorized as either Programmatic Construction or Mission-Enabling Construction.

The budget request for Programmatic Construction includes funding in FY 2021 for:

- Lithium Processing Facility, Y-12
- Tritium Finishing Facility, SRS
- Exascale Computing Facility Modernization Project, LLNL
- U1a Complex Enhancements Project, Nevada National Security Site
- TA-55 Reinvestment Project, Phase 3, LANL

- HE Science and Engineering Facility, Pantex
- HE Synthesis, Formulation and Production, Pantex
- Transuranic Liquid Waste Facility, LANL
- Uranium Processing Facility, Y-12
- Chemistry and Metallurgy Research Replacement Project, LANL

The budget request for Mission-Enabling Construction includes funding in FY 2021 for:

- 138-kilovolt Power Transmission System Replacement, Nevada National Security Site
- Emergency Operations Center, LLNL
- Emergency Operations Center, SNL

Additional information on planned infrastructure investments can be found in Chapter 4, "Infrastructure and Workforce."

5.5.3 Key Milestones

Key milestones for Programmatic Construction are shown in the relevant program sections, as many of the capabilities depend on completion of line-item projects to execute their designed mission. Schedules for the highest-priority Programmatic and Mission-Enabling project proposals are displayed in Figures 4–2 through 4–4. Projects proposed within the FYNSP include higher-fidelity estimates; some planned projects in the out-years may convert to alternative strategies once each respective Analysis of Alternatives is completed.

Per the *National Defense Authorization Act for Fiscal Year 2018*, DOE/NNSA established the Infrastructure Modernization Initiative (IMI) program to reduce deferred maintenance (DM) and repair needs by no less than 30 percent by 2025. The IMI will be carried out under the current budget structure by the Recapitalization: Infrastructure and Safety and Maintenance and Repair of Facilities programs. The initial plan was transmitted to Congress in September 2018.

5.5.4 Infrastructure Maintenance and Recapitalization Investments

As part of the IMI, DOE/NNSA has deployed BUILDER, a system developed by the Army Corps of Engineers and recognized by the National Academy of Sciences as a best-in-class practice for infrastructure management. The BUILDER system uses comprehensive inventory, life-cycle, cost, and assessment data and risk-informed standards and policies to recommend repairs and replacements at the most opportune time, thus improving DOE/NNSA's ability to pinpoint and prioritize investments. Historical approaches greatly underestimated the replacement plant value (RPV) of DOE/NNSA's facilities. Using BUILDER-based calculations provides a more accurate and transparent understanding of DOE/NNSA's infrastructure. The DM costs are tied to the RPV (it costs more to repair a more expensive facility); therefore, as expected, DM increased with the deployment of the new approach. As depicted in **Table 5–2**, the ratio of DM to RPV has decreased, which is an indication that recent investments have been successful.

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

Metric	FY 2017	FY 2018	FY 2019
RN	$5.2B	$5.1B	$8.9B
DM	$2.5B	$2.5B	$4.8B
RPV	$52.4B	$55B	$124.3B
RN/RPV Ratio	9.92%	9.27%	7.16%
DM/RPV Ratio	4.80%	4.63%	3.85%

RN = Repair Needs
DM = Deferred Maintenance
RPV = Replacement Plant Value

In response to GAO recommendations, this information is provided to improve transparency in the budget. **Table 5–3** compares investments in Maintenance and Recapitalization to benchmarks (based on the percentage of RPV) derived from the DOE Real Property Asset Management Plan and associated guidance. To address these benchmark shortfalls, DOE/NNSA has increased recapitalization investments by $236 million from FY 2020 to FY 2021. Recapitalization continues to include deactivation and demolition of excess and underutilized facilities to reduce the NNSA footprint. Maintenance investments reflect an increase of $342 million from FY 2020 to FY 2021. Overall funding for maintenance has grown significantly, but appropriately, over the last several years. This increase will support current maintenance staffing levels to maintain and preserve facilities in a condition that is 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 2021 DOE/NNSA infrastructure maintenance and recapitalization investments

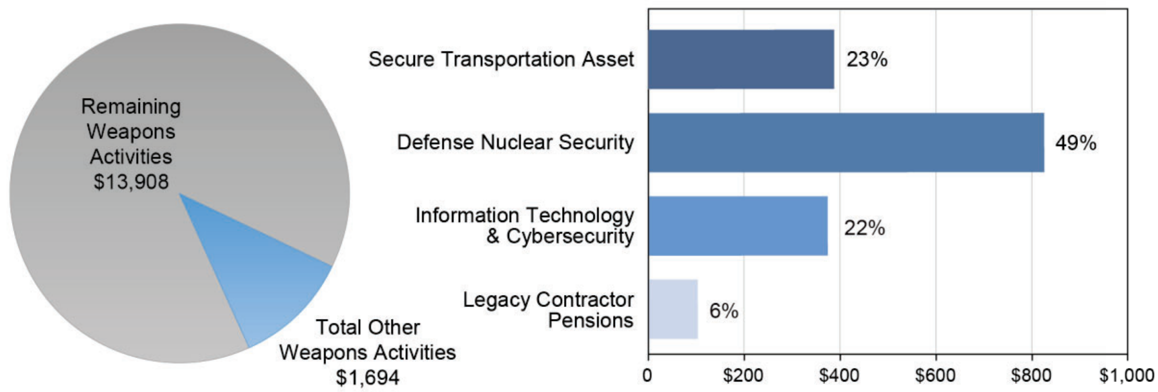
		FY 2019	FY 2020	FY 2021
Replacement Plant Value (RPV) ($B)		124.3	125.3	126.3
Maintenance Benchmark 2 – 4% RPV	Infrastructure & Safety Maintenance Investments ($K)	515,000	456,000	792,000
	Other NNSA Maintenance Investments (direct and indirect funded) ($K)	284,922	298,008	304,266
	Total NNSA Maintenance Investments (SK)	799,922	754,008	1,096,266
	Maintenance as % RPV	0.64%	0.60%	0.87%
Recapitalization Benchmark 1%	Infrastructure & Safety Recapitalization Investments ($K)	450,000	447,657	670,000
	Other NNSA Recapitalization Investments ($K)	109,057	135,341	149,117
	Total NNSA Recapitalization Investments ($K)	559,057	582,998	819,117
	Recapitalization as % RPV	0.45%	0.47%	0.65%

5.6 Other Weapons Activities

5.6.1 Budget

The funding schedule for Other Weapons Activities is illustrated in **Figure 5–9**.

Other Weapons Activities Funding for FY 2021
(Dollars in Millions)



Fiscal Year ($M)

	2020	2021	2022	2023	2024	2025
Secure Transportation Asset	292.7	390.1	336.8	345.3	354.7	381.0
Defense Nuclear Security	775.0	826.9	916.5	880.1	939.9	932.8
Information Technology & Cybersecurity	300.0	375.5	387.3	394.0	403.4	415.2
Legacy Contractor Pensions	91.2	101.7	43.4	81.6	73.5	77.6
Total Other Weapons Activities	1,458.9	1,694.1	1,684.0	1,701.1	1,771.4	1,806.5

Note: Numbers may not add due to rounding

Figure 5–9. Funding schedule for Other Weapons Activities, FY 2020 – FY 2025

5.6.2 Secure Transportation Asset

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

5.6.2.1 FY 2021 Budget Request Compared to FY 2020 Enacted Budget

The budget request for Operations and Equipment increased 44 percent due to continued design, testing, and assembly of the Mobile Guardian Transporter (MGT), upgrade/redesign of the Tractor Control Unit, and life-cycle replacement of aircraft.

The budget request for Program Direction increased 15 percent to sustain and maintain the manpower to meet requirements and support mission capacity, as well as to support an increase in workers' compensation claims (resulting from a non-mission accident), travel, and cost of inflation.

5.6.2.2 Key Milestones

Aging transportation assets must be replaced to meet and maintain convoy safety and security requirements. The STA milestones illustrated in **Figure 5–10** will enable DOE/NNSA to support evolving transportation requirements for the current and future stockpile. There are two changes from last year's plan:

- The FY 2020 milestone, *Design and begin production of the next Generation Armored Tractor (T4) and Escort Vehicle (EV4)*, was postponed to FY 2021 due to changes in contract requirements that were based on the original procurement plan
- The FY 2020 milestone to award the contract for EV4 was not completed in FY 2020 due to changes in contract requirements and COVID-19 restrictions. The contract award is projected to be completed by the third quarter FY 2021, based on the EV4 Master Schedule

There were no substantive changes to the remainder of the STA milestones illustrated in Figure 5–10.

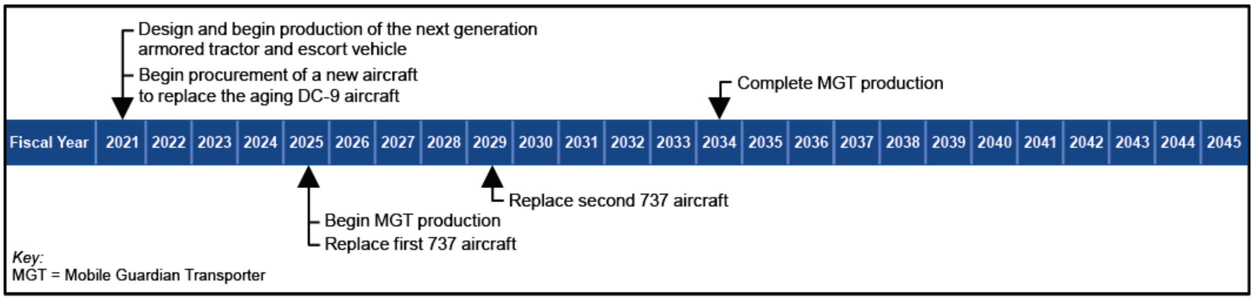


Figure 5–10. Key milestones for Secure Transportation Asset

5.6.3 Defense Nuclear Security

DOE/NNSA missions must be carried out in a secure environment protected by safeguards and security personnel, layers of physical security systems and technology, and sophisticated cybersecurity systems. Together, this approach protects DOE/NNSA's facilities, special nuclear material (SNM), employees, key networks, and information resources.

5.6.3.1 FY 2021 Budget Request Compared to FY 2020 Enacted Budget

The budget request for Defense Nuclear Security (DNS) increased based on additional security requirements associated with growth across the nuclear security enterprise, including plutonium pit production efforts. The additional costs also complete implementation and sustain operation of counter unmanned aircraft systems (CUAS) at sites possessing Category 0/I SNM, as well as support the Physical Security Center of Excellence and the Center for Security Technology, Analysis, Response and Testing. The funding also supports planned equipment lifecycle replacements across the enterprise, and implement upgrades to NNSA's Special Access Program classified network.

Funding for the DNS construction project, 17-D-710, the West End Protected Area Reduction, decreased due to receipt of funding in FY 2020.

5.6.3.2 Key Milestones

The 10-Year Physical Security Systems Refresh Plan, which was sent to Congress in August 2017, is being implemented through the Security Infrastructure Revitalization Program (SIRP). The SIRP refreshes security infrastructure across the enterprise based on a long-range plan that is modified periodically based on DOE/NNSA's budget, mission, and needs.

The DNS milestones illustrated in **Figure 5–11** are directly linked to modernization of the national security infrastructure and will assure that DOE/NNSA mission requirements for the current and future stockpile are carried out in a safe and secure environment. Changes from last year's plan are:

- The FY 2024 milestone, *Complete Los Alamos National Laboratory Perimeter Intrusion Detection and Assessment System (PIDAS)*, was added
- The FY 2025 milestone, *Complete Savannah River Site PIDAS*, was added
- The FY 2026 milestone*, Complete Pantex PIDAS physical security system components and infrastructure refresh for Zone 12*, was updated
- The FY 2028 milestone, *Complete Pantex PIDAS physical security system components and infrastructure refresh for Zone 4*, was added
- *The FY 2030 milestone, Complete* first iteration of SIRP, was postponed to FY 2035

The milestones from the last SSMP anticipated to be completed in FY 2020 are:

- *Complete deployment of Argus Security System as the standard access control and alarm system at all Category 1 SNM sites*
- *Complete CUAS implementation and sustain operations at sites possessing Category 0/1 quantities of SNM*
- *Complete Design Basis Threat analysis for remaining NNSA Category 1 sites*

There were no substantive changes to the remainder of the DNS milestones included in Figure 5–11.

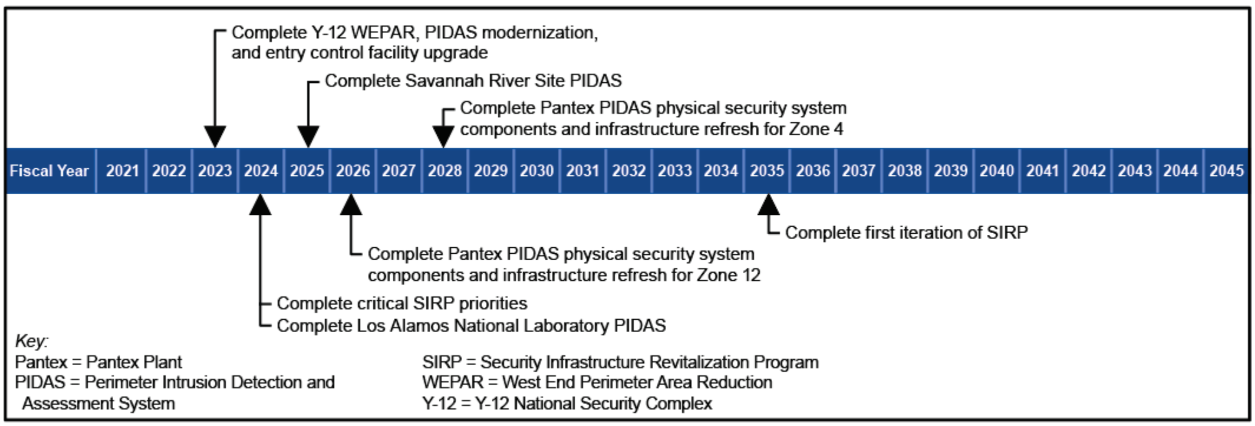


Figure 5–11. Key milestones for Defense Nuclear Security

5.6.4 Information Technology and Cybersecurity

IT and Cybersecurity is focused on developing integrated IT initiatives that provide an effective technology infrastructure and support to the nuclear security enterprise shared services. These initiatives will fundamentally redesign DOE/NNSA IT environments to provide a more secure and agile set of capabilities including unified communication, agile cloud infrastructure, and next-generation collaboration services across the nuclear security enterprise.

5.6.4.1 FY 2021 Budget Request Compared to FY 2020 Enacted Budget

The budget request for IT and Cybersecurity increased 25 percent to continue planned modernization efforts. The budget increase assures that DOE/NNSA can meet requirements necessary to sustain continuous enhancement of cybersecurity and IT operations.

As DOE/NNSA mission requirements expand in scope, complexity and budget, IT and Cybersecurity programs require modernization, expansion, and innovation. Increases in the IT and Cybersecurity budget are at a level that implements strategic protections. Cybersecurity is a defense/deterrence mechanism and a powerful tool. In the evolving threat environment, DOE/NNSA must maintain an aggressive approach to cyber defense capabilities protecting information, systems, and networks on which DOE/NNSA depends for mission support and execution.

5.6.4.2 Key Milestones

The milestones in **Figure 5–12** are necessary steps toward achieving a fully modernized IT infrastructure and cybersecurity posture for the nuclear security enterprise. Changes from last year's plan are:

- The FY 2021 milestone, *Develop phase II system architecture for modernizing the Enterprise Secure Computing (ESC) environment*, was added
- The FY 2021 milestone, *Implement special network access*, was added
- The FY 2021 milestone, *Implement the DOE/NNSA Application Modernization Strategy,* was added
- The FY 2021 milestone, *Implement a Telecommunications Security Program within DOE/NNSA,* was added
- The FY 2021 milestone, *Complete the modernization of the Information Assurance Response Center (IARC) cybersecurity infrastructure,* was added

The milestones from the last SSMP anticipated to be completed in FY 2020 are:

- *Complete deployment of a new sensor platform across all DOE/NNSA sites*
- *Complete LLNL Phase I of hybrid cloud platform for the Enterprise Secure Computing (ESC) cloud environment*
- *Complete SNL Phase I of hybrid cloud platform for ESC cloud environment testing*
- *Establish East Coast Data Center for secondary hybrid cloud platform for ESC cloud environment*
- *Implement Phase I of IT Modernization Plan*

There were no substantive changes to the remainder of the IT and Cybersecurity milestones illustrated in Figure 5–12.

