Fiscal Year 2022
Stockpile Stewardship and Management Plan

Report to Congress
March 2022

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) has the mission to protect the American people by maintaining a safe, secure, and effective nuclear weapons stockpile; by advancing nuclear nonproliferation and reducing global nuclear threats; and by providing nuclear propulsion systems for the U.S. Navy.

DOE/NNSA's largest responsibility is our nuclear weapons program. Nuclear deterrence has been and remains the cornerstone of the Nation's security posture, and its credibility serves as the ultimate insurance policy against a nuclear attack. DOE/NNSA holds the unique obligation to maintain the capabilities – people, infrastructure, and tools – to design, produce, and certify the Nation's nuclear weapons stockpile. Our nuclear deterrence work is conducted in a distributed enterprise consisting of federal employees and specialized technical talent in government-owned, contractor-operated national laboratories, production facilities, and security sites. Since the days of the Manhattan Project, the highly talented people of the nuclear security enterprise have responded to an ever-evolving global security environment.

The *Fiscal Year 2022 Stockpile Stewardship and Management Plan* (SSMP) describes DOE/NNSA's plans to maintain the U.S. nuclear weapons stockpile and the capabilities of the nuclear security enterprise. DOE/NNSA also publishes the annual *Prevent, Counter, and Respond: A Strategic Plan to Reduce Global Nuclear Threats* report to Congress that describes the vital companion missions to advance nuclear nonproliferation and reduce global nuclear threats. In keeping with our commitments to Congress and the public, updated versions of these reports are published each year.

The fiscal year (FY) 2022 SSMP describes the active work across DOE/NNSA's nuclear security enterprise to achieve program requirements, including producing 80 plutonium pits per year and achieving the first production unit for the W80-4 Life Extension Program (LEP) and W87-1 Modification Program. The major activities in other weapon and infrastructure modernization work, science programs, and supporting functions are also discussed.

DOE/NNSA completed production of the W76-1 LEP, provided the W76-2 low-yield ballistic missile warhead for initial deployment in FY 2020, and completed first production unit delivery of both the B61-12 LEP and W88 Alteration 370 warheads in FY 2021. Also in FY 2021, the Los Alamos Pit Production Project and the Savannah River Plutonium Processing Facility each completed the Critical Decision 1 acquisition milestone and both continued design and project baseline analyses in preparation for Critical Decision 2. The nuclear security enterprise is at its busiest since the Cold War and our ability to innovate and accelerate delivery is front and center in all our programs.

DOE/NNSA's ability to continue to execute its mission depends on a modern, flexible, and resilient nuclear security infrastructure. This SSMP reflects continued investments in refurbishment and recapitalization of the national laboratories, production facilities, and security sites that are crucial to delivering on the Nation's nuclear weapons stockpile and supporting our workforce. Together with continued support from Congress, DOE/NNSA will advance its effort to realize the responsive, agile infrastructure needed for today and tomorrow.

President Biden has committed to exploring options to reduce the role of nuclear weapons in our national security strategy, while still ensuring our strategic deterrent remains safe, secure, and effective and that our extended deterrence commitments to our allies remain strong and credible. At the same time, the geopolitical environment today amplifies the need to retain a robust nuclear deterrent program and the associated infrastructure as we pursue these longer-term goals. The Nuclear Posture Review now underway will inform NNSA programs and our future requests and reports to Congress.

For over 75 years, the nuclear security enterprise has met every challenge, keeping the country safe and leading incredible scientific and engineering endeavors and discoveries. DOE/NNSA is fully committed and intensely focused on maintaining our tradition of delivering a safe, secure, and effective stockpile for the American people.

Pursuant to statute, this FY 2022 SSMP is provided to:

The Honorable Patrick Leahy
Chairman, Senate Committee on Appropriations

The Honorable Richard Shelby
Vice Chairman, Senate Committee on Appropriations

The Honorable Jack Reed
Chairman, Senate Committee on Armed Services

The Honorable Jim Inhofe
Ranking Member, Senate Committee on Armed Services

The Honorable Dianne Feinstein
Chairman, Subcommittee on Energy and Water Development
Senate Committee on Appropriations

The Honorable John Kennedy
Ranking Member, Subcommittee on Energy and Water Development
Senate Committee on Appropriations

The Honorable Angus King
Chairman, Subcommittee on Strategic Forces
Senate Committee on Armed Services

The Honorable Deb Fischer
Ranking Member, Subcommittee on Strategic Forces
Senate Committee on Armed Services

The Honorable Rosa L. DeLauro
Chairwoman, 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 Mike Rogers
Ranking Member, House Committee on Armed Services

The Honorable Marcy Kaptur

Chairwoman, 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 Doug Lamborn

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

Should you have any questions or need additional information, please contact Mr. Jason Miller, Acting Associate Administrator for Congressional and Intergovernmental Affairs, at (202) 586-8368.

Sincerely,

Jill Hruby
Under Secretary for Nuclear Security
Administrator, NNSA

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Message from the Secretary

At the Department of Energy (DOE), we are committed to protecting the American people and working seamlessly with the Department of Defense to maintain a safe, secure, and effective stockpile. DOE's National Nuclear Security Administration (NNSA) plays a critical role in our Nation's nuclear deterrence by stewarding the science and technology needed to certify the stockpile without nuclear explosive testing, delivering nuclear weapons life extension and modernization programs, and renewing our infrastructure to attract and retain the Nation's top talent. Through these activities, DOE/NNSA is prepared to flexibly address today's dynamic global security environment.

DOE is steadfast in its support of the people of the NNSA Enterprise. The extensive NNSA work plan presented in this report requires a national commitment. DOE, NNSA, and our entire nuclear security enterprise are prepared to do the hard work required over the next decade and beyond to responsibly achieve the agile and resilient enterprise needed for this generation and those to come. The Nation has placed a somber and unique responsibility on our enterprise, and we will provide innovative solutions to deliver.

We await the detailed planning being finalized in this Administration's *Nuclear Posture Review*, but we know DOE/NNSA will continue to have a pivotal role in providing nuclear deterrence. 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 today and tomorrow.

Sincerely,

Jennifer Granholm
Secretary of Energy

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Executive Summary

This *Fiscal Year 2022 Stockpile Stewardship and Management Plan* (SSMP), including its classified annex, describes the Department of Energy's 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 Request to Congress for Weapons Activities. This fiscal year (FY) 2022 SSMP is a detailed 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* while maintaining flexibility for the outcomes of the ongoing Biden-Harris Administration Nuclear Posture Review.

This SSMP reflects a rigorous mapping of the military requirements and nuclear security enterprise needs to assure an effective deterrent and meet the Nation's nuclear deterrent objectives. DOE/NNSA and the Department of Defense (DoD) are inextricably linked. The DoD and DOE/NNSA partnership manages weapons modernization needs from concept assessment to full-scale production and finally to retirement. With four major warhead modernization activities underway, DOE/NNSA is executing an unprecedented variety of complicated component development and production projects through this process and continues to make progress across all four warhead programs. DOE/NNSA and DoD remain in complete schedule alignment.

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. 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. Despite the challenges imposed by coronavirus disease-2019 (COVID-19)-related restrictions, DOE/NNSA has not missed any major deliverables or milestones.

Near-Term and Out-Year Mission Goals:

- Deliver the B61-12 gravity bomb.
- Deliver the W88 Alteration (Alt) 370 (with a refresh of the conventional high explosive).
- Achieve the first production unit of the W80-4 warhead life extension program (LEP) and ensure alignment with the DoD Long Range Standoff 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 unit until a suitable replacement is identified.