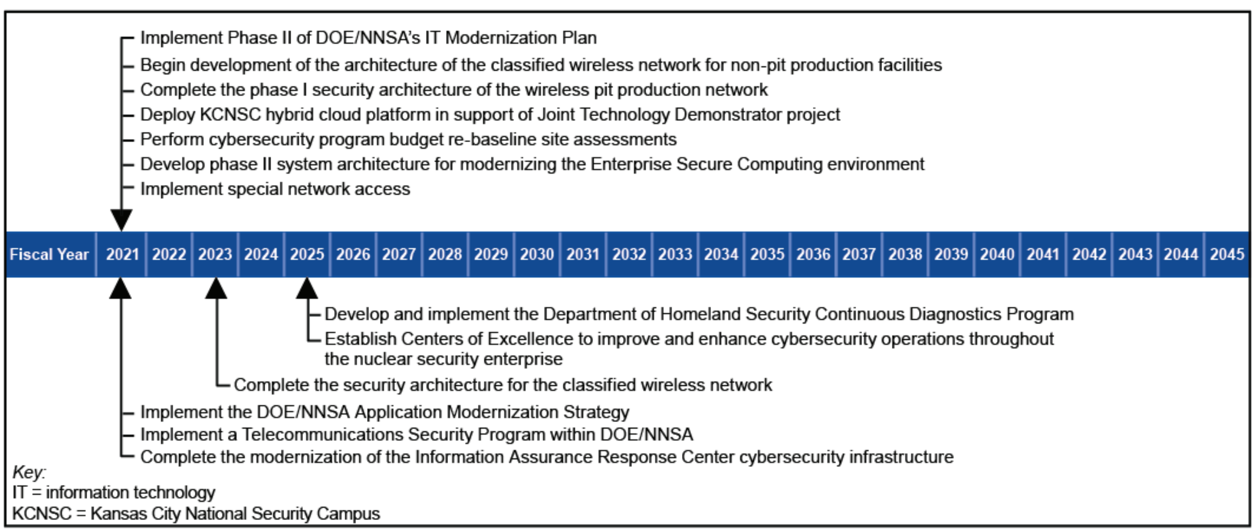


Figure 5–12. Key milestones for Information Technology and Cybersecurity

5.7 Budget Projections Beyond FY 2025

This section explains the cost estimation methodology that DOE/NNSA uses to create long-term budget projections. These projections are used to evaluate, over a longer timeframe than considered in the FYNSP and during programming activities, the total required resources to accomplish the program of record, how those resources are allocated, and the overall affordability of the program (see Section 5.8).

5.7.1 Basis for Budget Projections

For most of Weapons Activities, the FY 2021 – FY 2025 budget request was generated as part of the DOE/NNSA planning and programming process and reflects a roll-up of individual estimates developed interactively by Federal program managers and DOE/NNSA's management and operating (M&O) partners using historical cost data, current plans for programs and projects, and expert judgment. The budget requests for Stockpile Major Modernization programs are informed by the processes described in Section 5.7.3. The budget estimates for FY 2026 and beyond reflect the costs of continuing the program of record described in this SSMP while sustaining and enhancing the Weapons Activities capabilities that are essential to executing the program of record.

The budget projections beyond the FYNSP are based on requirements and will vary, depending on the individual program or subprogram. Some portions of the Weapons Activities portfolio are assumed to continue beyond the FYNSP at the same level of effort as during the FYNSP.[13] For these cost projections, such as for Stockpile Sustainment, an escalation factor of three percent was applied to account for annual labor rate increases at M&O sites, which are typically higher than inflation rates.

Some portions of the program will not proceed at the same level of effort from FY 2026 through FY 2045. This applies primarily to Stockpile Major Modernization programs and major programmatic construction projects. The estimates and the basis for each of these elements of the Weapons Activities portfolio are described in these next sections.

5.7.2 Sustaining the Current Stockpile

Costs associated with Stockpile Sustainment include warhead-specific assessment activities, limited life component exchanges, required and routine maintenance, safety studies, periodic repairs, resolution and timely closure of significant finding investigations, military liaison work, and surveillance for continued safety, security, and effectiveness of the stockpile. These costs are incurred every year that a weapon is in the stockpile and can vary based on the number of warheads or types of warheads in the stockpile. DOE/NNSA is considering developing a new cost-estimating strategy to appropriately account for these variables. For the purpose of this SSMP, Stockpile Sustainment program costs are projected using the same escalation factor as other level of effort programs.

5.7.3 Stockpile Major Modernization

Stockpile Major Modernization programs have the goal of extending the lives of warheads for several more decades. Figure 2–1 in Chapter 2, "Managing the Stockpile," provides a summary of planned Stockpile Major Modernization activities.

The next sections summarize cost estimates for Stockpile Major Modernization programs within the current 25-year period. The basis for the cost estimates varies from those using top-down cost models (such as analogy comparisons to past work completed, parametric relationships, and subject matter

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

expert judgment) to those using bottom-up models (deterministic, unit cost, and activity-based), depending on where the warhead program is in the *Phase 6.x Process*.

5.7.3.1 Cost Estimates across the *Phase 6.x Process*

Cost estimates for the B61-12 LEP, W88 Alt 370, W80-4 LEP and W87-1 Modification Program follow the *Phase 6.x Process*.[14] **Figure 5–13** delineates the governing cost estimate type for each phase of the *Phase 6.x Process*. DOE/NNSA works in conjunction with DoD and M&O partners to develop, refine, and update the estimates throughout the *Phase 6.x Process*.

Phase 6.1	Phase 6.2	Phase 6.2A[1]	Phase 6.3[1]	Phase 6.4[1]	Phase 6.5[1]	Phase 6.6
Concept Assessment	Feasibility Study & Design Options	Design Definition & Cost Study	Development Engineering	Production Engineering	First Production	Full-Scale Production
Management and Budget Cost 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 6.2A and independent cost estimates prior to entry in Phases 6.3, 6.4 and 6.5.

Figure 5–13. Cost estimates across the *Phase 6.x Process*

Prior to 2020, DOE/NNSA published a Defense Programs independent cost estimate for each system in the SSMP. Under the current reorganization, the DOE/NNSA Office of Management and Budget, Office of Analysis and Evaluation continues to develop and publish these Management and Budget planning cost estimates (Management and Budget cost estimates) for the SSMP.[15] These cost estimates can be initiated at very early design maturity, often well before Phase 6.1 [Concept Assessment], and are planning estimates for alternatives analysis, early programming, and budget deliberations. Management and Budget Stockpile Major Modernization planning cost estimates are:

- Performed by an organization separate from the Federal program office[16]
- Based on a known scope and cost uncertainty at the time and updated annually for the SSMP[17]
- Inclusive of 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 and DoD costs)[18]
- Unconstrained by future budget availability, which may differ from future budget requests

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[14] The *Phase 6.x Process* is based on the Joint Nuclear Weapons Life-Cycle Phases developed in coordination with DoD. In the Joint Nuclear Weapons Life-Cycle Phases, Phase 6 refers to "Quantity Production and Stockpile Maintenance & Evaluation." DOE/NNSA has followed the *Phase 6.x Process* for planning Stockpile Major Modernization programs to date.

[15] Under the current reorganization, all independent cost estimates will be conducted by the Office of Cost Estimating and Program Evaluation.

[16] GAO extolls the value of cost estimates using a different methodology and the potential benefit to decision-makers in the *GAO Cost Estimating and Assessment Guide*.

[17] Planning estimates assume scopes that are in line with current policy objectives (such as a commitment to surety upgrades) in addition to extending the warhead life. The Nuclear Weapons Council approves the specific scope for the weapon modernization program based on the alternatives developed during Phase 6.2. 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.

[18] 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.

These cost estimates are enumerated in the SSMP until the Weapon Design and Cost Report (WDCR) is approved. The estimate methodology is described in more detail in Section 5.7.3.2.

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

The Baseline Cost Report (BCR), which is also developed by the program team, formally updates the WDCR based on late development and pre-production activities. The BCR is updated based on refined scopes and schedule definitions and represents a more definitive cost estimate than either the MB cost estimate or WDCR. The NNSA Administrator approves a program baseline, including the WDCR, 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 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 Phases 6.3, 6.4 (Production Engineering), and 6.5 (First Production).

5.7.3.2 Management and Budget Cost Estimating Methodology

The Management and Budget cost estimates for Stockpile Major Modernization programs are developed four ways:

- Performed using a "top-down" analogy method that is consistent with early-stage planning[19]
- Informed by ongoing and past program costs (such as the development of the W76-1, B61-12, W88 Alt 370, and production of the W76-1) and the evaluation of the relative complexities of future systems[20]
- Based on time-phased development[21] costs using a standard profile[22] as well as production costs using a nonlinear cost growth profile similar to that of the W76-1
- Based on technical and programmatic inputs from Federal Program Managers, Federal site offices, and subject matter experts across the national security laboratories and nuclear weapons production facilities

Cost ranges reflect the underlying technical and modeling uncertainties of the programmatic scope at the time. During the early stages of warhead acquisitions (Phases 1/6.1 and Phases 2/6.2), designs may experience scope changes due to ongoing down-select decisions regarding threshold and objective requirements, which may result in cost changes compared to those reported in previous SSMPs. These ranges will typically be greatest for earlier-stage programs and narrow over time. The cost estimates for

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

[20] These program and subject matter experts evaluate the relative scope complexity between the complete W76-1 and near-complete B61-12 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.

[21] Development costs include all national nuclear security laboratory and production development costs, which is how DoD defines RDT&E and is consistent with Rayleigh profile usage in cost estimating.

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

future systems with little design definition were based on the W87-1 estimate with an expanded range due to uncertainty in scope and quantities and the escalation rate so far in the future.

5.7.3.3 Current Estimates

Figures 5–15 through 5–18 and Tables 5–5 through 5–13 provide cost estimates for each Stockpile Major Modernization program for the 25-year SSMP timeframe. **Table 5–4** delineates the type of cost estimate for each of the warhead modernization programs included in the 25-year SSMP. Additional details on the basis for each estimate are provided for each individual program in Sections 5.7.3.4 through 5.7.3.11.

Table 5–4. Cost estimates for life extension programs and major alterations within the 25-year program of record[23]

Life Extension Program, Major Alteration, or Modification Program	*Type of Cost Estimate*	*Total Estimated Cost (FY 2020 dollars in billions)*	*Total Estimated Cost (then-year dollars in billions)*
W76 LEP	BCR/SAR	4.2	3.5
W76-2 Modification Program	BCR/SAR	0.075	0.075
B61-12 LEP	BCR/SAR[24]	8.4	8.3
W88 Alt 370	BCR/SAR[25]	2.9	2.8
W80-4 LEP	WDCR/SAR[26]	9.7	11.0
W87-1 Modification Program	MB Cost Estimate	11.1	13.8
W93	MB Cost Estimate	14.2	18.2
Future Strategic Land-Based Warhead	MB Cost Estimate	14.2	19.2
Future Strategic Sea-Based Warhead	MB Cost Estimate	14.2	20.5
B61 Follow-On	MB Cost Estimate	14.2	26.3

BCR/SAR = Baseline Cost Report/Selected Acquisition Report
MB = Management and Budget
WDCR = Weapon Design and Cost Report

A summary table with high, low, and nominal (proposed budget or BCR/SAR value) estimates for DOE/NNSA and DoD, in both constant FY 2020 and then-year dollars, is listed for each Stockpile Major Modernization program. Where appropriate, the tables also include pre-SAR values for pre-Phase 6.2 costs.[27] The low estimates presented in the tables and graphs as the green line represent the mid-point (p50) of the cost estimate. The high estimates continue to represent the 85 percent (p85) for the B61-12, W88 Alt 370 and W80-4, but was increased to the 90th percent (p90) for the W87-1 to reflect the greater uncertainty.

[23] SAR and WDCR values are provided when available. For programs that only have a Management and Budget cost estimate, the proposed budget is provided. Tables 5-5 through 5–13 provide values for a high and low estimate range, in addition to the SAR, WDCR, or Management and Budget cost estimate totals. Due to the differing types of cost estimates, the accuracy of these total program cost estimates varies.

[24] Defense Programs is still finalizing the B61-12 BCR updates. The values represent the current assessed values, but may change for next year's SSMP as a result.

[25] Defense Programs is still finalizing the W88 Alt 370 BCR updates. The values represent the current assessed values, but may change for next year's SSMP as a result.

[26] Defense Programs initial annual SAR for the W80-4 was submitted to Congress in May 2020. The total program cost estimate is $11 billion in Then-Year-Dollars. The $107 million reduction compared to the WDCR reflects design simplifications and execution adjustments through FY 2026.

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

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

Items to consider when comparing estimates to one another:

- The constant-year cost totals in the tables are the most comparable because inflation effects become significant over warhead modernization activity timeframes. Consideration should also be given to the varying quantities of warheads being refurbished for each system. The FY 2021 SSMP's classified Annex provides additional information on production quantities.
- The then-year Management and Budget cost estimates in the tables and figures are derived from constant-year estimates using the escalation rates in the Office of Management and Budget (OMB) Table 10.1.[28] For years beyond the 6 years projected in Table 10.1, the escalation rate for the final year is used.[29] The escalation rate used by the sites to produce the WDCRs and BCRs may differ from the OMB number used in the Management and Budget cost estimates. For example, official program office estimates may use escalation rates specific to each site and function, rather than a national average.
- Published estimate ranges are meant to reflect the underlying technical and cost uncertainty of the assumed scope. Early-stage programs, particularly those before Phase 6.3, may experience significant scope changes, as the Nuclear Weapons Council may update and/or down-select design options and significantly impact the work scope and cost estimate.
- Only the Management and Budget cost estimates include pre-Phase 6.2 costs. The WDCR and BCR/SAR estimates do not include these costs.

5.7.3.4 W76 Life Extension Program (W76-1) Cost Estimate

The W76-1 warhead last production unit was produced in December 2018 and was delivered to the Navy in April 2019. Remaining component production for life of program requirements are scheduled to complete in FY 2022. **Table 5–5** represents the actual program cost.

Table 5–5. Total actual cost for W76-1 Life Extension Program

FY 2001 – FY 2019 (dollars in billions)	DOE/NNSA		DoD	
	FY 2020 Dollars	Then-Year Dollars	FY 2020 Dollars	Then-Year Dollars
SAR Total	4.2	3.5	N/A	N/A

SAR = Selected Acquisition Report

5.7.3.5 W76-2 Modification Program Cost Estimate

The DOE/NNSA laboratories and production facilities completed a compressed Phase 6.3 through 6.5 process and are currently accomplishing Phase 6.6 activities. The remaining warhead production and deliveries are scheduled to complete in FY 2020. **Table 5–6** represents the total estimated costs.

Table 5–6. Total estimated cost for W76-2 Modification Program

FY 2019 – FY 2020 (dollars in millions)	DOE/NNSA		DoD	
	FY 2020 Dollars	Then-Year Dollars	FY 2020 Dollars	Then-Year Dollars
Total Cost	75	75	N/A	N/A

[28] Available at https://www.whitehouse.gov/omb/historical-tables/.

[29] Recommendation from OMB Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*.

5.7.3.6 B61-12 Life Extension Program Cost Estimate

The B61-12 LEP program is currently in Phase 6.4, Production Engineering. The program experienced an issue with commercial off-the-shelf (COTS) base metal electrode capacitors in late 2019, affecting six electrical assemblies that required rework, validation, and qualification testing. The new component and system validation scope, along with efforts to improve component producibility resulted in an increase of $673 million from the previous reported cost estimate of $7.6 billion. This new cost estimate is based on the analysis documented in an updated BCR to be issued at a future date. The overall program cost is now estimated at $8.3 billion (then-year dollars); these cost increases are being managed within the DOE/NNSA Stockpile Major Modernization portfolio. The B61-12 LEP is continuing to use Other Program Money for multi-system production process improvements. The costs of these related programs are estimated to be $648 million. The nominal values for development and production in **Figure 5–14** and **Table 5–7** reflect DOE/NNSA's FY 2020 BCR update (to be released) and may change slightly as the BCR update is finalized and reconciled with DOE/NNSA's Office of Cost Estimating and Program Evaluation's independent cost estimate.