- Provide the enduring capability to produce 80 plutonium pits per year 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, including plutonium, uranium, lithium, tritium, and high explosives (HE).
- Provide experimental and computational capabilities to support annual assessment and certification of the stockpile.

Key Accomplishments:

Sustaining the Stockpile

- In 2020, DOE/NNSA delivered all scheduled limited life components (LLCs) for the B61, W76, W78, W80, B83, W87, and W88.
- Completed calibration services of over 1,200 critical equipment calibrations on time in support of production activities.
- Sustained base capabilities for multi-system operations and maintenance support to meet all LLC exchange gas transfer system (GTS) fills and GTS Surveillance DOE/NNSA deliverables to DoD.
- DOE/NNSA conducted surveillance activities for all weapon systems using data collection from flight tests, laboratory tests, and component evaluations to assess stockpile reliability without explosive nuclear testing, which culminated in completion of all annual assessment reports and generation of laboratory director letters to the President.
- Throughout 2020, the Office of Secure Transportation (OST) maintained its spotless record of accomplishing 100 percent of assigned missions safely and securely, with no mission degradation despite the operational challenges inherent during the COVID-19 pandemic.
- OST conducted the Mobile Guardian Transporter Test Article - 1 crash test. This highly successful endeavor proved the design and production process to date has been both rigorous and efficient.

Weapons Modernization

- The B61-12 LEP entered Phase 6.5, *First Production*, and achieved the system-level first production unit in November 2021.
- The W88 Alt 370 entered Phase 6.5, *First Production*, and achieved the system-level first production unit in July 2021.
- Successfully completed all Conceptual Design Reviews for the W80-4 and aligned assets to support first production unit development and Air Force planned initial operational capability.
- Finalized and documented W87-1 Modification Program surety architecture down-select, completed Customer Requirements Review with the Air Force, and coordinated flight test requirements with the Air Force.

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 (M&O) 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.
- Continue implementation of 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:

- In May 2020, the Exascale Class Computer Cooling Equipment Project at Los Alamos National Laboratory (LANL) reached Critical Decision-4 (CD-4), *Project Completion*, 10 months ahead of schedule and $20 million under budget.
- Applied Lawrence Livermore National Laboratory (LLNL) computing expertise to accelerate scientific discovery related to the COVID-19 virus; developed rapid, accurate diagnostic technologies; and supported rapid discovery of potential medical countermeasures.
- COVID-19-related research and development (R&D) work at LANL included a team that studied the virus' genetic sequence found that it originated from animals.
- Shot 4,000 was achieved by Sandia National Laboratories' (SNL) Cygnus Dual Axis Radiographic Source at the Nevada National Security Site (NNSS). Cygnus, a key diagnostic capability for subcritical experiments, was originally expected to be used for just a few hundred shots.
- Executed the Nightshade A plutonium subcritical experiment as part of the Red Sage series to examine the spall behavior of new and aged materials.
- *R&D World* magazine named 13 DOE/NNSA projects led by LLNL, LANL, NNSS, and SNL as winners in the annual R&D 100 Awards, which honor the 100 most innovative technologies and services of the past year.

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. The recommended strategy is a two-site solution:

  - Produce 30 pits per year at the Plutonium Facility at LANL during 2026
  - Repurpose the Mixed Oxide Fuel Fabrication Facility at the Savannah River Site (SRS) as part of the Savannah River Plutonium Processing Facility (SRPPF) to produce 50 pits per year as close to 2030 as possible

- 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 extending 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 HE 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 Advanced Sources and Detectors 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.

Key Accomplishments:

- Pit Production: Executing activities to support fulfilling the requirement to produce not less than 80 pits per year. Began engineering evaluations of production processes at LANL to qualify those processes for the first production unit and completed the CD-1, *Approve Alternative Selection and Cost Range*, package for the SRPPF.
- Tritium: Completed irradiation of 1,584 tritium-producing burnable absorber rods (TPBARs) in Fuel Cycle 16 in May 2020 at Watts Bar Unit 1 in Tennessee and commenced irradiation of 1,792 TPBARs in Fuel Cycle #17 at Watts Bar Unit 1 in June 2020. Commenced irradiation of 544 TPBARs during Fuel Cycle 4 in Watts Bar Unit 2 in November 2020 (first ever insertion of TPBARs into this unit).
- HE: In 2020, DOE/NNSA achieved CD-0, *Approve Mission Need*, for the Energetic Materials Characterization Facility, which will provide a modernized capability to conduct HE research, development, test, and evaluation; HE safety testing; development and production of detonators to support annual assessments; LEPs/Alt work; surveillance; future HE technology insertion; and detonator production.
- Lithium: In September 2020, DOE/NNSA re-established and qualified lithium reactor operations that had previously shut down in 2012.
- Uranium: Y-12 produced the first test button using the new electrorefining technology that will replace the current high-hazard enriched uranium purification process in the Manhattan Project-era Building 9212. Operators produce purified enriched uranium metal in a disc-like shape, called a button, so that it can be safely stored until it is used to produce a weapons component. This

new technology will be safer, more efficient, and is a major step toward allowing DOE/NNSA to reduce mission dependency on Building 9212.

- DOE/NNSA finished the exterior structure and reached beneficial occupancy of Building 225 at LLNL, which will house the future LLNL-Kansas City National Security Campus Polymer Enclave.

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. Executing a much-increased scope of activities centered around warhead modernizations in an aged enterprise has resulted in several operational adjustments and critical equipment being operated at significantly increased rates. This has required some innovative adaptation of current capabilities and the development of just-in-time capabilities. Weapons 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 now and into the future. Recent budget increases will enable continued execution of the weapons modernization programs as well as reverse decades of deterioration of critical DOE/NNSA infrastructure and loss of capability. With continued support, DOE/NNSA will ensure that the nuclear deterrent has the responsive, agile infrastructure needed to meet requirements.

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Fiscal Year 2022 Stockpile Stewardship and Management Plan

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Legislative Language

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

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

Pursuant to previous statutory requirements, the Department of Energy/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 2022 Stockpile Stewardship and Management Plan (SSMP) is a detailed report of DOE/NNSA's 25-year program of record to maintain the safety, security, and effectiveness of the nuclear stockpile and is primarily captured in this single, unclassified document. A classified annex to the SSMP contains supporting details concerning the U.S. nuclear stockpile and stockpile management.

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

Chapter 1
Introduction and Strategic Context for Managing the Nuclear Weapons Stockpile

The U.S. nuclear deterrent is the foundation of the national defense, and its credibility serves as the ultimate insurance policy against a nuclear attack. While the ultimate goal of eliminating nuclear weapons has been an aspiration for generations, the reality of today's evolving and uncertain international security environment must be recognized. China and Russia are advancing their nuclear capabilities, which challenges U.S. advantages directly. The United States must respond to the increasing desire of state and non-state actors to reshape the world in their favor, at the expense of the Nation, its allies, and partners and, at times, in contravention of international norms and rules.

The U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) and Department of Defense (DoD) are inextricably linked in achieving the nuclear deterrent mission. To execute the Nation's nuclear weapons programs, DOE/NNSA, in partnership with DoD through the Nuclear Weapons Council, conducts activities in a joint nuclear weapons acquisition process known as the joint nuclear weapons life cycle process. DoD and DOE/NNSA use this process to manage weapons sustainment and modernization needs from concept assessment to full scale production, and finally to retirement. Progress continues to be made across the four current major warhead programs as the DOE/NNSA continues to execute an unprecedented variety of complicated component development, qualification, system integration, and production activities. While DOE/NNSA remain in complete schedule alignment, sustained funding and support are critical to remain in alignment while meeting milestone and delivery targets.

The W80-4 and W87-1 are making more significant changes than any life extension program in the Stockpile Stewardship Program era, which stresses stewardship tools in significant and unprecedented ways.

The weapons comprising the U.S. nuclear stockpile are assessed to be safe, reliable, effective, and secure. DOE/NNSA's scientific infrastructure is currently adequate to support stockpile actions. The DOE/NNSA plans to address near-term gaps in required scientific capabilities by deploying the DOE/NNSA's first exascale computing platform in fiscal year (FY) 2023 and by improving capabilities to conduct subcritical experiments through the Enhanced Capabilities for Subcritical Experiments project by FY 2026. DOE/NNSA's production infrastructure has atrophied to the point of an increased risk to the mission. DOE/NNSA is executing a number of production facility and capability modernization activities with completion dates designed to minimize potential impacts to the continued operational effectiveness of the U.S. nuclear deterrent.

Further, modernizing the nuclear weapons stockpile and recapitalizing the supporting infrastructure needed to produce and maintain the stockpile are critical to maintaining necessary deterrent capabilities. Many of DOE/NNSA's facilities are beyond their life expectancy, and many others are in poor condition. Assessments of facilities throughout the enterprise have identified numerous potential single-point failures. If not appropriately addressed, the age and condition of DOE/NNSA's infrastructure will put its deterrence mission, as well as the safety of its workforce, the public, and the environment, at risk.

DOE/NNSA is undertaking a risk-informed, complex, and time-constrained modernization and recapitalization effort to ensure continued mission success. Details of many of these plans are contained in the following chapters.

1.1 Overview

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

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 the potential performance of and our understanding of the stockpile's aged, modified, or modernized nuclear weapons
  - Maintain and modernize the supporting infrastructure
  - Sustain DOE/NNSA's highly skilled workforce necessary for this work
- The SSMP provides DOE/NNSA's formal response to multiple statutory reporting requirements, which can be found in Appendix A, "Requirements Mapping," and, among others, include:
  - Annual Life Extension Program reporting required under the Explanatory Statement accompanying the *Consolidated Appropriations Act, 2017* (P.L. 115-31)
  - Status of programs, projects, and activities within the Stockpile Responsiveness Program requested through language in the House Report accompanying the Energy and Water Development and Related Agencies Appropriations Bill, 2021 (H. Rept. 116-449)

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

Consistent with the past two transition year budgets (FY 2018 and FY 2010), the FY 2022 President's Budget does not include program-based defense budget levels beyond the budget year. Instead, the defense estimates for FY 2023-2026 simply reflect inflated FY 2022 levels, not policy judgments. The Administration will include outyear defense program funding levels in the FY 2023 Budget, in accordance with strategy documents currently under development. The FY 2023 President's Budget will be accompanied by a Future Years Nuclear Security Program that reflects this Administration's policy judgments through the ongoing Nuclear Posture Review.[1]

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

1.2 Policy Framework Summary

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

Other policy documents reinforce the requirement for a nuclear weapons infrastructure that is flexible, responsive, and resilient enough to meet changing geopolitical challenges while providing direction and guidance to DOE/NNSA on accomplishing the nuclear weapons mission. The 2021 *Interim National Security Strategic Guidance* states that the U.S. will "take steps to reduce the role of nuclear weapons in our national security strategy, while ensuring our strategic deterrent remains safe, secure, and effective and that our extended deterrence commitments to our allies remain strong and credible."

1.3 The DOE/NNSA Nuclear Security Enterprise

The DOE/NNSA nuclear security enterprise (**Figure 1–1**) consists of DOE/NNSA Headquarters (located in Washington, DC; Germantown, Maryland; and Albuquerque, New Mexico); the DOE/NNSA field offices; the three national security laboratories (two of which have production missions); the four nuclear weapons production sites; and the Nevada National Security Site (NNSS). DOE/NNSA implements the overall nuclear weapons strategy, in collaboration with its management and operating (M&O) partners, and oversees and coordinates activities to ensure they are accomplished in an efficient, fiscally responsible manner.

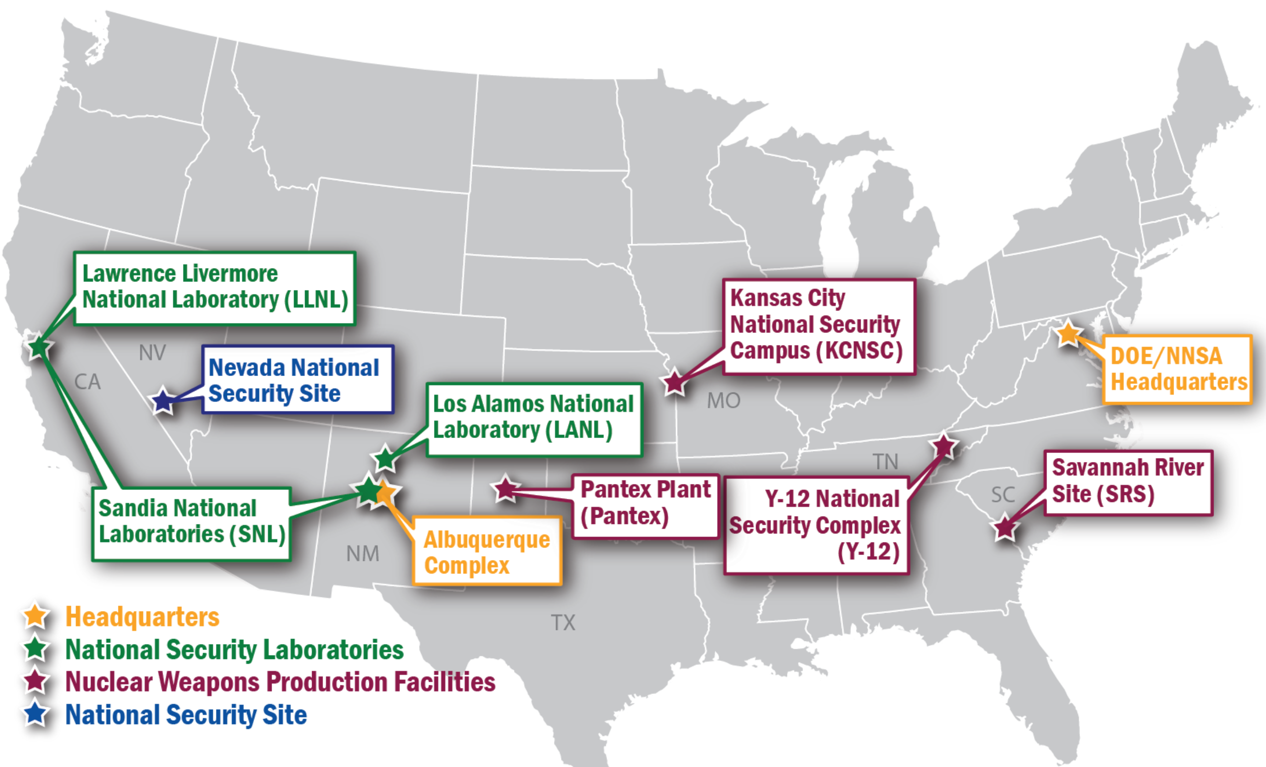


Figure 1–1. The DOE/NNSA nuclear security enterprise

1.3.1 National Security Laboratories

Three national security laboratories are devoted to nuclear weapons design and data interpretation:

- Lawrence Livermore National Laboratory (LLNL) in Livermore, California
- Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico
- Sandia National Laboratories (SNL) in Albuquerque, New Mexico, and Livermore, California

The primary mission of these national security laboratories is to research, develop, sustain, and implement nuclear weapons design, simulation, modeling, and experimental capabilities and competencies to ensure confidence in the current and future stockpile without nuclear explosive testing. All three laboratories are Federally Funded Research and Development Centers (FFRDCs).[2] The national security laboratories engage in long-term research, development, test, and evaluation activities for the nuclear weapons missions and apply science, technology, and engineering to solve other national security challenges, such as nuclear threat reduction. Other DOE national laboratories also support the Weapons Activities and Defense Nuclear Nonproliferation programs.