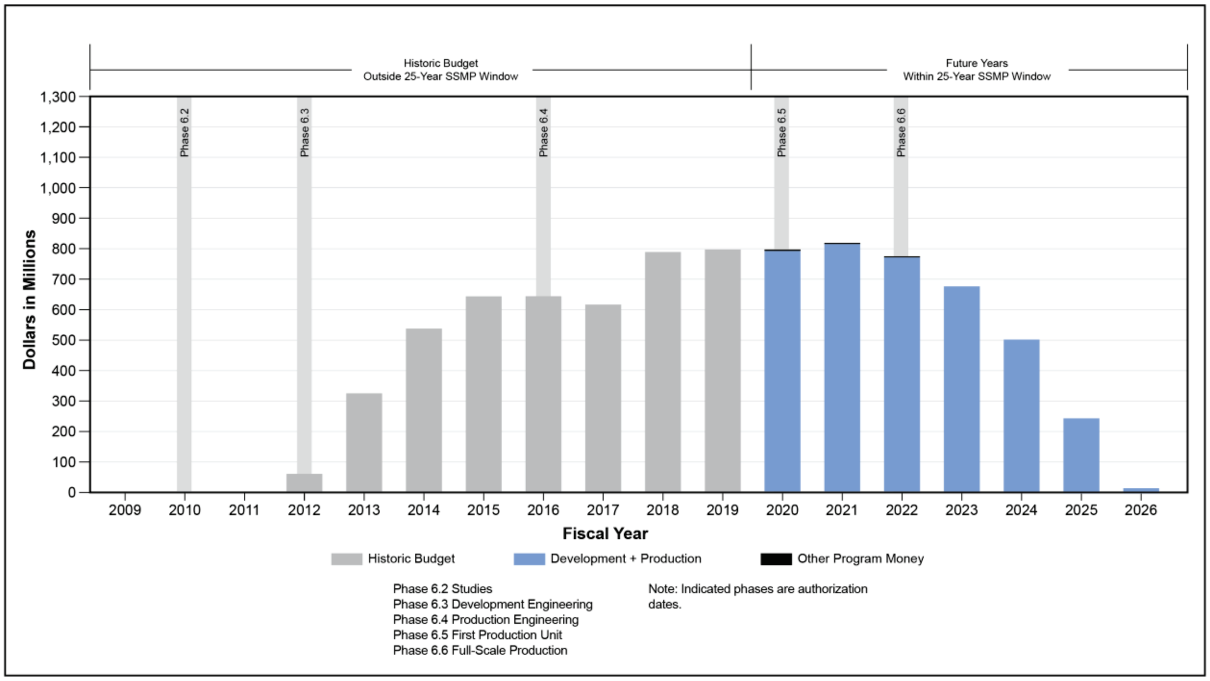

Figure 5–14. B61-12 Life Extension Program cost from FY 2012 to completion[30]

Table 5–7. Total estimated cost for B61-12 Life Extension Program

	DOE/NNSA		DoD	
Dollars in Billions	***FY 2020 Dollars***	***Then-Year Dollars***	***FY 2020 Dollars***	***Then-Year Dollars***
Pre-SAR Cost	0.5	0.4	N/A	N/A
FY 2012 – FY 2026				
SAR Total	8.4	8.3	N/A	N/A
SAR Other Program Money Total	0.7	0.6	N/A	N/A
MB High Estimate [a]	9.8	9.7	0.2	0.2
MB Low Estimate [a]	8.9	8.8	0.2	0.2

MB = Management and Budget SAR = Selected Acquisition Report
[a] Including Other Program Money

[30] The value for FY 2012 has been updated from previous SSMPs to represent the appropriate SAR value for that year. The SAR value represents money spent after Phase 6.3 approval in July 2012.

5.7.3.7 W88 Alt 370 Cost Estimate

The W88 Alteration 370 Program, currently in Phase 6.4, Production Engineering, was scheduled to deliver the first production unit in the first quarter of FY 2020. Delivery of the system-level first production unit was formally rescheduled by the Nuclear Weapons Council for the fourth quarter of FY 2021 due to delays resulting from an issue with COTS base metal electrode capacitors used in three major components of the W88 Alt 370. DOE/NNSA completed a high-fidelity cost estimate (the BCR) in FY 2017 and is currently updating that cost estimate to include the recently completed bottom-up estimate updates for capacitor-affected components. While the other components remain in production, the capacitor replacement has resulted in a cost impact of $184 million to the program for a new total of $2.80 billion. The W88 Alt 370 Program is continuing to use other DOE/NNSA programs for multi-system production process improvements. The estimated costs of these related programs (Other Program Money) remain unchanged at $171 million. The numbers in **Figure 5–15** and **Table 5–8** reflect the changes that will be included in the BCR update (to be released) and may change slightly as the BCR update is finalized and reconciled with DOE/NNSA's Office of Cost Estimating and Program Evaluation's independent cost estimate.

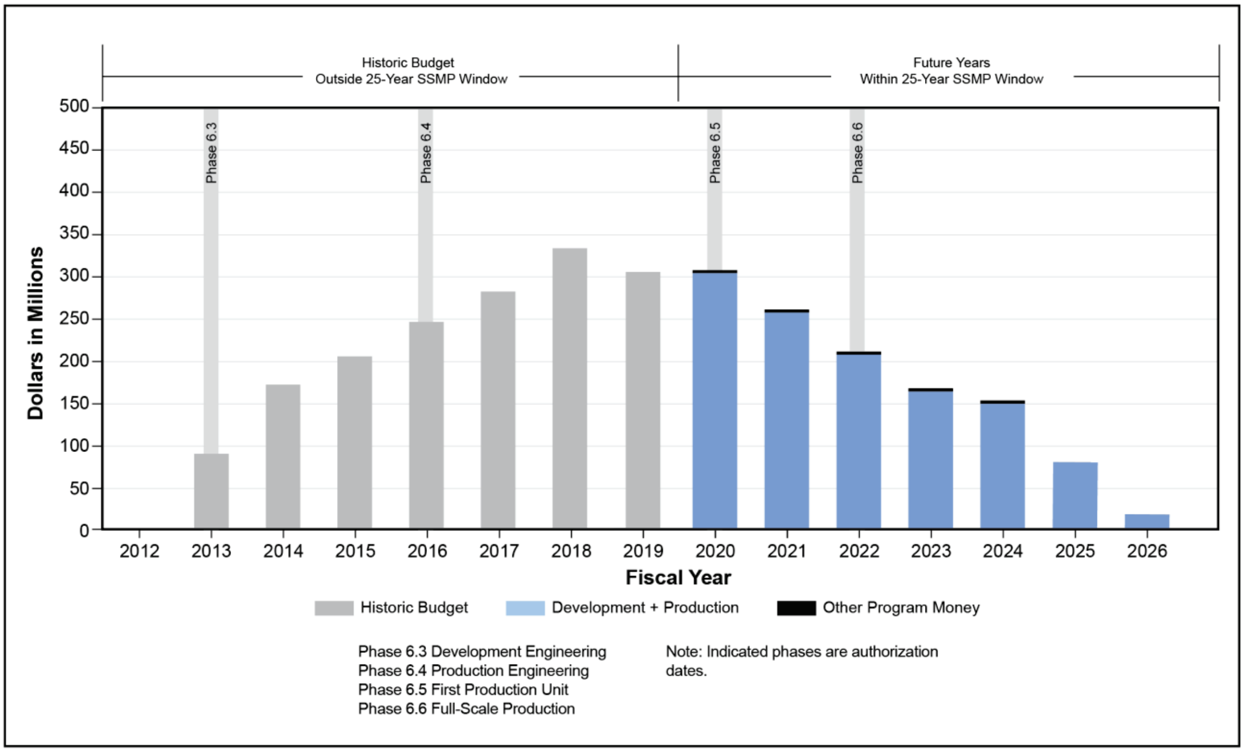

Figure 5–15. W88 Alteration 370 (with conventional high explosive refresh) from FY 2013 to completion

Table 5–8. Total estimated cost for W88 Alteration 370 (with conventional high explosive refresh) Program

Dollars in Billions	*DOE/NNSA*		*DoD*	
	FY 2020 Dollars	*Then-Year Dollars*	*FY 2020 Dollars*	*Then-Year Dollars*
Pre-SAR Cost	0.1	0.1	N/A	N/A
FY 2013 – FY 2026				
SAR Total	2.9	2.8	N/A	N/A
SAR Other Program Money Total	0.2	0.2	N/A	N/A
MB High Estimate [a]	3.3	3.3	1.1	1.0
MB Low Estimate [a]	3.2	3.0	1.1	1.0

MB = Management and Budget SAR = Selected Acquisition Report

[a] Including Other Program Money

5.7.3.8 W80-4 Life Extension Program Cost Estimate

In FY 2019, the W80-4 LEP completed the WDCR and entered Phase 6.3, Development Engineering, where the design will continue to be refined. The current cost estimates are displayed in **Figure 5–16** and **Table 5–9**. This estimate (solid bars) reflects a decrease in the FYNSP from what was in the FY 2020 SSMP as a result of design simplifications with resulting savings applied to off-setting increased costs due to the capacitor change for the B61-12 and W88 Alt 370. This change will be represented in the next SAR.

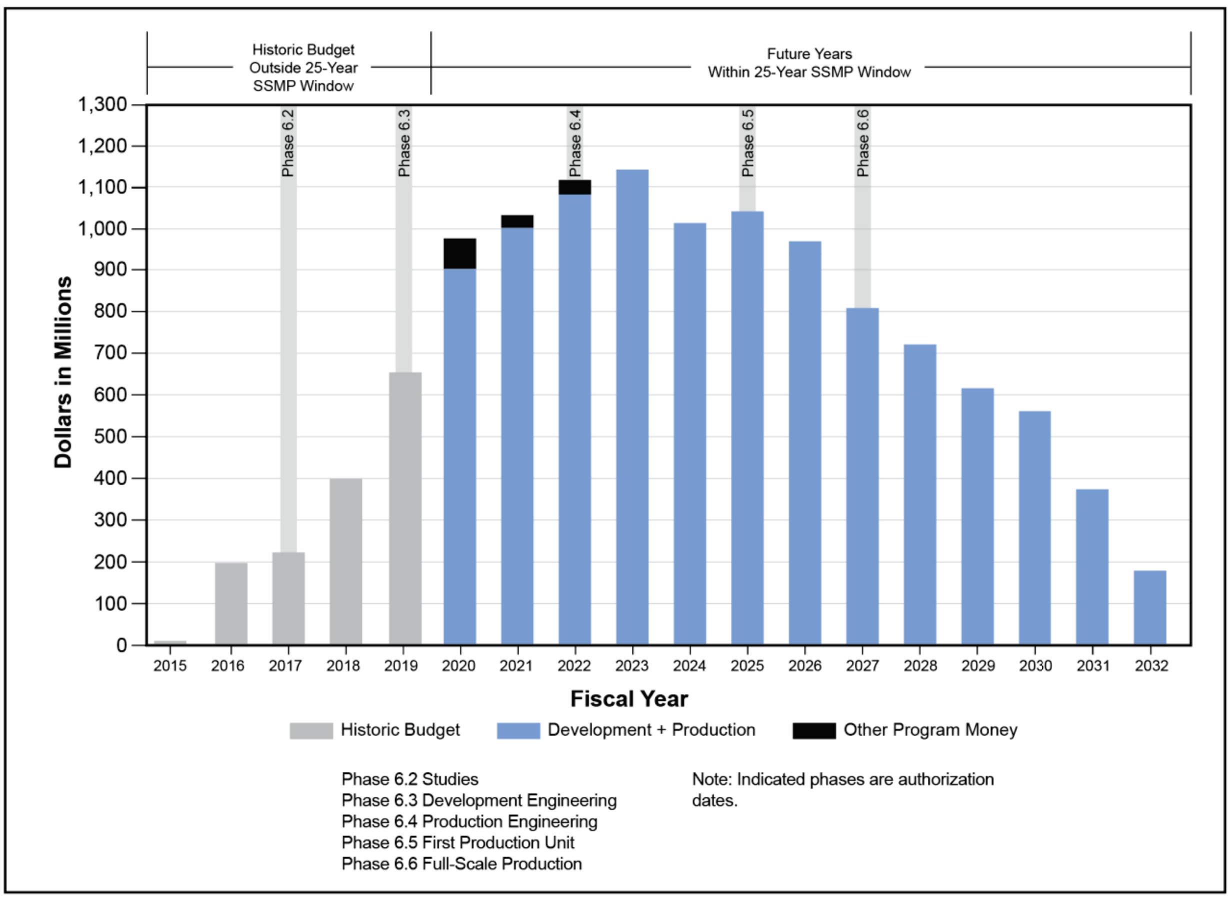

Figure 5–16. W80-4 Life Extension Program cost from FY 2015 to completion

Table 5–9. Total estimated cost for W80-4 Life Extension Program

	DOE/NNSA		*DoD*	
Dollars in Billions	***FY 2020 Dollars***	***Then-Year Dollars***	***FY 2020 Dollars***	***Then-Year Dollars***
Pre-SAR Cost	0.9	1.0	N/A	N/A
FY 2012 – FY 2026				
SAR Total	9.7	11.0	N/A	N/A
SAR Other Program Money Total	0.2	0.2	N/A	N/A
MB High Estimate [a]	10.2	11.6	0.2	0.3
MB Low Estimate [a]	8.6	9.8	0.1	0.1

MB = Management and Budget SAR = Selected Acquisition Report

[a] Including Other Program Money

5.7.3.9 W87-1 Modification Program (formerly IW1) Cost Estimate

In August 2018, the Nuclear Weapons Council authorized a restart of Phase 6.2 activities for the W87-1 Modification Program, and the program is on track to support fielding of the Ground-Based Strategic Deterrent by FY 2030. In 2019, the Nuclear Weapons Council reviewed a series of surety architecture design options; to include a detailed cost, risk/benefit, and cost analyses before selecting a single surety option for W87-1. DOE/NNSA continues to evaluate other component design options and trades. In FY 2021, the W87-1 Modification Program will complete Phase 6.2, Feasibility Study and Design Options, and enter Phase 6.2A, Design Definition and Cost Study. The cost estimate in **Figure 5–17** represents the latest projected program cost reflecting the single architecture Nuclear Weapons Council decision and is a reduction in cost from the high-complexity scope case published in the FY 2020 SSMP and 2019 congressional report.[31] The scope complexity and resulting cost estimate is also informed by a greater understanding of production complexity, system engineering and integration complexity due to interfacing with the Ground-Based Strategic Deterrent and the anticipated challenges of using new materials. The estimates in Figure 5–17 and **Table 5–10** do not include costs associated with the production of plutonium pits for the W87-1 after the capability to produce 30 pits per year is demonstrated at LANL and 50 pits per year at SRS. Those costs are contained in Plutonium Modernization.

[31] *W78 Replacement Program (W87-1): Cost Estimates and Use of Insensitive High Explosives*, Report to Congress, December, 2018.

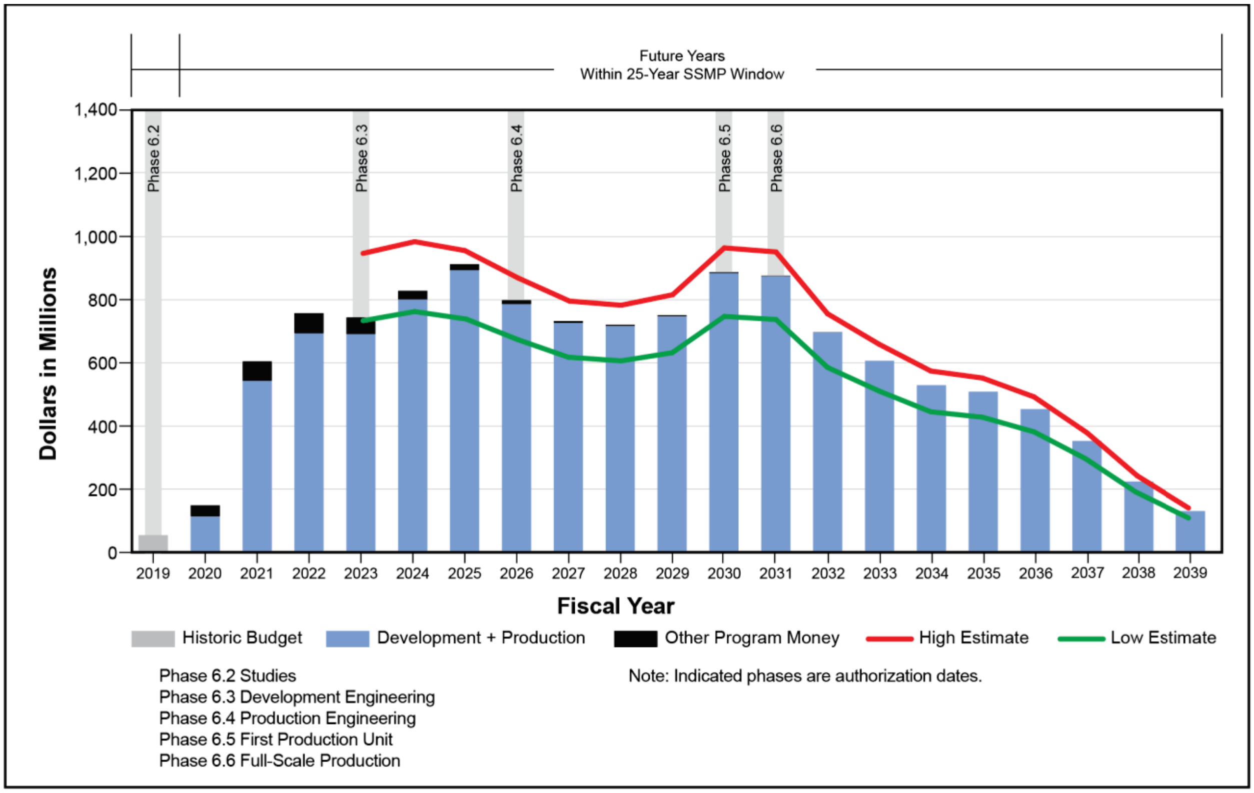

Figure 5–17. W87-1 Modification Program cost from FY 2019 to completion

Table 5–10. Total estimated cost for W87-1 Modification Program

FY 2019 – FY 2037 (dollars in billions)	DOE/NNSA		DoD	
	FY 2020 Dollars	Then-Year Dollars	FY 2020 Dollars	Then-Year Dollars
MB High Estimate [a]	11.1	13.8	1.0	1.2
MB Low Estimate [a]	9.0	10.7	0.9	1.1
Proposed Budget	N/A	12.3	N/A	1.1

MB = Management and Budget
[a] Including Other Program Money

5.7.3.10 W93 Cost Estimate

The W93 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 of record. The W93 cost estimate (see **Table 5–11**) provides a planning estimate only. It is based on the W87-1 Modification Program, with increased uncertainty, since the W87-1 Modification Program most closely aligns with the safety and surety requirements for future weapon. It should not be inferred that the W93 will closely resemble the W87-1 Modification Program. This estimate will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

Table 5–11. Total estimated cost for W93

Dollars in Billions	DOE/NNSA		DoD	
	FY 2020 Dollars	Then-Year Dollars	FY 2020 Dollars	Then-Year Dollars
MB High Estimate [a]	14.2	18.2	1.0	1.3
MB Low Estimate [a]	9.6	11.8	0.9	1.2
Proposed Budget	N/A	15.0	N/A	1.2

MB = Management and Budget
[a] Including Other Program Money

5.7.3.11 Future Strategic Missile Warhead Cost Estimate

DOE/NNSA is also coordinating with DoD to define the appropriate ballistic missile warheads to support threats anticipated through 2030 and beyond, in accordance with the 2018 *Nuclear Posture Review*. The military capabilities required from the Future Strategic Land-Based Warhead and the Future Strategic Sea-Based Warhead, formerly referred to as Interoperable Warheads or Future Ballistic Missile Warheads, are being analyzed, and appropriate requirements are being developed to address emerging threats and aging concerns in candidate stockpile warheads. In addition to these warheads, a replacement air-delivered warhead and submarine-launched warhead (for the W76-1/2) will be needed in the 2040s.

The Future Strategic Missile Warhead cost estimates (see **Table 5–12** and **Table 5–13**) provide a planning estimate for notional systems based on an existing stockpile weapon scope with increased uncertainty in design scope and quantities, adjusted for out-year escalation. These estimates will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

Table 5–12. Total estimated cost for Future Strategic Missile – Land-Based Warhead

Dollars in Billions	DOE/NNSA		DoD	
	FY 2020 Dollars	Then-Year Dollars	FY 2020 Dollars	Then-Year Dollars
MB High Estimate [a]	14.2	19.2	1.0	1.3
MB Low Estimate [a]	9.6	13.0	0.4	0.6
Proposed Budget	N/A	16.1	N/A	N/A

MB = Management and Budget
[a] Including Other Program Money

Table 5–13. Total estimated cost for Future Strategic Missile – Sea-Based Warhead

Dollars in Billions	DOE/NNSA		DoD	
	FY 2020 Dollars	Then-Year Dollars	FY 2020 Dollars	Then-Year Dollars
MB High Estimate [a]	14.2	20.5	1.0	1.4
MB Low Estimate [a]	9.6	13.9	0.4	0.6
Proposed Budget	N/A	17.2	N/A	N/A

MB = Management and Budget
[a] Including Other Program Money

5.7.3.12 B61 Follow-On Cost Estimate

The B61 Follow-On cost estimate (see **Table 5–14**) provides a planning estimate for a notional system based on the current B61-12 scope with increased uncertainty in design scope and quantities adjusted for out-year escalation. This estimate will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

Table 5–14. Total estimated cost for B61 Follow-On

	DOE/NNSA		DoD	
Dollars in Billions	*FY 2020 Dollars*	*Then-Year Dollars*	*FY 2020 Dollars*	*Then-Year Dollars*
MB High Estimate [a]	14.2	26.3	0.2	0.4
MB Low Estimate [a]	10.0	18.5	0.2	0.3
Proposed Budget	N/A	22.4	N/A	0.3

MB = Management and Budget

[a] Including Other Program Money

5.7.3.13 Summary of Cost Estimates

Figure 5–18 represents a summary of cost estimate ranges for all presently known warhead modernization programs from FY 2020 through FY 2045 based on schedule assumptions that are subject to change.

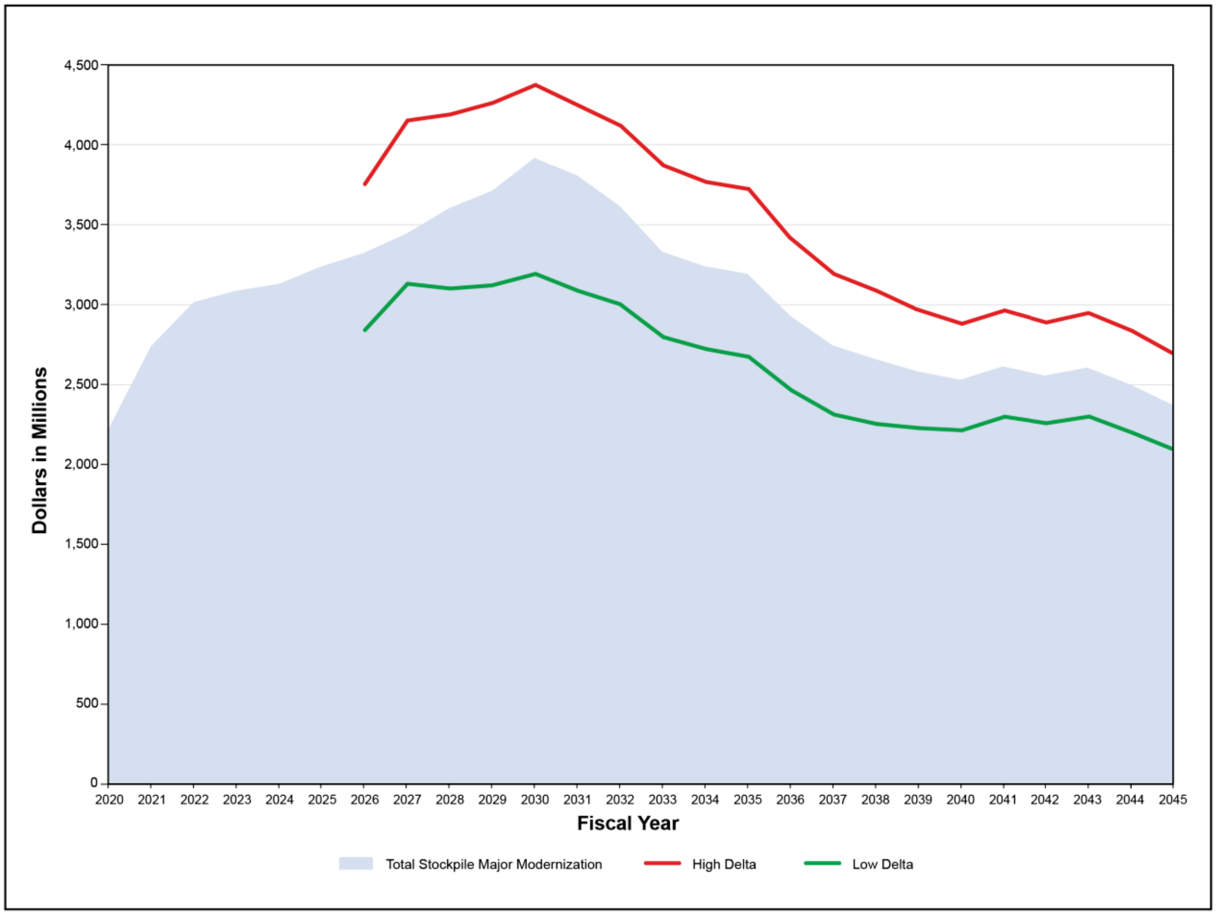

Figure 5–18. Total U.S. projected nuclear weapons life extension costs for FY 2020 – FY 2045 with high and low estimates (then-year dollars)

5.7.4 Construction

5.7.4.1 Cost Estimation for Capital Acquisitions

In FY 2020, DOE/NNSA began publishing cost estimates for early-stage capital acquisitions.[32] These early planning estimates, published as long as a decade or more before a project's initial mission approval, primarily inform Weapons Activities' long-term cost projections for programmatic construction and are supplemental to DOE acquisition requirements in DOE Order 413.3B.

Notably, these cost estimates are:

- Performed by an organization separate from the Federal program office[33]
- Performed using a top-down parametric method that is consistent with early-stage planning[34]
- Based on historic DOE/NNSA project schedules, costs, and project phasing
- Based on current anticipated project scopes
- Based on affordability analysis with total construction funding constrained
- Updated annually for the SSMP

Once a project begins the acquisition process, the approved cost estimate ranges at the CD-0 milestone (Mission Approval) supersede previous estimates and becomes the basis for resource planning. The project then progresses as described in DOE Order 413.3B (i.e., alternative selection and cost range at CD-1, performance baseline at CD-2, etc.). Per DOE Order 413.3B, the project cost estimates are reconciled with independent cost estimates or independent cost reviews performed by either the Office of Cost Estimating and Program Evaluation (pre-CD-2) or DOE's Office of Project Management (post-CD-2).

The early-stage planning estimates use technical input based on an assumed scope. However, these assumptions do not predetermine the project's actual acquisition strategy or the outcome of subsequent analyses of alternatives (AoAs). The assumed scope should be considered notional until the project reaches and defines performance baseline at CD-2.

The cost estimation professional society, AACE International, has published a cost estimate classification system[35] based on the scope definition of the project. DOE/NNSA has mapped the AACE International cost estimate classes to their most common uses for capital acquisitions.[36] **Table 5–15** summarizes the cost estimation classification system, including the level of project definition, the expected uncertainty range, and the corresponding DOE/NNSA capital acquisition milestones. Note that the estimate ranges and typical applications represent rough expectations and cannot simply be applied to an estimate to determine uncertainty.

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[32] Estimates developed independent of the program are a best practice identified by GAO and other professional organizations as a tool to objectively compare to program estimates and identify potential issues early.

[33] The DOE/NNSA Office of Management and Budget, Office of Analysis and Evaluation performs the cost estimates on behalf of Defense Programs.

[34] GAO extolls the value of independent cost estimates using a different methodology and the potential benefit to decision-makers in the *GAO Cost Estimating and Assessment Guide*.

[35] AACE International Recommended Practice 18R-97, Cost Estimation Classification System as Applied in Engineering, Procurement and Construction for the Process Industries.

[36] DOE Guide 413.3-21A Cost Estimating Guide.

Table 5–15. Cost Estimate Classification System

Estimate Class	Primary Characteristic: Maturity Level of Project Definition (percent)	Secondary Characteristic: DOE Capital Acquisition Milestone	Typical Types of Estimate	Methodology	Expected Accuracy Range (percent)
Class 5	0 to 2	Mission Need (CD-0)	Planning Estimate, Rough Order of Magnitude	Capacity factored, parametric models, judgment, or analogy	L: -20 to -50 H: +30 to +100
Class 4	1 to 15	Alternative Selection (CD-1)	Analysis of Alternatives, Conceptual Design	Equipment factored or parametric models	L: -15 to -30 H: +20 to +50
Class 3	10 to 40	Project Baseline (CD-2) (low-risk projects)	Preliminary Design	Semi-detailed unit costs with assembly level line items	Low: -10 to -20 H: +10 to +30
Class 2	30 to 75	Start of Construction (CD-3)/ Project Baseline (CD-2) (high-risk projects)	Final Design	Detailed unit cost with forced detailed take-off	L: -5 to -15 H: +5 to +20
Class 1	65 to 100			Detailed unit cost with detailed take-off	L: -3 to -10 H: +3 to +15

5.7.4.2 FY 2021 through FY 2045 Estimates

The budget estimate for capital acquisitions in FY 2021 through FY 2025 reflects the current program of record. DOE/NNSA is executing the schedules of multiple ongoing major capital acquisition projects, such as the Uranium Processing Facility and U1a Complex Enhancements projects. A list of major capital acquisition project proposals has been developed through the efforts of a series of working groups and deep dives with representatives from DOE/NNSA sites and responsible Federal offices. The schedule for the highest-priority project proposals is depicted by major capital acquisition projects and project proposals listed in Chapter 4, "Infrastructure and Workforce," Figure 4–2. This planning schedule will be updated annually. Changes will be made based on available funding and programmatic priorities.

The current program and the vetted project proposals included in Figure 4–2 are the basis for the cost estimates. **Table 5–16** lists low and high estimate projections in then-year dollars for Weapons Activities capital acquisition projects from FY 2021 through FY 2045. As mentioned in the previous section, several of these projects contain a high degree of scope and cost uncertainties, resulting in a significant cost range. This year's SSMP high estimate benefits from the inclusion of additional historic data in model development.

Table 5–16. Weapons Activities capital acquisition estimated costs, FY 2021 – FY 2045

Then-Year Dollars, in Billions	*Low* [a]	*High* [b]
Weapons Activities capital acquisition estimated costs	73.1	86.6

[a] "Low" reflects the base capital acquisition estimate captured in Figure 5–19. The low value is programmatically informed and represents the 85th percentile for the construction projects listed in Section 4.1.2.

[b] "High" includes additional SRT&E facilities to support stockpile stewardship and additional recapitalization costs for production.

The difference in the high and low estimates as compared to the FY 2020 SSMP are a result of revised cost estimates, the addition of new project proposals, and changing acquisition strategies.

5.8 Affordability Analysis

DOE/NNSA's method for evaluating potential affordability is part of a portfolio management approach in line with the level of uncertainty affecting the out-years. The projected cost of continuing the program beyond the FYNSP incorporates some amount of uncertainty in the out-year projects based on the uncertainties in Stockpile Major Modernization and construction project costs. These later plans and estimates are compared to external straight-line budget projections that have not been adjusted to be more predictive. Variances are managed as the out-years estimates move into the FYNSP window, and greater scrutiny and prioritization are applied throughout the programming and budget processes.

The DOE/NNSA program of record is based on requirements established through the Nuclear Weapons Council in coordination with DoD. DOE/NNSA must invest in making available the necessary capabilities and infrastructure to execute modernization programs to meet DoD timelines. In the event that adjustments must be made in future years, DOE/NNSA will work with DoD to consider and adjust schedule and/or scope to major activities, including potential effects to warhead modernization programs and infrastructure projects.

5.8.1 Estimate of Weapons Activities Program Costs and Affordability

Figure 5–19 depicts updated Weapons Activities budget projections beyond the FYNSP, based on the FY 2021 President's Budget Request and the program of record described in Chapters 2 through 5. Assumptions for cost estimates are based on the current nuclear security environment. The budget projection incorporates the Stockpile Major Modernization program cost estimates described in Section 5.7.3 and the cost estimates for the planned major programmatic construction projects described in Section 5.7.4 and Chapter 4, Section 4.1.2. Figure 5–19 also includes out-year estimates for:

- Reestablishing a plutonium pit production capability
- Reestablishing a Domestic Uranium Enrichment capability
- Revitalizing DOE/NNSA's production centers:
  - Revitalizing Pantex assembly/disassembly capabilities
  - Expanding non-nuclear component production at KCNSC
  - Modernizing Y-12 capabilities to support strategic material production
- Establishing and modernizing DOE/NNSA's SRT&E capabilities for certifying nuclear weapons
- Modernizing tritium development, production, and processing capabilities

Figure 5–19 also includes estimates for a portfolio of replacement-in-kind projects that will sustain other existing mission capabilities. Programs that do not have specific cost estimates are escalated at 2.1 percent to account for inflation and annual labor rate increases at M&O sites.

In Figure 5–19, the projected future costs for the Weapons Activities portfolio for FY 2026–FY 2045 should be interpreted as the range between the red high-range total lines and the green low-range total lines for Weapons Activities in the figure, which represent a quantification of cost uncertainty. This total cost range is necessary because of uncertainties related to the individual components of the estimates, Stockpile Major Modernization programs, and the construction costs described earlier in this chapter.

The dashed line represents an escalation of the final year of the FY 2021 FYNSP.[37] This line represents a likely estimate of future years' budget authority. The out-year Weapons Activities cost projection

[37] The FY 2021 Budget assumes a flat National Defense topline for FY 2026 through FY 2030, including a flat DOE/NNSA topline. 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 2026 through FY 2045 will be escalated at 2.1 percent.

illustrated in Figure 5–19 falls mostly below the escalated budget request, and DOE/NNSA considers this program to be affordable. In the event that adjustments need to be made, DOE/NNSA will determine changes to planned modernization programs and/or construction projects in coordination with DoD.

The basis for these estimates is updated annually as DOE/NNSA develops the FYNSP request, which may lead to changes in the overall projection. This information illustrates the potential evolution of the program's direction; it does not represent precise costs for any years other than within the FYNSP. Schedules and scopes can be adjusted for out-year activities as part of annual programming to address shortfalls, and DOE/NNSA will use updated estimates for these activities.

It is important to note that the projection does not include potential emerging requirements. Such requirements may necessitate additional Stockpile Major Modernization programs, enhanced Stockpile Sustainment activities, or further infrastructure investments in order for DOE/NNSA to maintain a safe, secure, and effective nuclear deterrent in the future. Figure 5–19 also does not take into consideration unknown requirements, but DOE/NNSA will include any emerging requirements in future SSMPs and cost analyses.