1.3.2 Nuclear Weapons Production Facilities

The four nuclear weapons production sites conduct a range of stockpile management activities:[3]

- The Kansas City National Security Campus in Kansas City, Missouri, produces non-nuclear components.
- The Pantex Plant in Amarillo, Texas, manufactures and tests high explosive (HE) components, and assembles, disassembles, and refurbishes stockpile weapons and components.
- The Y-12 National Security Complex in Oak Ridge, Tennessee, manufactures uranium components and dismantles and stores highly enriched uranium.
- The Savannah River Site (SRS) in Aiken, South Carolina, extracts, recycles, and loads tritium into gas transfer systems.[4]

In addition to Weapons Activities work, these facilities also support DOE/NNSA's nuclear nonproliferation, counterproliferation, and counterterrorism missions.

1.3.3 Nevada National Security Site

NNSS near Las Vegas, Nevada, works with the national security laboratories to provide facilities, infrastructure, and personnel to conduct unique nuclear and non-nuclear experiments that are essential to maintaining the stockpile. It is the primary location where experiments with radioactive and other high-hazard materials are conducted and is the only location where HE-driven plutonium experiments can be conducted at weapon-scale with weapon-relevant amounts of special nuclear material. NNSS also

[2] FFRDCs are unique nonprofit entities sponsored and funded by the U.S. Government to meet special long-term research or development needs that cannot be met as effectively by existing in-house or contractor resources. FFRDCs are operated, managed, and/or administered by either a university or consortium of universities, another not-for-profit or nonprofit organization, or an industrial firm either as an autonomous organization or an identifiable separate operating unit of a parent organization.

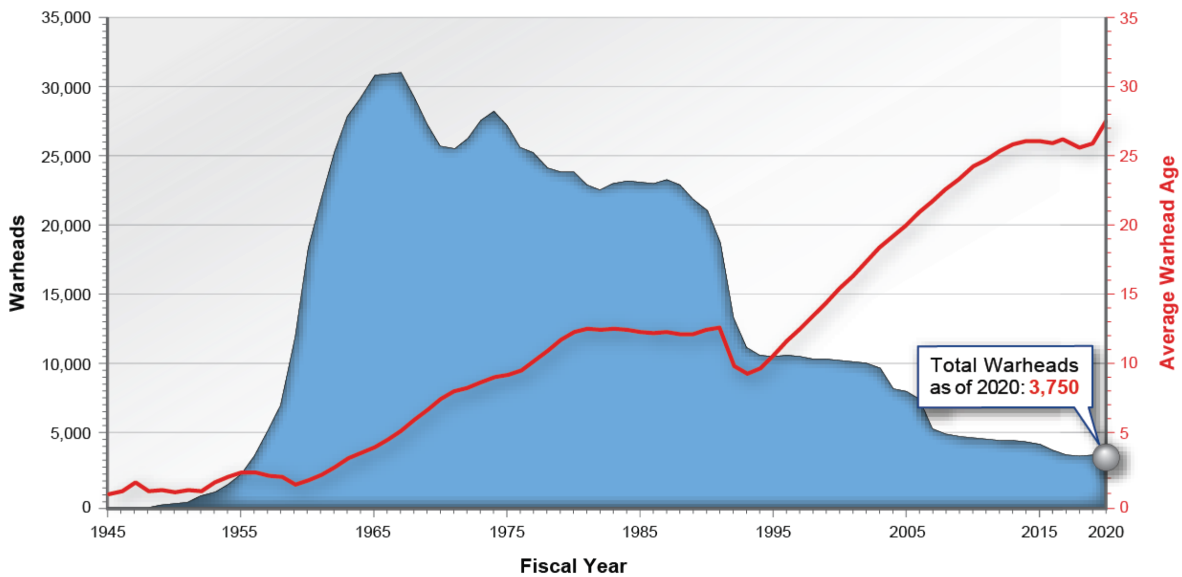
[3] Some production capabilities also exist at LANL and SNL. LANL manufactures pits, detonators, detonator cables, and radioisotope thermoelectric generators. SNL manufactures neutron generators, power sources, explosive components and energetic materials, surety technologies, and strategic, radiation-hardened microsystems such as custom application-specific integrated circuits.

[4] DOE's Savannah River National Laboratory at SRS also conducts research and development in support of tritium processing and gas transfer system design and certification activities.

develops and deploys state-of-the-art diagnostics and instrumentation, analyzes data, stores programmatic materials, conducts criticality experiments, and supports other DOE/NNSA activities.

1.4 Introduction to the Nuclear Weapons Stockpile

The size and composition of the nuclear stockpile continues to change in response to U.S. national security needs. The average age of weapons in the stockpile remains high. Many weapons are considerably past their original design life and require stockpile management to assess their condition and perform additional maintenance and enhanced surveillance to ensure operability and extend weapon lifetimes. With four major warhead modernization activities underway, DOE/NNSA is making significant progress toward reducing the average warhead age. The change over time in the size and age of the nuclear weapons stockpile is illustrated in **Figure 1–2**.



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

Figure 1–2. Size and age of the U.S. nuclear weapons stockpile, 1945–2020

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

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

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

Type [a]	Description	Delivery System	Laboratories	Mission	Military
Warheads—Strategic Ballistic Missile Platforms					
W78	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LANL/SNL	Surface to surface	Air Force
W87-0	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LLNL/SNL	Surface to surface	Air Force
W76-0/1/2	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
W88	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
Bombs—Aircraft Platforms					
B61-3/4	Non-strategic bomb	F-15, F-16, certified NATO aircraft	LANL/SNL	Air to surface	Air Force/Select NATO forces
B61-7	Strategic bomb	B-2 bombers	LANL/SNL	Air to surface	Air Force
B61-11	Strategic bomb	B-2 bomber	LANL/SNL	Air to surface	Air Force
B83-1	Strategic bomb	B-52 and 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
LLNL = Lawrence Livermore National Laboratory
NATO = North Atlantic Treaty Organization
SNL = Sandia National Laboratories

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

1.5 Overall Strategy, Objectives, and Prioritization of Weapons Activities

DOE/NNSA continues to execute its long-standing nuclear modernization efforts in conjunction with DoD delivery platforms, the nuclear weapons required for those platforms, and the DOE/NNSA infrastructure needed to produce and maintain those weapons. This will ensure the necessary flexibility for future policy decisions related to nuclear modernization as the United States adjusts to the changing international threats facing the United States. The nuclear weapons stockpile is currently safe, secure, and militarily effective. However, the legacy stockpile systems are aging, and DOE/NNSA's production infrastructure has atrophied considerably. The United States must invest in the weapons and infrastructure modernization programs to provide the capabilities needed to ensure the deterrent's viability into the future. Due to long lead times, the United States will not have the weapons and infrastructure in place to support the nuclear arsenal unless DOE/NNSA re-establishes these capabilities now.