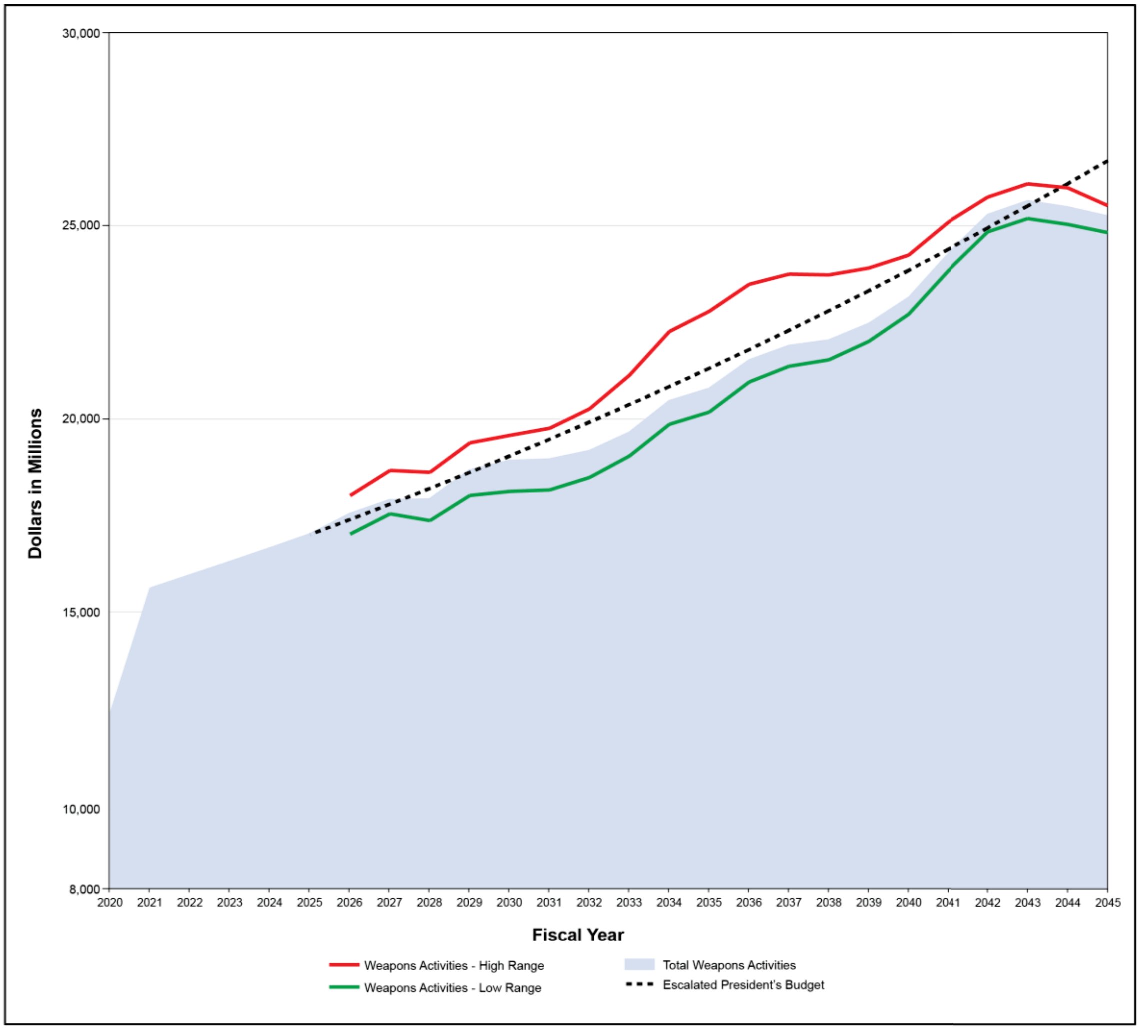

Figure 5–19. Projected out-year budget estimates for DOE/NNSA Weapons Activities in then-year dollars with high- and low-cost estimates, including the escalated President's Budget Request

Chapter 6
Conclusion

"The U.S. nuclear deterrent is the foundation of our national defense and its credibility serves as the ultimate insurance policy against a nuclear attack."

The Honorable Lisa E. Gordon-Hagerty, Administrator of the National Nuclear Security Administration
U.S. Department of Energy, March 2020

This DOE/NNSA *Fiscal Year 2021 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP), together with the classified Annex, is a key planning document for the nuclear security enterprise. The SSMP compiles the results of plans and planning efforts developed across numerous DOE/NNSA programs and organizations and documents the 25-year strategic plan necessary for the safety, security, and effectiveness of the U.S. nuclear weapons stockpile, while maintaining the scientific and engineering tools, capabilities, and infrastructure that underpin the enterprise. The DOE/NNSA Federal workforce prepares each SSMP in collaboration with its management and operating partners and coordinates the effort with DoD through the Nuclear Weapons Council.

In response to evolving and new demands, and challenges related to stewardship and stockpile management, DOE/NNSA publishes a new version of the SSMP each year. The FY 2021 SSMP builds on previous SSMPs and updates the costs and resources required for execution of the program based on current and emerging mission needs, the strategic environment, and revised and updated guidance.

Appendix A
Requirements Mapping

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

The *Fiscal Year 2021 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (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 2021 SSMP.

A.2 Ongoing Requirements

50 U.S. Code § 2523	*FY 2020 Response*	*FY 2021 Response*
§ 2523. Nuclear weapons stockpile stewardship, management, and responsiveness plan		
(a) Plan requirement The Administrator, in consultation with the Secretary of Defense and other appropriate officials of the departments and agencies of the Federal Government, shall develop and annually update a plan for sustaining the nuclear weapons stockpile. The plan shall cover, at a minimum, stockpile stewardship, stockpile management, stockpile responsiveness, stockpile surveillance, program direction, infrastructure modernization, human capital, and nuclear test readiness. The plan shall be consistent with the programmatic and technical requirements of the most recent annual Nuclear Weapons Stockpile Memorandum.	*Unclassified* All Chapters ——— *Classified Annex*	*Unclassified* All Chapters ——— *Classified Annex*
(b) Submissions to Congress		
(1) In accordance with subsection (c), not later than March 15 of each even-numbered year, the Administrator shall submit to the congressional defense committees a summary of the plan developed under subsection (a).	*N/A*	*Unclassified* All Chapters ——— *Classified Annex*
(2) In accordance with subsection (d), not later than March 15 of each odd-numbered year, the Administrator shall submit to the congressional defense committees a detailed report on the plan developed under subsection (a).	*Unclassified* All Chapters ——— *Classified Annex*	*N/A*
(3) The summaries and reports required by this subsection shall be submitted in unclassified form, but may include a classified annex.		
(c) Elements of biennial plan summary Each summary of the plan submitted under subsection (b)(1) shall include, at a minimum, the following:		
(1) A summary of the status of the nuclear weapons stockpile, including the number and age of warheads (including both active and inactive) for each warhead type.	*N/A*	*Unclassified* Chapter 1, Section 1.2 ——— *Classified Annex*

50 U.S. Code § 2523	***FY 2020 Response***	***FY 2021 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.	*N/A*	*Unclassified* Chapter 1, Sections 1.3, 1.4; Chapter 2, Sections 2.1–2.4; Chapter 4, Section 4.1; Chapter 5, Sections 5.1–5.7
(3) A summary of the methods and information used to determine that the nuclear weapons stockpile is safe and reliable, as well as the relationship of science-based tools to the collection and interpretation of such information.	*N/A*	*Unclassified* Chapter 2, Sections 2.1.1, 2.1.2; Chapter 3, Sections 3.5–3.8
(4) A summary of the status of the nuclear security enterprise, including programs and plans for infrastructure modernization and retention of human capital, as well as associated budgets and schedules.	*N/A*	*Unclassified* Chapter 1, Section 1.4; Chapter 4, Sections 4.1–4.2; Chapter 5, Sections 5.1–5.7
(5) A summary of the status, plans, and budgets for carrying out the stockpile responsiveness program under section 2538b of this title.	*N/A*	*Unclassified* Chapter 2, Sections 2.1.1.5, 2.2.9.2; Chapter 3, Sections 3.6.1.2, 3.6.2.1; Chapter 5, Section 5.4.2.2
(6) A summary of the plan regarding the research and development, deployment, and lifecycle sustainment of technologies described in subsection (d) (7).	*N/A*	
(7) A summary of the assessment under subsection (d)(8) regarding the execution of programs with current and projected budgets and any associated risks.	*N/A*	
(8) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*N/A*	*Unclassified* Chapter 1, Section 1 text box; Chapter 5, Section 5.1.1
(9) Such other information as the Administrator considers appropriate.	*N/A*	*N/A*
(d) Elements of biennial detailed report Each detailed report on the plan submitted under subsection (b)(2) shall include, at a minimum, the following:		
(1) With respect to stockpile stewardship, stockpile management, and stockpile responsiveness—		

50 U.S. Code § 2523	***FY 2020 Response***	***FY 2021 Response***
(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 1.2; Chapter 2, Sections 2.1.12, 2.5, 2.5.1–2.5.9 ——— *Classified Annex* Chapter 2, Sections 2.1, 2.2; Tables 2-1, 2-2	*N/A*
(B) for each five-year period occurring during the period beginning on the date of the report and ending on the date that is 20 years after the date of the report— (i) the planned number of nuclear warheads (including active and inactive) for each warhead type in the nuclear weapons stockpile; and (ii) the past and projected future total lifecycle cost of each type of nuclear weapon;	*Unclassified* Chapter 8, Sections 8.7.1–8.7.3 ——— *Classified Annex* Chapter 2, Sections 2.2, 2.5; Tables 2-1, 2-3	*N/A*
(C) the status, plans, budgets, and schedules for warhead life extension programs and any other programs to modify, update, or replace warhead types;	*Unclassified* Chapter 2, Sections 2.1.1, 2.5, 2.5.1–2.5.8; Chapter 8, Sections 8.2, 8.7.3 ——— *Classified Annex* Chapter 2, Sections 2.2, 2.5; Tables 2-3, 2-4	*N/A*
(D) a description of the process by which the Administrator assesses the lifetimes, and requirements for life extension or replacement, of the nuclear and non-nuclear components of the warheads (including active and inactive warheads) in the nuclear weapons stockpile;	*Unclassified* Chapter 2, Sections 2.2, 2.2.1–2.2.9; Chapter 3, Sections 3.1.1, 3.2.2	*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 2.2, 2.2.1–2.2.9; Chapter 3, Sections 3.1.1, 3.1.2	*N/A*

50 U.S. Code § 2523	***FY 2020 Response***	***FY 2021 Response***
(F) any concerns of the Administrator that would affect the ability of the Administrator to recertify the safety, security, or reliability of warheads in the nuclear weapons stockpile (including active and inactive warheads);	*Unclassified* Chapter 2, Sections 2.1, 2.1.1, 2.2.7, 2.3.6, 2.4.1, 2.4.3, 2.4.6; Chapter 3, Sections 3.2.1.3, 3.2.2.3, 3.2.3.3, 3.2.4.3, 3.3 ——— *Classified Annex* Chapter 2, Sections 2.5, Table 2-4	*N/A*
(G) mechanisms to provide for the manufacture, maintenance, and modernization of each warhead type in the nuclear weapons stockpile, as needed;	*Unclassified* Chapter 2, Sections 2.1, 2.1.1, 2.2, 2.2.1–2.2.7, 2.3, 2.3.1–2.3.6, 2.4, 2.4.1–2.4.8, 2.5, 2.5.1–2.5.8; Chapter 3, Section 3.2	*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 2, Sections 2.2, 2.2.1–2.2.7, 2.3, 2.3.1–2.3.6; Chapter 3, Section 3.2	*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, Sections 1.4, 1.4.1–1.4.3, 1.4.5; Chapter 3, Sections 3.1.5; Chapter 7; Appendix D	*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 3, Section 3.1.1	*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 8.1, 8.2, 8.3.1–8.3.3, 8.7.2, 8.7.3	*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 8.1	*N/A*
(M) the status, plans, activities, budgets, and schedules for carrying out the stockpile responsiveness program under section 2538b of this title;	*Unclassified* Chapter 3, Section 3.2; Chapter 8, Sections 8.2, 8.3.2	*N/A*

50 U.S. Code § 2523	*FY 2020 Response*	*FY 2021 Response*
(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 8.2, 8.3.2	*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—		
(A) a description of the information needed to determine that the nuclear weapons stockpile is safe and reliable;	*Unclassified* Chapter 2, Sections 2.2.1–2.2.7, 2.2.9; Chapter 3, Sections 3.1, 3.1.1, 3.1.2, 3.2.1–3.2.4	*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 3, Sections 3.2.1–3.2.4	*N/A*
(C) the criteria developed under section 2522(a) of this title (including any updates to such criteria).	*N/A*	*N/A*
(3) An assessment of the stockpile stewardship program under section 2521 (a) of this title by the Administrator, in consultation with the directors of the national security laboratories, which shall set forth—		
(A) an identification and description of— (i) any key technical challenges to the stockpile stewardship program; and (ii) the strategies to address such challenges without the use of nuclear testing;	*Unclassified* Chapter 3, Sections 3.2.1.3, 3.2.2.3, 3.2.3.3, 3.2.4.3, 3.3.1 ——— *Classified Annex* Chapter 2, Section 2.5, Table 2-4	*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 3, Sections 3.1.1, 3.2.1–3.2.4; Appendix D	*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 3, Sections 3.1.1, 3.3.2; Appendix D	*N/A*
(D) an assessment of the core scientific and technical competencies required to achieve the objectives of the stockpile stewardship program and other weapons activities and weapons-related activities of the Administration, including—	*Unclassified* Chapter 7, Section 7.3.4; Appendix B	*N/A*
(i) the number of scientists, engineers, and technicians, by discipline, required to maintain such competencies; and	*Unclassified* Chapter 7, Sections 7.3.1, 7.3.2; Appendix D	*N/A*

50 U.S. Code § 2523	*FY 2020 Response*	*FY 2021 Response*
(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, Sections 7.4.1, 7.4.2; Appendix D	*N/A*
(4) With respect to the nuclear security infrastructure—		
(A) a description of the modernization and refurbishment measures the Administrator determines necessary to meet the requirements prescribed in—	*Unclassified* Chapter 4, Sections 4.2, 4.3	*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* Chapter 4, Sections 4.2, 4.3	*N/A*
(ii) the most recent quadrennial defense review if such strategy has not been submitted as of the date of the plan; and	*Unclassified* Chapter 4, Sections 4.2, 4.3	*N/A*
(iii) the most recent Nuclear Posture Review as of the date of the plan;	*Unclassified* Chapter 4, Sections 4.2, 4.3	*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 4, Sections 4.21, 4.2.2	*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 8.5.1, 8.7.4	*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 8.5.5	*N/A*
(5) With respect to the nuclear test readiness of the United States—		
(A) an estimate of the period of time that would be necessary for the Administrator to conduct an underground test of a nuclear weapon once directed by the President to conduct such a test;	*Unclassified* Chapter 3, Section 3.4	*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 3, Section 3.4	*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 3, Section 3.4	*N/A*
(D) a list and description of the infrastructure and physical plants that are essential to carrying out an underground nuclear test at the Nevada National Security Site; and	*Unclassified* Chapter 3, Section 3.4	*N/A*

50 U.S. Code § 2523	*FY 2020 Response*	*FY 2021 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 3, Section 3.4	*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:		
(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 3, Sections 3.2.2.3, 3.3.3	*N/A*
(B) An assessment of scientific and testing instrumentation for plutonium at elemental and bulk conditions.	*Unclassified* Chapter 3, Sections 3.2.1, 3.2.3	*N/A*
(C) An assessment of manufacturing and handling technology for plutonium and plutonium components.	*Unclassified* Chapter 2, Section 2.4.1; Appendix D, Section D.2.2	*N/A*
(D) An assessment of computational models of plutonium performance under static and dynamic loading, including manufactured and nonmanufactured conditions.	*Unclassified* Chapter 3, Sections 3.2.1–3.2.4	*N/A*
(E) An identification of any capability gaps with respect to the assessments described in subparagraphs (A) through (D).	*Unclassified* Chapter 3, Sections 3.2.1.2, 3.2.1.3	*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, Sections 8.2.1, 8.2.3.5, 8.3.1, 8.3.3, 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, Sections 8.2.1, 8.2.3.5, 8.3.1, 8.3.3, 8.8	*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 2, Section 2.4.1	*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 6 ——— *Classified Annex* Chapter 3	*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 6 ——— *Classified Annex* Chapter 3, Sections 3.2, 3.5; Tables 3-1, 3-2; Figure 3-2	*N/A*

50 U.S. Code § 2523	*FY 2020 Response*	*FY 2021 Response*
(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 6, Sections 6.1.1–6.1.3, 6.2.3, 6.2.4 ——— *Classified Annex* Chapter 3, Sections 3.3, 3.7	*N/A*
(C) a detailed description of how the funds identified for each program element specified pursuant to paragraph (1) in the budget for the Administration for each fiscal year during that five-fiscal-year period will help carry out that plan.	*Unclassified* Chapter 8, Sections 8.6.2, 8.6.3 ——— *Classified Annex* Chapter 3, Sections 3.4.2, 3.8; Tables 3-5, 3-6	*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 8.7–8.9	*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*
(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*

50 U.S. Code § 2523	***FY 2020 Response***	***FY 2021 Response***
(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.		

50 U.S. Code § 2538a	***FY 2020 Response***	***FY 2021 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 a pilot period of not less than 90 days during 2027 (subject to subsection [b]), demonstrates the capability to produce war reserve plutonium pits at a rate sufficient to produce 80 pits per year.	*Unclassified* Chapter 1, Section 1.4.5; Chapter 2, Section 2.4.1; Chapter 8, Section 8.2.4; Appendix D, Section D.2.2	*Unclassified* Message from the Administrator; Chapter 3, Sections 3.3.1.1; 3.7.9.2; Chapter 4, Section 4.1.2; Chapter 5, Sections 5.3.2.1, 5.3.3, 5.4.2.1–5.4.2.2, 5.6.3.1, 5.7.3.9
(b) Authorization of two-year delay of demonstration requirement The Secretary of Energy and the Secretary of Defense may jointly delay, for not more than two years, the requirement under subsection (a)(5) if- (1) the Secretary of Defense and the Secretary of Energy jointly submit to the congressional defense committees a report describing- (A) the justification for the proposed delay; (B) the effects of the proposed delay on stockpile stewardship and modernization, life extension programs, future stockpile strategy, and dismantlement efforts; and (C) whether the proposed delay is consistent with national policy regarding creation of a responsive nuclear infrastructure; and (2) the Commander of the United States Strategic Command submits to the congressional defense committees a report containing the assessment of the Commander with respect to the potential risks to national security of the proposed delay in meeting- (A) the nuclear deterrence requirements of the United States Strategic Command; and (B) national requirements related to creation of a responsive nuclear infrastructure.		*N/A*
(c) Annual certification Not later than March 1, 2015, and each year thereafter through 2027 (or, if the authority under subsection (b) is exercised, 2029), the Secretary of Energy shall certify to the congressional defense committees and the Secretary of Defense that the programs and budget of the Secretary of Energy will enable the nuclear security enterprise to meet the requirements under subsection (a).	*Unclassified* Chapter 2, Section 2.4.1; Chapter 8, Section 8.2.4;	Unclassified, Chapter 3, Sections 3.3.1.1.1.1, 3.3.1.1.1.3
(d) Plan If the Secretary of Energy does not make a certification under subsection (c) 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.3 Other Requirements

H.R.244 – Consolidated Appropriations Act, 2017, P.L. 115-31	*FY 2020 Response*	*FY 2021 Response*
SEC. 4. EXPLANATORY STATEMENT. The explanatory statement regarding this Act, printed in the House section of the Congressional Record on or about May 2, 2017, and submitted by the Chairman of the Committee on Appropriations of the House, shall have the same effect with respect to the allocation of funds and implementation of divisions A through L of this Act as if it were a joint explanatory statement of a committee of conference.		
Congressional Record – House, Vol 163, No 76—Book II, page H3753, May 3, 2017 (Explanatory Statement to Accompany the FY 17 Omnibus Appropriations [P.L. 115-31]]		
Life Extension Reporting. – The NNSA is directed to provide to the Committees on Appropriations of both Houses of Congress a classified summary of each ongoing life extension and major refurbishment program that includes explanatory information on the progress and planning for each program beginning with the award of the phase 6.3 milestone and annually thereafter until completion of the program.	*Classified Annex* Chapter 2, Sections 2.2, 2.2.1–2.2.6, 2.3	*Classified Annex*

A.4 Related Legislation

50 U.S. Code § 2521
§ 2521. Stockpile stewardship program (a) Establishment The Secretary of Energy, acting through the Administrator for Nuclear Security, shall establish a stewardship program to ensure – (1) the preservation of the core intellectual and technical competencies of the United States in nuclear weapons, including weapons design, system integration, manufacturing, security, use control, reliability assessment, and certification; and (2) that the nuclear weapons stockpile is safe, secure, and reliable without the use of underground nuclear weapons testing.
(b) Program elements The program shall include the following:
1) An increased level of effort for advanced computational capabilities to enhance the simulation and modeling capabilities of the United States with respect to the performance over time of nuclear weapons.
(2) An increased level of effort for above-ground experimental programs, such as hydrotesting, high-energy lasers, inertial confinement fusion, plasma physics, and materials research.
(3) Support for new facilities construction projects that contribute to the experimental capabilities of the United States, such as an advanced hydrodynamics facility, the National Ignition Facility, and other facilities for above-ground experiments to assess nuclear weapons effects.
(4) Support for the use of, and experiments facilitated by, the advanced experimental facilities of the United States, including - (A) the National Ignition Facility at Lawrence Livermore National Laboratory; (B) the Dual Axis Radiographic Hydrodynamic Testing facility at Los Alamos National Laboratory; (C) the Z Machine at Sandia National Laboratories; and (D) the experimental facilities at the Nevada National Security Site.
(5) Support for the sustainment and modernization of facilities with production and manufacturing capabilities that are necessary to ensure the safety, security, and reliability of the nuclear weapons stockpile, including - (A) the nuclear weapons production facilities; and (B) production and manufacturing capabilities resident in the national security laboratories.
(1) With respect to exascale computing—
(a) PLAN REQUIRED.—The Administrator for Nuclear Security shall develop and carry out a plan to develop exascale computing and incorporate such computing into the stockpile stewardship program under section 4201 of the Atomic 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.

50 U.S. Code § 2521
(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.

50 U.S. Code § 2522
§ 2522. Stockpile stewardship criteria
(a) Requirement for criteria The Secretary of Energy shall develop clear and specific criteria for judging whether the science-based tools being used by the Department of Energy for determining the safety and reliability of the nuclear weapons stockpile are performing in a manner that will provide an adequate degree of certainty that the stockpile is safe and reliable.
(b) Coordination with Secretary of Defense The Secretary of Energy, in developing the criteria required by subsection (a), shall coordinate with the Secretary of Defense.

50 U.S. Code § 2524
§ 2524. Stockpile management program
(a) Program required The Secretary of Energy, acting through the Administrator for Nuclear Security and in consultation with the Secretary of Defense, shall carry out a program, in support of the stockpile stewardship program, to provide for the effective management of the weapons in the nuclear weapons stockpile, including the extension of the effective life of such weapons. The program shall have the following objectives:
(1) To increase the reliability, safety, and security of the nuclear weapons stockpile of the United States.
(2) To further reduce the likelihood of the resumption of underground nuclear weapons testing.
(3) To achieve reductions in the future size of the nuclear weapons stockpile.
(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.

50 U.S. Code § 2538b
§ 2538b. Stockpile responsiveness program (a) Statement of policy It is the policy of the United States to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive.
(b) Program required The Secretary of Energy, acting through the Administrator and in consultation with the Secretary of Defense, shall carry out a stockpile responsiveness program, along with the stockpile stewardship program under section 2521 of this title and the stockpile management program under section 2524 of this title, to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons.
(c) Objectives The program under subsection (b) shall have the following objectives: (1) Identify, sustain, enhance, integrate, and continually exercise all of the capabilities, infrastructure, tools, and technologies across the science, engineering, design, certification, and manufacturing cycle required to carry out all phases of the joint nuclear weapons life cycle process, with respect to both the nuclear security enterprise and relevant elements of the Department of Defense. (2) Identify, enhance, and transfer knowledge, skills, and direct experience with respect to all phases of the joint nuclear weapons life cycle process from one generation of nuclear weapon designers and engineers to the following generation. (3) Periodically demonstrate stockpile responsiveness throughout the range of capabilities required, including prototypes, flight testing, and development of plans for certification without the need for nuclear explosive testing. (4) Shorten design, certification, and manufacturing cycles and timelines to minimize the amount of time and costs leading to an engineering prototype and production. (5) Continually exercise processes for the integration and coordination of all relevant elements and processes of the Administration and the Department of Defense required to ensure stockpile responsiveness. (6) The retention of the ability, in consultation with the Director of National Intelligence, to assess and develop prototype nuclear weapons of foreign countries and, if necessary, to conduct no-yield testing of those prototypes.
(d) Joint nuclear weapons life cycle process defined In this section, the term “joint nuclear weapons life cycle process” means the process developed and maintained by the Secretary of Defense and the Secretary of Energy for the development, production, maintenance, and retirement of nuclear weapons.

Appendix B
Exascale Computing Initiative

The 2017 *National Security Strategy* mandates that "to maintain our competitive advantage, the United States will prioritize emerging technologies critical to economic growth and security, such as data science, encryption, gene editing, new materials, nanotechnology, advanced computing technologies, and artificial intelligence." In addition, the 2018 *Nuclear Posture Review* states that the Department of Energy's National Nuclear Security Administration (DOE/NNSA) will "maintain and enhance the computational, experimental, and testing capabilities needed to annually assess nuclear weapons." To maintain competitive advantage and the necessary capabilities for the annual assessment, the United States must retain state-of-the-art capabilities in high performance computing (HPC). HPC will also help ensure national security, economic prosperity, technological strength, and scientific and energy research leadership. Failure to address national security, science, and growing big data needs will open the door to other nations with a demonstrated commitment to HPC investment to take the lead in a number of areas. Risk would increase not only in high-end computing, but also could eventually in science, national defense, energy innovation, and the commercial computing market.

The National Strategic Computing Initiative (NSCI) was established as a Federal interagency campaign in 2015 to maximize the benefits of HPC for U.S. economic competitiveness, scientific discovery, and national security. Other agencies with major responsibilities for the NSCI include the National Science Foundation, the intelligence community, and the Departments of Commerce, Defense, Justice, and Homeland Security. Major focus areas of the NSCI are the exploration and development of quantum computing, bio computing, and exascale computing. Within that initiative, DOE, represented by a partnership between the DOE Office of Science and NNSA, has the lead responsibility for focusing and implementing the joint Exascale Computing Initiative. This initiative focuses on advanced simulation that continues exploiting MOSFET[1] technology to emphasize sustained HPC to advance DOE/NNSA missions. The objectives and the associated scientific challenges define a mission need for a computing capability of 2 to 10 exaFLOPS[2] in the early to mid-2020s.

B.1 Challenges

To deliver the exascale computing capability for the nuclear security mission within the next decade while maintaining and modifying the integrated design codes (IDCs), NNSA will need to focus on six challenges:

- Developing HPC technologies and systems, in close partnership with computer vendors, that will provide at least an eight-fold increase in sustained application code performance over the currently largest NNSA supercomputer (a 125-petaFLOPS system)

[1] MOSFET stands for metal-oxide semiconductor, field-effect transistor. This technology, which has been the incumbent technology associated with Moore's law in microelectronics since the 1960s, theoretically begins failing significantly at speeds faster than exascale speeds.

[2] 1 exaFLOPS = 10^{18} floating-point operations per second.

- Addressing code performance on the current advanced architecture and next-generation systems, which employ heterogeneous architectures that are very different from the homogeneous computing environment we have experienced in the past 2 decades
- Advancing the Advanced Simulation and Computing (ASC)-funded laboratory and open-source software stack to run efficiently on the new advanced architectures and to support emerging workflows
- Developing prototype systems to assess the viability of alternate HPC architecture paths for the ASC
- Improving remote computing infrastructure to facilitate access across the DOE/NNSA complex to exascale and other leading-edge platforms wherever each may be sited
- Modernizing computing facilities to ready them for site future petascale and exascale platforms through increasing structural integrity, power, and cooling capabilities

B.2 Approaches and Strategies

To achieve DOE/NNSA's exascale goals, the U.S. Government has been interacting with industry in HPC technology development. Past partnerships between the U.S. Government and industry have led to development of innovative technologies that met both Federal and private sector objectives. NNSA is continuing its partnership with the DOE Office of Science on the Exascale Computing Initiative, including investments in research and development (R&D) of hardware and systems technologies, software tools, and applications with computer vendors, the national laboratories, and universities. In addition, the two organizations collaborated on the joint April 2018 CORAL-2 procurement, which will deliver one exascale-class system to DOE's Office of Science in FY 2021 – 2022 and another to NNSA in FY 2023. This joint procurement supports the program offices when they share critical non-recurring engineering development costs with the selected vendor team.

The current spend plan for Exascale Computing Initiative elements is delineated in **Table B–1**. In FY 2021, the NNSA portion of the Exascale Computing Initiative is categorized as ASC's Advanced Technology Development and Mitigation (ATDM) subprogram, which is a part of the Defense Applications and Modeling portfolio (composed of Integrated Codes, Physics and Engineering Models, and Verification and Validation subprograms) that funds the application of the next-generation exascale technologies for the weapons mission, as well as a portion of the Computational Systems and Software Environment (CSSE) subprogram that procures the El Capitan system. In addition, the NNSA Exascale Computing Initiative portfolio includes the Exascale Computing Facility Modernization (ECFM) project to prepare for siting the NNSA El Capitan exascale system in FY 2023. Future exascale investments will include improvements to remote computing infrastructure to advance complex-wide HPC capabilities.

Table B–1. NNSA Exascale Computing Initiative funding schedule for FY 2021 through 2025

Exascale Computing Initiative Elements (dollars in millions)	*FY 2021 Request*	*FY 2022 Request*	*FY 2023 Request*	*FY 2024 Request*	*FY 2025 Request*
Advanced Technology Development and Mitigation	40	40	17	5	–
Defense Applications and Modeling	28	28	33	40	–
Computational Systems and Software Environment	24	20	30	36	–
Exascale Computing Facility Modernization	29.2	–	–	–	–
Procurement	114	181	167	146	68
Total, NNSA Exascale Initiative	235.2	269	247	227	68

Advanced Technology Development and Mitigation

A major portion of the ASC ATDM subprogram is designated as part of the DOE Exascale Computing Project (ECP), a jointly managed collaboration between NNSA and DOE Office of Science via DOE Order 413.3B (tailored). This portion consists of the following two focus areas.

- *ATDM/ECP Application Development:* NNSA is responsible for determining the scope and management of the stockpile simulation application development that is included in this focus area. Confidence in the safety and reliability of the nuclear weapons stockpile relies on high-fidelity simulations of all of the physical processes occurring within a nuclear weapon and the processes that support the design, production, maintenance, and evaluation of the nuclear arsenal, including life extension programs and weapons dismantlement. The ASC IDCs model various aspects of nuclear weapons, and each has on the order of several million lines of code to accurately reflect the multi-scale, multi-physics phenomena occurring in a nuclear weapon. The accuracy of these IDCs underpins confidence in the U.S. nuclear deterrent and must be improved through ATDM Application funding to ensure continued future confidence in the Nation's stockpile. Exploiting the multi-level parallelism demanded by emerging architectures leading to exascale requires significant investment in new stockpile simulation code development over the next 5–7 years.
- *ATDM/ECP Software Technology*: With its stockpile stewardship mission, ASC will make strategic investments in ECP software technology to directly support its IDC development requirements, where appropriate. Funding will support further development of compilers, math libraries, and programming models for the NNSA suite of weapons codes that are aligned with the algorithms and approaches used in those codes. This focused research is needed to optimize the performance of the algorithms within the overall simulations that are the most time-demanding or require the highest control of precision in numerical approximations. Investments also will be made in various performance analysis tools and visualization techniques to aid code developers and users to navigate the new advanced architecture systems. The remainder of the ATDM portfolio includes funding that supports a project at the national security laboratories to work on the DOE-National Cancer Institute Collaboration that seeks to increase the capacity and capability of an enduring national HPC ecosystem.

Construction: Exascale Computing Facility Modernization at Lawrence Livermore National Laboratory

In addition to hardware and software technology development efforts, the exascale systems must meet exacting power usage, reliability, and functionality criteria. Each exascale-class platform will require a peak of between 28 and 45 megawatts to operate, as well as requisite cooling. Managing a service load of this magnitude, which is over and above existing capabilities in ASC facilities, is necessitating major facility modernizations. The ECFM project is intended to fill this gap by adding 40 megawatts of power (bringing the total to 85 megawatts) and 18,000 tons of water cooling (bringing the total to 28,000 tons) by calendar year 2022. A detailed engineering assessment in preparation for Critical Decision (CD)-2/3 (Approve Performance Baseline/Approve Start of Construction) proved that the building already met requirements to support 315 pounds per square foot of rack load and adequate square footage, so no additional structural or architectural investments are necessary in this area. The ECFM is essential for Lawrence Livermore National Laboratory (LLNL) to successfully site the NNSA exascale system at the beginning of FY 2023. Soon after receiving CD-2/3 in FY 2020 the ECFM project team awarded construction contracts and moved into the construction phase of the project.

Computational Systems and Software Environment – Exascale System (El Capitan)

NNSA is embarking on a multi-year collaboration with the selected 2023 exascale system vendor and its subcontractors to work on non-recurring engineering and system integration issues for El Capitan. The collaboration focuses on system engineering efforts and software technologies to assure the 2023 exascale system will be a capable and productive computing resource for the Stockpile Stewardship Program.

Computational Systems and Software Environment – Next-Generation Computing Technologies

In FY 2021, NNSA will transition its previously ATDM-funded computing technology activities to CSSE. NNSA will continue evaluating its next-generation IDCs' performance portability on advanced architecture prototype systems. Funding will be for development, maintenance, and user support for the NNSA tri-laboratory software stack that will be required for the next-generation codes to run efficiently on these advanced technology systems. In addition, NNSA will continue investing in the application of advanced machine learning techniques, which are well suited to the imminent advanced architectures, to address stockpile stewardship challenges.

Defense Application and Modeling – Next-Generation Application Development

In FY 2021, NNSA will begin transitioning the viable and validated ATDM next-generation code and associated capabilities into its Integrated Codes, Physics and Engineering Modeling, and Verification and Validation subprograms to support the annual assessment activities.