The need to modernize the nuclear weapons stockpile and recapitalize the supporting infrastructure needed to produce and maintain that stockpile has reached a key juncture. Approximately 60 percent of DOE/NNSA's facilities are more than 40 years old, and more than 50 percent are in poor condition. Recent increases in operational needs have stressed these facilities and highlighted the need for upgrades to ensure capacities can be met. Assessments of facilities throughout the enterprise have identified numerous single-point failures. Production capabilities allowed to lapse are needed once again, and re-establishing these capabilities is both a priority and a challenge. If not appropriately addressed, the age and condition of DOE/NNSA's infrastructure will put at risk DOE/NNSA's missions, as well as the safety of its workforce, the public, and the environment.

The FY 2022 budget for Weapons Activities includes funding for several nuclear modernization programs with the goal of maximizing the President's decision space during the NPR:

> ***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 and diverse workforce to meet mission deliverables*

- **Retain the B83-1.** On August 28, 2018, the Nuclear Weapons Council authorized the retention of the B83-1 gravity bomb past its planned retirement date to support military needs. DOE/NNSA completed the planning, scheduling, and budgeting required to maintain the B83-1 through the Nuclear Weapons Council-determined retirement date.
- **Define the Capability to Effectively Engage and Defeat Hardened and Deeply Buried Targets.** The Nuclear Weapons Council established a joint NNSA/DoD Hard and Deeply Buried Target Defeat Team, coordinated through the Assistant Secretary of Defense for Nuclear Chemical and Biological Defense Programs/Office of Nuclear Matters, to determine future options for defeating such targets.
- **Begin a Sea-Launched Cruise Missile program.** Feasibility studies of this capability are being coordinated by a joint DoD-DOE/NNSA working group led by DoD's Office of Nuclear Matters. The Nuclear Weapons Council issued notice of a preferred warhead solution, a W80-4-like variant, to minimize impacts to the strategic nuclear stockpile. However, the final selection will be determined at the conclusion of the Analysis of Alternatives.
- **Advance the W87-1 Modification Program.** The W87-1 Modification Program will replace the aging W78 warhead using a modification of the existing legacy W87-0 design and will deploy new technologies that improve safety and security, address material obsolescence, and improve warhead manufacturability. In FY 2020, DOE/NNSA:
  - Evaluated warhead technologies
  - Progressed the maturity of select technologies
  - Conducted a feasibility study of design options
  - Continued program management and control implementation
  - Established formal risk reporting and management
  - Conducted requirements analysis and completed a customer requirements review that was integrated with Air Force acquisition programs
  - Conducted systems engineering
  - Began early system test and qualification planning.
- **Develop the W93.** The W93/Mk7 is a new program of record being established to meet requirements set by DoD. Anchored on previously tested nuclear components, the W93 will incorporate modern technologies to improve safety, security, and flexibility to address future threats. It will be designed for ease of manufacturing, maintenance, and certification. All of its key nuclear components will be based on currently deployed and previously tested nuclear designs, as well as extensive stockpile component and materials experience. It will not require additional nuclear explosive testing to be certified.

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

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

- Completing the B61-12 Life Extension Program (LEP).
- Completing the W88 Alteration (Alt) 370.
- Synchronizing DOE/NNSA's W80-4 warhead with DoD's Long Range Standoff cruise missile program and completing the W80-4 LEP by FY 2031.
- Exploring future ballistic missile warhead options to meet the required military characteristics based on the threats and vulnerabilities of potential adversaries. These options include the possibility of common reentry systems for Air Force and Navy systems.

Achieving this strategy requires modernization activities to address issues such as aging, the unavailability of replacement parts, evolving threats, 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 LEPs. Other modernization efforts include Alts, which do *not* change the weapon's operational capabilities, as well as modification programs, which *do* change the weapon's operational capabilities. DOE/NNSA also conducts surveillance 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 weapon life cycle and addresses DoD and DOE/NNSA warhead modernization needs from concept assessment to full-scale production to retirement or storage. With several 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 warhead programs. DOE/NNSA and DoD coordinate weapon modernization and sustainment efforts to synchronize with nuclear weapon delivery system programs.

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, develop, and enhance science capabilities to assess effects of aging, remanufacture and material options, and evolving threat environments on warhead performance.
  - Develop modern materials and design and manufacturing options to enable a more modern and efficient production complex.
  - 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 (NOTE: These capabilities are discussed in the FY 2022 SSMP in Chapter 3, "Weapons Activities Capabilities that Support the Nuclear Security Enterprise"):
  - Renew and sustain critical production, manufacturing, and research capabilities.
  - Assure a stable, reliable, and trusted domestic supply chain for nuclear weapon components and subsystems.
- 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.

The Integrated Stockpile Model in **Figure 1–3** shows how the main activities of the stockpile cycle — plan, modernize, maintain, assess, and certify — link these strategies to sustain the stockpile and support mission priorities.

Figure 1–3. Integrated stockpile model

1.6 Partnership with the Department of Defense

DOE/NNSA and DoD work collaboratively to maintain and modernize the stockpile and delivery systems. DOE/NNSA's role is to ensure that nuclear weapons remain safe, secure, and reliable, while DoD's role is to provide a range of delivery options that can be tailored to meet the desired objectives. These complementary efforts are coordinated through the congressionally-mandated Nuclear Weapons Council. This is a joint DoD and DOE/NNSA coordinating body established by Congress to facilitate the alignment of requirements and to establish priorities as the two Departments fulfill their shared responsibility for providing the Nation's nuclear deterrent.

The Nuclear Weapons Council's current structure and business processes ensure coordination. Senior-level attention is focused on the capabilities and capacities needed to maintain and modernize an effective nuclear weapons stockpile that meets the requirements of an increasingly challenging international security environment. The Nuclear Weapons Council regularly convenes to synchronize efforts between DoD and DOE/NNSA on the vision, strategy, and execution of the nuclear program aligned with the National Defense Strategy. The Nuclear Weapons Council also reviews costs and schedules for options related to the nuclear stockpile, driving DOE/NNSA and the Services to meet requirements in ways that are both cost-effective and timely. The Nuclear Weapons Council fully supports DOE/NNSA's efforts to establish a responsive and resilient nuclear security enterprise to meet U.S. deterrence and assurance needs.

1.7 Challenges in Executing the Stockpile Stewardship and Management Plan

DoD has embarked on the first recapitalization of the triad[5] since the end of the Cold War, and this effort cannot be accomplished alone. The partnership between DoD and DOE/NNSA continues to thrive through the interagency Nuclear Weapons Council, which has made tremendous progress to align priorities, schedules, and investments between the Departments to ensure the future viability of the Nation's nuclear deterrent.

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

One of the most critical challenges that DOE/NNSA must address is the modernization and recapitalization of existing infrastructure in parallel with increasing mission requirements. 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

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

critical for the production facilities and strategic material production capabilities and capacities within the nuclear security enterprise.

DOE/NNSA must re-establish a number of full-rate production capabilities to meet planned DoD warhead deliveries. If any of these facilities experience operational shutdowns due to mounting age-associated issues, stockpile maintenance and warhead deliveries will be affected. Considering that it can take a decade or more to plan and complete facility replacement projects, it is crucial 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 a plan to renew the essential time-critical manufacturing capabilities prioritized to meet DoD near- to intermediate-term warhead deliveries and to maintain workforce safety. This plan focuses on five areas:

- Establishing a production capability of 80 pits per year.
- Re-establishing HE 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 research, development, testing, and production capabilities.

Figure 1–4 shows the timeline necessary to meet warhead needs.