B.3 Collaborative Management

As the ECP spans across DOE/NNSA, its management equally involves both organizations' Federal and laboratory personnel. The ECP overall management structure includes the Integrated Project Team in **Figure B–1**. The Integrated Project Team provides planning, execution, coordination, and communication for the ECP to ensure that the project's objectives are achieved on schedule and within budget and are consistent with quality, environment, safety, and health standards.

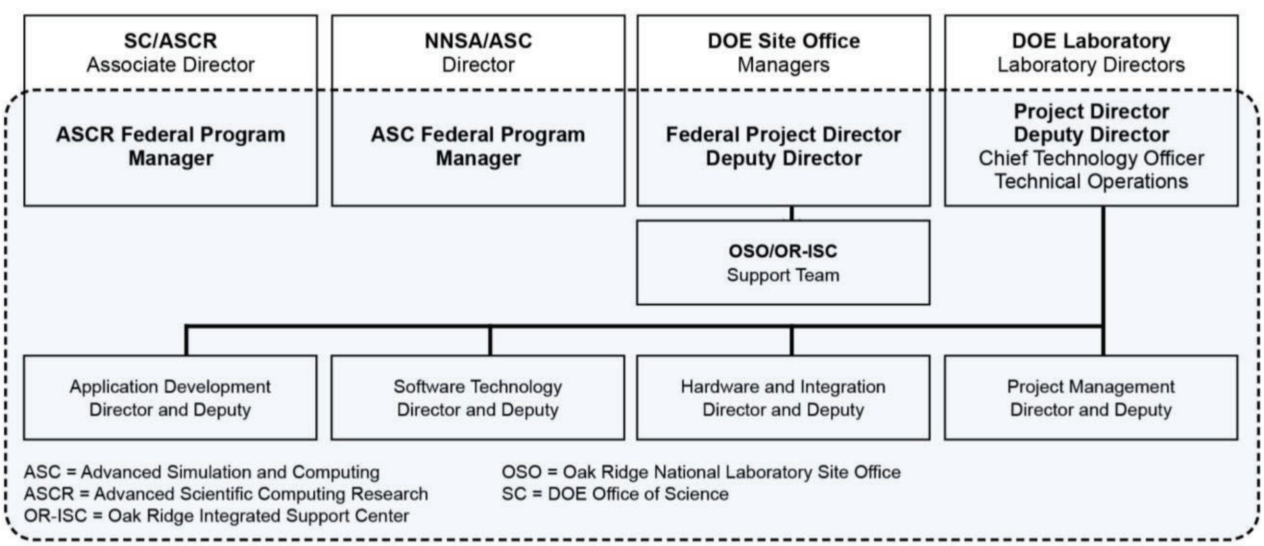

Figure B–1. Exascale Computing Project integrated project team

B.4 Milestones

DOE/NNSA has five milestones for FY 2021:

- Continue engagement with the El Capitan system vendor on non-recurring engineering activities
- Map ASC applications to target exascale architecture with machine-specific performance analysis
- Install El Capitan's early access hardware at LLNL
- Begin transition of selected NNSA ATDM application and software technologies to the ASC Defense Applications and Modeling portfolio for annual assessment mission
- Begin transition of selected NNSA ATDM computing technologies to its CSSE portfolio

B.5 Conclusion

DOE/NNSA, through the ASC Exascale effort, is investing in products and approaches that are directly related to anticipated disruptive changes in the HPC ecosystem. Activities include R&D partnerships with multiple HPC vendors, development of next-generation weapons codes with new simulation capabilities, advancing the tri-laboratory software stack, procuring an exascale system, deploying prototype systems to assess the viability of new computing technologies, and upgrading facilities to house future exascale and petascale systems. Cooperation with computer vendors has also led to significant advances in HPC software and hardware technologies. These activities have provided experience and lessons learned and have already delivered a variety of software development tools and libraries that many ASC applications now rely on. To complete this effort, more intensive research, development, and engineering effort is needed for DOE/NNSA to achieve the goal of deploying an exascale capability in 2023.

Appendix C
Capabilities and Definitions

This appendix describes the breadth of capabilities maintained by Weapons Activities programs in the Department of Energy/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. The capabilities represent the underlying disciplines, activities, and specialized skills required to meet DOE/NNSA missions. In this document, the capabilities are presented as facets of seven interdependent portfolios, each containing a suite of capabilities that together address a particular aspect of Weapons Activities. In part, this appendix supports legislative requirements listed in Appendix A.

Capability	*Definition*	*Portfolio*
Accelerator and Pulsed Power Science, Technology, and Engineering [a]	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. Pulsed power devices accumulate energy over long periods of time and release it rapidly to generate pressures, temperatures, and radiation conditions similar to those produced in or by nuclear weapons. Experiments and testing with these devices produces data critical to understanding physical phenomena, qualifying nuclear weapon components and improving performance assessments.	Weapon Science and Engineering
Advanced Experimental Diagnostics and Sensors	Advanced diagnostics and sensors provide detailed measurements of materials, objects, and dynamic processes that are critical to weapon operation and other national security operations. Standard diagnostics provide lower-resolution data suitable for basic inquiries, but not for detailed part, process, or physics qualification; continued diagnostic and sensor development is important to addressing these limitations. An example of an advanced diagnostic is static or multi-frame dynamic radiography at high resolution. Radiography is an imaging technique that uses X-rays or subatomic particles (e.g., protons, neutrons) to view the internal structure of an object that is opaque to visible light. Static radiography of a stationary object is used during the post-fabrication inspection process to ensure that components are defect-free and meet exacting quality requirements. Dynamic radiography takes multiple images of a dynamic process to examine physical behavior in progress.	Weapon Science and Engineering

Capability	***Definition***	***Portfolio***
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 include additive manufacturing, use of microreactors, microwave casting, and electrorefining.	Weapon Component Production
Atomic and Plasma Physics	Atomic physics is the study of atomic systems, such as a collection of atoms and electrons, and their interaction with X-rays. 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 and X-rays.	Weapon Science and Engineering
Chemistry and Chemical Engineering [a]	Chemistry studies the elemental composition, structure, bonding, and properties of matter. Chemical engineering is essential for purifying, synthesizing, processing, and fabricating materials at large scale. The stability of material properties and the nature of reactions, and interactions are critical components of system aging studies. How materials and properties change with time must be understood to ensure reliability and safety of the stockpile.	Weapon Science and Engineering
Energetic and Hazardous Material Handling, Packaging, Processing, and Manufacturing (High Explosives and Lithium)	Energetic and hazardous materials have the potential to harm humans, animals, or the environment. As a result they require safe and secure handling, packaging, processing, manufacturing, and inspection. These materials include lithium, beryllium, mercury, explosives, propellants and detonators.	Weapon Material Processing and Manufacturing
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.	Weapon Design and Integration
High Energy Density Physics	High energy density physics is the study of matter and radiation under extreme conditions such as those in a functioning nuclear weapon and reproduced in high-temperature experiments. Facilities such as the National Ignition Facility, Omega Laser Facility, and the Z pulsed power facility generate high energy density states producing data exploring the physical processes that occur in plasma states to validate computational models.	Weapon Science and Engineering
High Explosives and Energetics Science and Engineering [a]	High explosives and energetics science and engineering is 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. Understanding of these materials is necessary for understanding nuclear weapon performance.	Weapon Science and Engineering

Capability	***Definition***	***Portfolio***
High Performance Computing	High performance computing encompasses software, hardware, and facilities of sufficient power to achieve the dimensionality, resolution, and complexity in simulation codes to accurately model the performance of weapon systems and components and the fundamental physical processes that are critical to nuclear operation. This capability includes research and development in computer, information, and mathematical sciences to support developing and operating high-performance computing.	Weapon Simulation and Computing
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 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.	Weapon Science and Engineering
Information Technology and Cybersecurity	Information technology and cybersecurity provides infrastructure and protection for both classified and unclassified computing networks, secure communications, applications, systems, and logical environments. It ensures electronic information and information assets are operating nominally and are protected from unauthorized access and malicious acts that would adversely affect national and economic security.	Transportation and Security
Laser and Optical Science, Technology, and Engineering [a]	Lasers are coherent light sources delivering intense beams of energy to localized regions to generate and probe high energy density conditions similar to those produced during nuclear weapon operation. A laser's rapid energy delivery enables studies of fundamental properties of matter, radiation transport, hydrodynamics and turbulence, thermonuclear ignition and burn, as well as outputs and effects. Advancements in these areas is important to qualifying new components and systems and improving performance assessments.	Weapon Science and Engineering
Materials Science and Engineering	Materials science, in the context of stockpile stewardship, is the study of how materials in a nuclear weapon behave under moderate to extreme conditions of temperature and pressure. Materials engineering involves the evaluation and selection of materials for these environments. Strength, aging, compatibility, viability, and damage mechanics are among the materials characteristics to be evaluated. Materials science and engineering play a key role in resolving stockpile and production issues, validating computational models, and developing new materials (e.g., materials produced through additive manufacturing).	Weapon Science and Engineering
Metal and Organic Material Fabrication, Processing, and Manufacturing	Specialized components and materials that are not commercially available must be produced within the nuclear security enterprise. This production requires synthesis of organic materials and processing, manufacturing, and inspection of metallic and organic products, based on knowledge of material behavior, compatibility, and aging. This would include, but is not limited to, polymer material and part manufacturing.	Weapon Material Processing and Manufacturing

Capability	*Definition*	*Portfolio*
Non-Nuclear Component Production [a]	Non-nuclear weapon components and assembly processes require special manufacturing, assembly, and inspection protocols. The components include, but are not limited to, cable assemblies; electronic assemblies; microelectronics packaging; gas transfer systems; arming, fuzing, and firing assemblies; lightning arrestor connectors; environmental sensing devices; radars; neutron generators; and power sources.	Weapon Component Production
Nuclear Physics and Engineering [a]	Nuclear physics is the study of atomic nuclei and their constituents and nuclear engineering is the translation of nuclear physics principles to the practical application of nuclear interactions, especially fission and fusion. The need to understand the design and function of the nuclear explosive package drives the requirement to improve understanding of both fission and fusion.	Weapon Science and Engineering
Physical Security	Physical security protects the Nation's nuclear materials, infrastructure assets, and the workforce at DOE/NNSA sites involved in Weapons Activities. It protects assets from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile or noncompliant acts that may adversely affect national security, program continuity, and employee security.	Transportation and Security
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.	Weapon Design and Integration
Radiochemistry [a]	Radiochemistry is the study of radioactive materials and their interactions. It is critical to evaluating data from legacy underground testing as well as modeling problems in nuclear forensics and attribution. Thermonuclear fusion experiments at the National Ignition Facility, Omega Laser Facility, and the Z pulsed power facility can use radiochemical tracers in their diagnostic suites.	Weapon Science and Engineering
Secure Transportation	Protection and movement of nuclear weapons, weapon components, and special nuclear material between facilities includes design and fabrication or modification of vehicles, design and fabrication of special communication systems, and training of Federal agents.	Transportation and Security
Simulation Codes and Models	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.	Weapon Simulation and Computing
Special Nuclear Materials Handling, Packaging, and Processing (Plutonium and Uranium)	Components that contain special nuclear materials (e.g., plutonium, enriched uranium) require special conduct of operations, physical security protection, facilities, and equipment to handle, package, process manufacture, and inspect these components.	Weapon Material Processing and Manufacturing

Capability	*Definition*	*Portfolio*
Weapon Simulation and Computing [a]	Weapon Simulation and Computing encompasses software, hardware, and facilities of sufficient power to achieve the dimensionality, resolution, and complexity in simulation codes to accurately model the performance of weapon systems and components and the fundamental physical processes that are critical to nuclear operation. This capability includes research and development in computer, information, and mathematical sciences to support developing and operating high-performance computing.	Weapon Simulation and Computing
Testing Equipment Design and Fabrication	Design and fabrication of special test equipment to simulate environmental and functional conditions ensure that products meet specifications. Data from test equipment provide evidence for qualification, certification, reliability, surety, and surveillance.	Weapon Assembly, Storage, Testing, and Disposition
Tritium Production, Handling, and Processing	Tritium has a 12-year half-life and must be periodically replenished in gas transfer systems. Production, handling, and processing of tritium includes the recovery, extraction, refinement, storage, filling, and inspection of gas transfer systems.	Weapon Material Processing and Manufacturing
Weapon Assembly, Storage, and Disposition [a]	This capability includes assembly and disassembly of all warheads, including components and subsystems contained within a device. This encompasses the breadth of national security enterprise capabilities requiring special conduct of operations, equipment, facilities, and quality control. Disassembly, inspection, and disposition of the warhead, components, and subsystems requires similar special conduct of operations, equipment, and facilities. Storage of weapons and sub-systems requires special safety and security processes and protocols.	Weapon Assembly, Storage, Testing, and Disposition
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 special nuclear materials and other exotic materials. Component process development is needed whenever process changes are made to reduce cost or production time.	Weapon Component Production
Weapon Component and System Prototyping	The development, qualification, and manufacture of high-fidelity, full-scale prototype weapon components and systems reduce the cost and life cycle time to develop and qualify new designs and technologies. This capability includes the ability to design, manufacture, and employ mockups with sensors to support laboratory and flight tests that provide evidence that components can function with Department of Defense delivery systems in realistic environments.	Weapon Component Production
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.	Weapon Assembly, Storage, Testing, and Disposition

Capability	*Definition*	*Portfolio*
Weapons Engineering Design, Analysis, and Integration	Elements of weapons engineering include the following life cycle phases: concept exploration, requirements satisfaction, conceptual design, detailed design and development, production, certification, and qualification. This capability also encompasses systems integration, which includes understanding and developing the interfaces among the non-nuclear subsystems, between the non-nuclear components and the nuclear explosives package, and between the DOE/NNSA and Department of Defense systems.	Weapon Design and Integration
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.	Weapon Design and Integration
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.	Weapon Design and Integration

[a] Title changed since FY 2020 Stockpile Stewardship and Management Plan.

Appendix D
Glossary

3D printing—Also known as additive manufacturing, which turns digital three-dimensional models into solid objects by building them up in layers.

abnormal environment—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, yet is sufficiently important to the user regarding assembly, maintenance, storage, or test operations to require controlled application and identification.

annual assessment process—The authoritative method to evaluate the safety, reliability, performance, and military effectiveness of the stockpile by subject matter experts based upon new and legacy data, surveillance, and modeling and simulation. It is a principal factor in the Nation's ability to maintain a credible deterrent without nuclear explosive testing. The Directors of the three national security laboratories complete annual assessments of the stockpile, and the Commander of the U.S. Strategic Command provides a separate assessment of military effectiveness. The assessments also determine whether underground nuclear explosive testing must be conducted to resolve any issues. The Secretaries of Energy and Defense submit the reports unaltered to the President, along with any conclusions they deem appropriate.

arming, fuzing, and firing system—The electronic and mechanical functions that ensure a nuclear weapon does not operate when not intended during any part of its manufacture and lifetime, but do ensure the weapon will operate correctly when a unique signal to do so is properly activated.

B61—An air-delivered gravity bomb.

B61-12 Life Extension Program (LEP)—An LEP to consolidate four families of the B61 bomb into one and improve the safety and security of the oldest weapon system in the U.S. arsenal.

B83-1—An air-delivered gravity bomb.

Boost—The process that increases the yield of a nuclear weapon's primary stage through fusion reactions.

canned subassembly (CSA)—A component of a nuclear weapon that is hermetically sealed in a metal container. A CSA and the primary make up a weapon's nuclear explosive package.

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.

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

conventional high explosive (CHE)—A high explosive that detonates when given sufficient stimulus via a high-pressure shock. Stimuli from severe accident environments involving impact, fire, or electrical discharge may also initiate a CHE. See also "insensitive high explosive."

critical decision (CD)—The five levels a DOE project typically progresses through, which serve as major milestones approved by the Chief Executive for Project Management. Each CD marks an authorization to increase the commitment of resources and requires successful completion of the preceding phase. These five phases are CD-0, Approve Mission Need; CD-1, Approve Alternative Selection and Cost Range; CD-2, Approve Performance Baseline; CD-3, Approve Start of Construction/Execution; CD-4, Approve Start of Operations or Project Completion.

cybersecurity—The physical, technical, administrative, and management controls for providing the required and appropriate levels of protections of information and information assets against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional. Cybersecurity also ensures the required and appropriate level of confidentiality, integrity, availability, and accountability for the information stored, processed, or transmitted on electronic systems and networks.

data loss prevention (DLP)—DLP is a strategy for making sure that end users do not send sensitive or critical information outside the corporate network. DLP also includes software products that aid network administrators in controlling what data end users can transfer.

defense-in-depth—The security approach whereby layers of cybersecurity and information assurance solutions are used to establish an adequate security posture. Implementation of this strategy also is recognized due to the highly interactive nature of the various systems and networks. Cybersecurity defense-in-depth must be considered within the context of the shared risk environment, given that any single system cannot be adequately secured unless all interconnected systems are adequately secured.

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.

deuterium—An isotope of hydrogen whose nucleus contains one neutron and one proton.