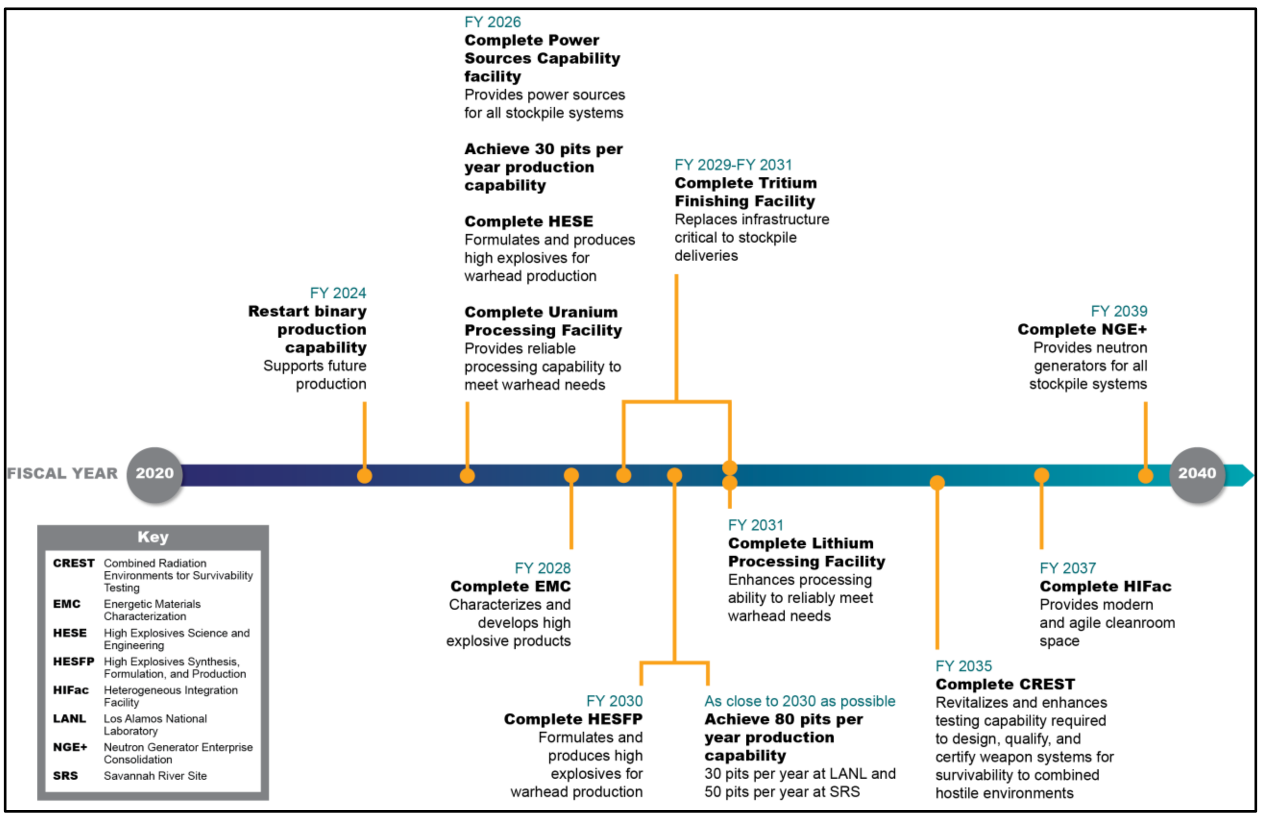


Figure 1–4. Timeline for key infrastructure and capability investments for future warheads

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

The condition of the facilities in the nuclear security enterprise imposes a risk to the mission. Accordingly, DOE/NNSA prioritizes strategies to address infrastructure challenges 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 current and emerging challenges:

- The current stockpile program of record represents a continued increase in scope, including restarting production operations that have been dormant for decades and increasing the overall production rates of many components. DOE/NNSA is restoring capabilities and increasing 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 design, qualify, certify, and produce warheads in accordance with stringent and evolving stockpile specifications and requirements. The increased number of concurrent weapon system builds entails three requirements:
  - Maturing new options with shortened development cycles
  - Advancing the ability to predict weapon performance in configurations that were not tested underground
  - Evaluating the impact of new materials and processes, reusing aging components in future systems, and enhancing production throughput
- DOE/NNSA must continue efforts to develop and exercise the capabilities required to support all phases of the joint nuclear weapons life cycle process, transfer knowledge and skills to the newer generation of nuclear weapon designers and engineers, accelerate and enhance the weapon life cycle, and strengthen integration between DoD and DOE/NNSA. This continued focus is reflected in the addition of a new Appendix D to report on the programs, projects, and activities of the Stockpile Responsiveness Program.
- The availability and trustworthiness of the nuclear weapons supply chain must be sustained to assure industrial base viability and guard against potential counterfeit and sabotage. DOE/NNSA has also 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 of key and critical facilities. DOE/NNSA is also interacting and collaborating with partners to establish research and development efforts that could serve as a future production capability.

COVID-19

The COVID-19 pandemic presented a series of unprecedented challenges for the nuclear security enterprise and its workforce. The health and safety of our employees is the Department's main focus. Due to its critical national security missions, DOE/NNSA could not and cannot temporarily cease operations and wait until the crisis is over.

DOE/NNSA adopted a policy of maximum telework and social distancing to safeguard the health and welfare of our workforce, while also identifying a number of mission-critical activities that could not be performed remotely and needed to continue on-site. DOE/NNSA worked with its sites to set priorities and relied on them to make decisions based on the local situation and regulations to protect the workforce.

The crisis created significant disruptions, but the workforce adapted and remained productive. Thanks to the steadfast commitment and perseverance of the nuclear security enterprise, DOE/NNSA has not missed any deliverables to its DoD partners and customers during the COVID-19 pandemic. In addition, despite the impact of the pandemic on international travel, DOE/NNSA has maintained strong relationships with foreign partners through the implementation of virtual engagements for technical exchanges, training, and coordination to further enhance international nuclear security and nonproliferation efforts. Any significant changes to individual programs or activities will be addressed in the appropriate section.

Workforce Recruiting and Retention

The nuclear security enterprise has many retirement-eligible employees who are expected to leave the workforce in the near future. To prepare for these retirements, new hiring initiatives are necessary to recruit, train, and 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
Stockpile Management

This chapter describes the manner in which the Department of Energy's National Nuclear Security Administration (DOE/NNSA) accomplishes the part of its Weapons Activities mission that more directly involves the stockpile warheads. These activities include: sustaining, modernizing, and dismantling nuclear weapons; maintaining and modernizing production operations; and optimizing the scientific tools that underpin these efforts.

Stockpile Management Accomplishments

- *Delivered all scheduled limited life components (LLCs) for the B61, W76, W78, W80, B83, W87, and W88.*
- *Obtained authorization for Phase 6.5, First Production, for the B61-12 and the W88 Alt 370.*
- *Completed W88 Alt 370 first production unit in July 2021.*
- *Completed B61-12 first production unit in November 2021.*
- *Completed Cycle 25 of the Annual Assessment process.*
- *Dispositioned site component programs and kept legacy piles from growing despite COVID-19.*

DOE/NNSA manages the stockpile through four major program areas, coordinating and planning with the Department of Defense (DoD) for the current and future stockpile:

- **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. It also includes modernization programs that do not constitute an LEP, Mod, or Alt, but provide a modernized warhead capability (e.g., the W93).
- **Weapons Dismantlement and Disposition (WDD)** handles dismantlement of retired weapons and disposition of weapon components 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 site production base capabilities for warhead modernization activities, weapon maintenance, surveillance, weapon assembly and disassembly, and weapon reliability and safety testing. Production Operations encompasses sustainment of all weapon systems capabilities that enable 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.

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

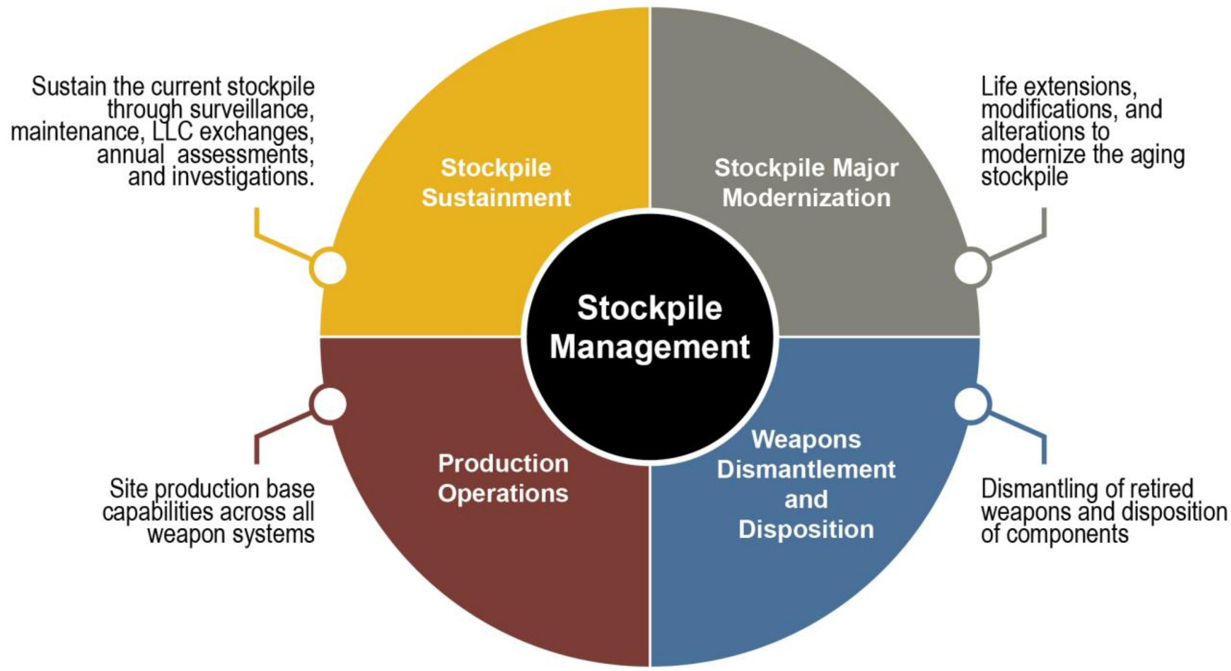


Figure 2–1. Major Stockpile Management Programs

Managing the stockpile requires comprehensive planning for all stockpile elements to integrate these activities with each other and with production capabilities. This chapter documents 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, as well as a workforce with the requisite skill set to execute these activities. These individual capabilities and the linkages to stockpile management are described at length in Chapters 3 and 4. Chapters 6 and 7 of this report address two specific elements of these capabilities, infrastructure and workforce, across all capabilities at an enterprise level, further reinforcing the need to sustain the health of capabilities 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 life cycle. Weapons that remain in the stockpile are eventually updated through modernization programs to address any anomalies and meet updated safety and security standards. These modernization activities (LEPs, Mods, and Alts) are addressed through the Stockpile Major Modernization activities discussed in Section 2.2.

2.1.1 Stockpile Surveillance

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

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

DOE/NNSA conducts stockpile surveillance through weapon disassembly and inspection, stockpile flight-testing, stockpile laboratory testing, component testing, material evaluation, and test equipment. DOE/NNSA continually refines planning requirements for stockpile evaluation activities based on new surveillance information, deployment of new diagnostic tools, annual assessment findings, and analysis of historical information using modern assessment methodologies and computational tools. **Figure 2–2** depicts the nominal flow of stockpile surveillance activities.

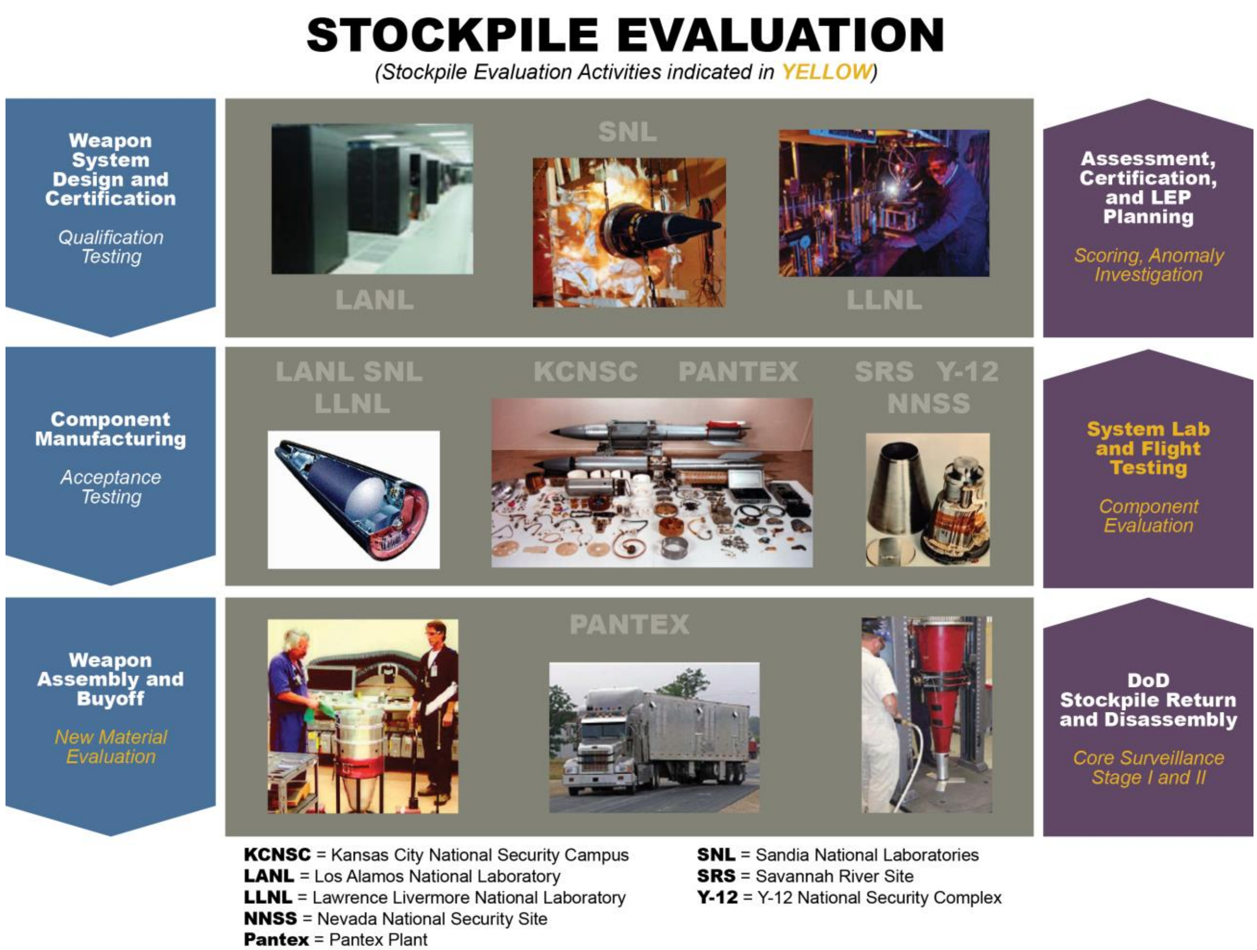


Figure 2–2. Flow of stockpile surveillance activities

2.1.1.1 Disassembly and Inspection (D&I)

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

2.1.1.2 System, Flight, Laboratory, and Component Testing

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

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

Components and materials from the D&I process undergo further evaluations to assess component physical configuration, functionality, performance margins and trends, material behavior, and aging characteristics. The testing can involve both nondestructive and destructive evaluation techniques.