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) through analysis of the ability to meet military requirements and assessment of schedule, cost, material, and production impacts.

encryption—Technical controls to protect information as it passes throughout a network and resides on computers. These methods protect sensitive information during storage and transmission and provide functionality to reduce the risk of both intentional and accidental data compromise and alteration.

enterprise forensics—The performance of real-time, remote inspections at the binary level of all data on a given system. The inspections include operating memory, physical storage devices, and virtualization mechanisms on any machine at a given time.

Enterprise Governance, Risk, and Compliance—The official corporate and enterprise program repository used to conduct continuous performance monitoring and reporting of information security program management, operations, and technical controls (e.g., authority-to-operate packages, deviations, incident management reporting).

Enterprise Information System—Systems within NNSA for which the authorization boundary covers multiple sites and multiple local Authorization Official jurisdictions.

exascale computing—Computing systems capable of at least 1 exaFLOPS, or a 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).”

firewalls—Systems that can be implemented in hardware and/or software that are designed to prevent unauthorized access to or from private networks connected to the Internet.

first production unit—The first system, subsystem, or component manufactured and accepted by NNSA as verifiably meeting all applicable quality and qualification requirements. The first production unit for a weapon is a production milestone. For milestone completion, two events must occur: (1) DoD or the Nuclear Weapons Council accepts the design and (2) DOE/NNSA verifies that the first produced weapon meets the design specifications.

fiscal year—The Federal budget and funding year that starts on October 1 and goes to the following September 30.

fission—The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial energy.

floating point operations per second (FLOPS)—The number of arithmetic operations performed on real numbers in a second; used as a measure of the performance of a computer system.

fusion—The process whereby the nuclei of two light elements, especially the isotopes of hydrogen (i.e., deuterium and tritium), combine to form the nucleus of a heavier element with the release of substantial energy and a high-energy neutron.

Future Years Nuclear Security Program (FYNSP)—A detailed description of the program elements (and associated projects and activities) for the fiscal year for which the annual budget is submitted and the four succeeding fiscal years.

general purpose infrastructure—The buildings, equipment, utilities, roads, etc., that support operation of the nuclear security enterprise, but are not specifically program-focused.

high explosives—Materials that detonate, with the chemical reaction components propagating at supersonic speeds. High explosives are used in the main charge of a weapon primary to compress the fissile material and initiate the chain of events leading to nuclear yield. See also “conventional high explosive” and “insensitive high explosive.”

high performance computing—The use of supercomputers and parallel processing techniques with multiple computers to perform computational tasks.

ignition—The point at which a nuclear fusion reaction becomes self-sustaining—that is, more energy is produced and retained in the fusion target than the energy used to initiate the nuclear reaction.

Information Assurance Response Center—The NNSA facility that continuously monitors all activity going through the nuclear security enterprise computer firewall system, to provide intrusion detection and event forensics.

information system—A combination of information, computer, and telecommunications resources and other information technology and personnel resources that collect, record, process, store, communicate, retrieve, and display information.

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.

Information Technology Infrastructure—The shared technology resources that provide the platform for the specific information system applications at a site or NNSA/DOE-wide. It consists of a set of physical devices and software applications that are required to operate the entire nuclear security enterprise.

insensitive high explosive—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.

intrusion prevention—A network security device that monitors network activities for malicious activities such as security threats or policy violations. The main function of an intrusion prevention system is to identify suspicious activity, log the information, and report it.

Joint Cybersecurity Coordination Center (JC3)—The cybersecurity incident response coordination, reporting, and tracking element for the entire DOE enterprise. JC3 provides computer security support to collect, analyze, and share cybersecurity information for all of DOE, including DOE’s Energy Information Administration and Power Marketing Administration, as well as NNSA’s national security laboratories, nuclear weapons production facilities, and Nevada National Security Site. JC3 is managed and operated by the DOE Chief Information Officer.

joint test assembly—(1) An electronic unit that contains sensors and instrumentation that monitor the weapon hardware performance during flight tests to ensure that the weapon components will function as designed. (2) An NNSA-developed configuration, based on NNSA-DoD requirements, for use in the flight test program.

life cycle—The series of stages through which a component, system, or weapon passes from initial development until it is consumed, disposed of, or altered in order to extend its lifetime.

life extension program (LEP)—A program that refurbishes warheads of a specific weapon type to extend the service life of a weapon. LEPs are designed to extend the life of a warhead by 20 to 30 years, while increasing safety and security.

lightning arrestor connector—Advanced interconnected nuclear safety devices designed to limit voltage during lightning strikes and other extreme high-voltage, high-temperature environments.

limited life component—A weapon component or subsystem whose performance degrades with age and must be replaced.

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 beginning at product development and ending with the highest, which is steady-state production.

mark quality—Weapon or weapon-related material that is certified by DOE/NNSA or its prime contractor quality organization to meet all applicable design requirements, drawings, and known design intent. Sometimes called "Diamond Stamp."

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.

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.

multilayered malware protection—Commercial software that guards against multiple threat vectors such as viruses, spyware, and Trojans. The software searches a hard disk or other media for known threat vectors and removes any that are found.

national security laboratory—Los Alamos National Laboratory, Sandia National Laboratories, or Lawrence Livermore National Laboratory.

national security system—Any telecommunications or information system operated by the U.S. Government whose function, operation, or use involves intelligence activities, cryptologic activities related to national security, command and control of military forces, or equipment that is an integral part of a weapon or weapons system or is critical to the direct fulfillment of military or intelligence missions. The term excludes any system used for routine administrative and business applications (including payroll, finance, logistics, and personnel management applications).

network—In relation to information technology and cybersecurity, a network is composed of a communications medium responsible for the transfer of information and all components attached to that medium.

network intrusion detection (NID)—An intrusion detection system inspects all inbound and outbound network activity and identifies suspicious patterns that may indicate an attempt to break into or compromise a system. NID systems (1) monitor all network traffic by inspecting and screening all inbound and outbound information technology network activity for patterns that may indicate an attempt to break in or compromise a system and (2) provide alerts based on predefined rules. These rules or signatures are updated as needed to reflect information learned from exploitation or attack attempts. When triggered, an NID system begins capturing network traffic related to the event in question, and the data are made available to security analysts. Notification is also sent to the Security Information and Event Management tool.

network monitoring—The use of a system that constantly monitors a computer network, providing vulnerability management and policy compliance tools; operating system, database, and application logs; and compilation of external threat data. A key focus is monitoring and managing user and service privileges, directory services, and other system configuration changes. Network monitoring also provides log auditing and review of incident responses.

NNSA Information Technology System—An information system that is owned and/or operated by NNSA or by contractors on behalf of NNSA to accomplish a Federal function. Regardless of whether NNSA Federal employees have access, this does not include information systems operated by management and operating contractors unless such systems' primary purposes are to accomplish Federal functions.

non-nuclear components—The parts or assemblies designed for use in nuclear weapons or in nuclear weapons training that do not contain special nuclear material; such components (e.g., radiation-hardened electronic circuits or arming, fuzing, and firing components) are not available commercially.

non-War Reserve—Weapon material that is not designated for the War Reserve stockpile, but is to be used by DOE/NNSA or delivered to DoD for the purpose of training, testing, and evaluating War Reserve material.

nuclear explosive package—An assembly containing fissionable and/or fusionable materials, as well as the main charge high-explosive parts or propellants capable of producing a nuclear detonation.

nuclear forensics—The investigation of nuclear materials to find evidence for the source, trafficking, and enrichment of the material.

nuclear security enterprise—The physical infrastructure, technology, and workforce at the national security laboratories, the nuclear weapons production sites, and the Nevada National Security Site.

Nuclear Weapons Council—The joint DOE/DoD Council composed of senior officials from both Departments who recommend the stockpile options and research priorities that shape national policies and budgets to develop, produce, surveil, and retire nuclear warheads and weapon delivery platforms and who consider the safety, security, and control issues for existing and proposed weapons programs.

nuclear weapons production site—The Kansas City National Security Campus, Pantex Plant, Y-12 National Security Complex, or Savannah River Site. Los Alamos National Laboratory and Sandia National Laboratories also perform some specific weapons production activities.

Other Program Money—Funding that is found outside of an LEP funding line (in other program lines), but is directly (uniquely) attributed to an LEP. Such funding would not be needed were it not for the LEP, although the activity or effort might still be done at some future point along a different timeline.

out-years—The years that follow the 5-year period of the FYNSP.

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 basically correspond to Phases 1 through 6 of the nuclear weapons life cycle.

physical security—The application of 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.

primary—The first stage of a two-stage nuclear weapon.

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.

Protected Distribution Systems—Wireline or fiber optic distribution systems used to transmit and protect unencrypted classified signal and data lines that exit secure areas and traverse through areas of lesser classification or security control.

qualification—The process of ensuring that design, product, and all associated processes are capable of meeting customer requirements. Authorizes the listed items for an intended use (i.e., War Reserve, Training, Evaluation, etc.). Generally includes Laboratory (Design Agency) 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.

quantification of margins and uncertainties—The methodology used in the post-nuclear-testing era to facilitate analysis and communicate confidence in assessing and certifying that stockpile weapons will perform safely, securely, and reliably. Scientific judgment of experts at the national security laboratories plays a crucial role in this determination, which is based on metrics that use experimental data, physical models, and numerical simulations.

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.

radiation case—A vessel that confines the radiation generated in a staged nuclear weapon.

reservoir—A vessel containing deuterium and tritium that permits its transfer as a gas in a nuclear weapon.

Retrofit Evaluation System Test—A test program conducted during retrofit of an NNSA weapon system on randomly selected, newly retrofitted weapons to determine the effect of the retrofit on the weapon system's reliability and to verify that the purpose of the retrofit is fully achieved. The program may consist of flight testing and/or laboratory testing.

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 DOE's and its contractors' facilities, property, and equipment.

security area—A defined area containing safeguards and security interests that requires physical protection measures. The types of security areas used by DOE/NNSA include property protection areas, limited areas, exclusion areas, protected areas, material access areas, and functionally specialized security areas such as sensitive compartmented information facilities, classified computer facilities, and secure communications centers.

security system—The combination of personnel, equipment, hardware and software, structures, plans and procedures, etc., used to protect safeguards and security interests.

service life—The duration of time that a nuclear weapon is maintained in the stockpile from Phase 5/6.5 (First Production) to Phase 7 (Retirement, Dismantlement, and Disposition). The terms "stockpile life," "deployed life," and "useful life" are subsumed by service 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.

Stewardship Capability Delivery Schedule (SCDS)—A planning framework for delivery of high-level science, technology, and engineering capabilities for mission application. The SCDS identifies the complex set of interlinked computational, experimental, and technology maturation activities needed for stockpile annual assessment, resolution of significant finding investigations, qualification and certification of life extension programs, and identification of options for the future deterrent.

stockpile-to-target sequence—A document that defines the logistical and employment concepts and related physical environments involved in delivering a nuclear weapon from storage and assembly, testing it, transporting it, and delivering the weapon to a target.

subcritical experiment—An experiment specifically designed to obtain data on nuclear weapons for which less than a critical mass of fissionable material is present and, hence, no self-sustaining nuclear fission chain reaction can occur, consistent with the Comprehensive Nuclear Test Ban Treaty.

supply chain risk management (SCRM)—The coordinated efforts of an organization to help identify, monitor, detect, and mitigate threats to supply chain continuity. Threats to the supply chain include cost volatility, material shortages, supplier financial issues and failures, and natural and manmade disasters. SCRM strategies and software help an organization foresee potential issues and adapt to both those risks and unforeseeable supply chain disruptions as quickly and efficiently as possible.

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 program to modify and maintain a set of nuclear weapon systems.

technology maturation—Advancing laboratory-developed technology to the point where it can be adopted and used by U.S. industry.

technology readiness level (TRL)—A measurement system to assess the maturity level of a particular technology that includes nine levels, where TRL 1 is the lowest (the associated scientific research is beginning) and TRL 9 is the highest (a technology has been proven through successful operation).

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.

threat information—Any information related to a threat that might help an organization protect itself against a threat or detect the activities of an actor. Major types of threat information include indicators; tactics, techniques, and procedures; security alerts; threat intelligence reports; and tool configurations.

tractor—A modified and armored vehicle to transport the Safeguards Transporter trailer.

tritium—A radioactive isotope of hydrogen whose nucleus contains two neutrons and one proton and is produced in nuclear reactors by the action of neutrons on lithium nuclei.

virtual desktop infrastructure—Software technology that separates the desktop environment and associated application software from the physical client device used to access it.

vulnerability scanning—The application of software that seeks out security flaws based on a database of known flaws, testing systems for the occurrence of these flaws, and generation of a report of the findings that can be used to tighten a networks security.

W76-1 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 Minute Man III LGM-30.

W80-4 LEP—An LEP for the W80 warhead aboard a cruise missile, delivered by the Air Force B-52 bomber and future launch platforms.

W88—A submarine-launched ballistic missile warhead, delivered by a Navy Trident II.

W88 Alteration (Alt) 370—An Alt of the W88 warhead to replace the arming, fuzing, and firing components and to refresh the conventional high explosive main charge.

W87-1—An intercontinental ballistic missile warhead designed to replace the W78 and support the Air Force's Ground-Based Strategic Deterrent missile system planned to replace the Minuteman III.

warhead—The part of a missile, projectile, torpedo, rocket, or other munitions 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.

wireless security—Security solution designed to test and evaluate the impact of mobile and fixed wireless communication devices used in or near classified and sensitive unclassified activity areas for the purpose of determining risks and countermeasures.

Appendix E
Lists of Figures and Tables

List of Figures

List of Tables

Appendix F
Acronyms and Abbreviations

AF&F	arming, fuzing, and firing
Alt	alteration
AoA	analysis of alternatives
ASC	Advanced Simulation and Computing
ASD	Advanced Sources and Detectors
ATDM	Advanced Technology Development and Mitigation
BCR	Baseline Cost Report
CAP	Capital Acquisition Planning
CD	Critical Decision
CMR	Chemistry and Metallurgy Research
CoLOSSIS	Confined Large Optical Scintillator Screen and Imaging System
CORAL	Collaboration of Oak Ridge National laboratory, Argonne National Laboratory, and Lawrence Livermore National Laboratory
COTS	commercial off-the-shelf
CREST	Combined Radiation Environments for Survivability Testing
CSSE	Computational Systems and Software Environment
CUAS	counter unmanned aircraft systems
DARHT	Dual-Axis Radiographic Hydrodynamic Test
DM	deferred maintenance
DNS	Office of Defense Nuclear Security
DoD	Department of Defense
DOE	Department of Energy
DUF_6	depleted uranium hexafluoride
ECFM	Exascale Computing Facility Modernization
ECP	Exascale Computing Project
ECSE	Enhanced Capabilities for Subcritical Experiments
ESC	Enterprise Secure Computing
FY	fiscal year
FYNSP	Future Years Nuclear Security Program
GAO	Government Accountability Office
GTS	gas transfer system
HE	high explosives
HED	high energy density
HERMES	High-Energy Radiation Megavolt Electron Source
HEU	highly enriched uranium
HOT SHOT	High Operational Tempo Sounding Rocket Program
HPC	high performance computing

ICF	inertial confinement fusion
IDCs	integrated design codes
IMI	Infrastructure Modernization Initiative
IT	information technology
JTA	joint test assembly
KCNSC	Kansas City National Security Campus
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
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
M/U	margin to uncertainty
MB	Management and Budget
MESA	Microsystems Engineering, Science and Applications
MFFF	Mixed Oxide Fuel Fabrication Facility
MGT	Mobile Guardian Transporter
Mod	modification
NEPA	National Environmental Policy Act
NSCI	National Strategic Computing Initiative
NMI	Nuclear Materials Integration
NNSA	National Nuclear Security Administration
NSCI	National Strategic Computing Initiative
OMB	Office of Management and Budget
Pantex	Pantex Plant
PIDAS	Perimeter Intrusion Detection and Assessment System
R&D	research and development
RD	restricted data
RDT&E	research, development, test and evaluation
RPV	replacement plant value
SAR	Selected Acquisition Report
SCE	Subcritical Experiments
SFI	significant finding investigation
SGT	Safeguards Transporter
SIRP	Security Infrastructure Revitalization Program
SLCM-N	Sea-Launched Cruise Missile
SNL	Sandia National Laboratories
SNM	special nuclear material
SRPPF	Savannah River Plutonium Processing Facility
SRS	Savannah River Site
SRT&E	Stockpile Research, Technology, and Engineering
SSMP	Stockpile Stewardship and Management Plan

ST&E	science, technology, and engineering
STA	Secure Transportation Asset
STS	stockpile-to-target sequence
TPBARs	tritium-producing burnable absorber rods
TVA	Tennessee Valley Authority
U.S.	United States
U.S.C.	United States Code
USSTRATCOM	U.S. Strategic Command
WDCR	Weapon Design and Cost Report
WDD	Weapons Dismantlement and Disposition
Y-12	Y-12 National Security Complex
Z	Z pulsed power facility

DOE/NA-0110

A Report to Congress

Fiscal Year 2021 Stockpile Stewardship and Management Plan – Biennial Plan Summary

December 2020

U.S. Department of Energy
National Nuclear Security Administration
1000 Independence Avenue, SW
Washington, DC 20585