2.1.1.3 Testing Equipment

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

2.1.1.4 Anomaly Investigative Process

When anomalies that could significantly affect weapon safety, security, reliability, or performance arise in surveillance data or are identified or reported to DOE/NNSA by DoD, a science and engineering analysis is conducted to determine whether observations are serious enough to open an SFI to address 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 design agency responsible for the anomalous component. Investigations can include modeling of historical data, focused materials experiments, research and studies, major system test replication, and subsystem and subcomponent tests. These SFIs can continue through several annual assessment cycles. SFIs are closed once the impacts to system performance or safety have been assessed and follow-up actions are determined, if necessary. A tracking and reporting system monitors SFI progress from the discovery of an anomaly through to its closure report and the status of any corrective actions. Most SFIs close with little to no impact to safety and reliability.

2.1.1.5 Challenges and Strategies

Table 2–1 provides a high-level summary of Surveillance challenges and the strategies to address each.

Table 2–1. Summary of Surveillance challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Health of legacy testers limiting component surveillance and JTA assembly.	Working toward improved imaging technologies with new sources and developing understanding of fundamental aging processes. Development of a proactive long-term tester sustainment plan and pursuit of appropriate funding.	Develop techniques for real-time data collection and rapid triage of issues through shelf life units with sensors, field-deployable diagnostics, and complete digitization of all build data. Implement advanced digital technologies such as digital twin methodology and manufacturing process-aware sensor suites.

2.1.2 Assessing the Stockpile

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

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.

2.1.2.1 Annual Assessment

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

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

2.1.2.2 Weapon Reliability

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

2.1.2.3 Advanced Certification and Qualification

Advanced certification activities improve the methodology and physics-based capabilities used to ensure the 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 validate simulation codes and models. These activities enhance DOE/NNSA's understanding of a weapon system's performance and possible failure modes, improve the quantification of margins and uncertainties, and improve the fidelity and agility of certification methodologies.

DOE/NNSA concentrates on developing and qualifying nuclear weapons components, subsystems, and integrated systems to meet military characteristics across the stockpile-to-target sequence (STS) environmental requirements (i.e., normal, abnormal, and hostile environments). These activities are defined in qualification plans and use experimental data, modeling, simulation capabilities, and production data to ensure system functionality. Experimental capabilities include, but are not limited to, flight tests, shock and vibration tests, thermal environment tests, multi-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.

Advanced certification and qualification activities promote the development of design for ease of manufacture and production. Close coordination between development of materials and components between design and production agencies enables design for manufacture. Additional information for Advanced Certification and Qualification is discussed in Chapter 4 of this report.

2.1.2.4 Quantification of Margins and Uncertainties

Assessing weapon performance through predictive capabilities requires the integration of many sources of data 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 within the bounds of specified operating characteristics or requirements. This methodology supports nuclear stockpile decision-making and enables risk-informed decisions. Its prediction of the performance factor is the ratio of margin (M) to uncertainty (U), or M/U. Margin is the difference between the expected value and the minimum value of a parameter to insure proper performance of some aspect of warhead functioning. Uncertainty is the degree to which these values are known. Stockpile Research, Technology, and Engineering activities (also referred to as Stockpile Stewardship activities) evaluate approaches to increase margin when possible and to quantify uncertainties by performing experiments in areas such as material properties to provide data for improving the fidelity of the models and experimental platforms used to simulate operation of the warhead. In summary, quantification of M/U increases confidence in stockpile performance.

2.1.2.5 Responsiveness

The Stockpile Responsiveness 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, and strengthens integration between DoD and DOE/NNSA. The Stockpile Responsiveness Program is covered in detail in Appendix D, "Stockpile Responsiveness Program."

2.1.3 Stockpile Maintenance

Maintaining the current stockpile comprises many ongoing activities:

- LLC exchanges of gas transfer systems (GTSs), power sources, and neutron generators 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, minor repairs and rebuilds, incorporation of surety features, and other changes.
- Maintaining production authorization by conducting periodic nuclear explosives safety studies.
- Maintaining specialized support equipment, such as custom tooling, for stockpile operations.
- Provisioning for spare and replacement parts that are consumed in stockpile operations.

2.1.3.1 Limited Life Components

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

Gas Transfer Systems

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

2.1.3.2 Challenges and Strategies

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

Table 2–2. Summary of Gas Transfer System challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	***Future Strategies Needed***
Integration of maintenance with a changing delivery schedule	Close coordination between DOE/NNSA, management and operating partners, and DoD.	Work with design agencies, DOE/NNSA, and DoD to determine GTS pre-fill options.

Power Sources

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

2.1.3.3 Challenges and Strategies

Table 2–3 provides a high-level summary of power sources challenges and the strategies to address each.

Table 2–3. Summary of Power Sources challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	***Future Strategies Needed***
Supply availability raises production capability risk, and facility inadequacies put R&D, test and evaluation, and production capabilities at an elevated risk of not meeting the mission.	DOE/NNSA completed an analysis of alternatives for a line item-sized investment and is now conducting activities needed to achieve Critical Decision-1, *Approve Alternative Selection and Cost Range*.	Modernize/recapitalize equipment and infrastructure in order to meet long-term, full life-cycle requirements for power sources.
The facility housing the power sources capability is beyond its design life and does not meet evolving mission needs or modern building code requirements. It has been repurposed many times and was not originally built to house the power source capability. Corrective measures and modifications have been employed to convert the facility to adjust to mission requirements, but the investments are not cost-effective, resulting in the need for an alternative solution.		

Neutron Generators

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

2.1.3.4 Challenges and Strategies

Table 2–4 provides a high-level summary of neutron generators challenges and the strategies to address each.

Table 2–4. Summary of Neutron Generators challenges and strategies

Challenges	Strategies: Current Strategy Being Implemented	Strategies: Future Strategies Needed
Aging facilities, infrastructure, equipment, and materials are the primary challenges to sustaining neutron generator production.	Near-term investments will focus on sustainment through ongoing recapitalization of existing facilities, infrastructure, and equipment, while making incremental improvements in process efficiency.	Formal planning to establish long-term capabilities that will ensure that mission deliverables are met while allowing consolidation, increased flexibility, improved efficiency, and expanded capabilities.

2.1.3.5 Minor Alterations

Weapon Alts are required to improve the safety, security, and reliability of nuclear weapons. While major Alts might rise to the level of creating a program (such as the W88 Alt 370), other Alts are routinely incorporated into nuclear weapons as a maintenance activity to respond to emerging issues, including issues identified during surveillance activities. Other Alts are scheduled on a priority basis, depending on their impact to the nuclear weapons stockpile.

2.1.3.6 Challenges and Strategies

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

Table 2–5. Summary of Minor Alterations challenges and strategies

Challenges	Strategies: Current Strategy Being Implemented	Strategies: Future Strategies Needed
Minor alterations are in competition with modernization programs (major Alts, Mods, etc.) at the Kansas City National Security Campus for resources (capacity, personnel, funding, floor space, etc.).	Formal planning to establish long-term capabilities that will ensure that mission deliverables are met while allowing consolidation, increased flexibility, improved efficiency, and expanded capabilities.	Integrate stockpile modernization and stockpile maintenance plans to ensure adequate capacity.

2.2 Stockpile Major Modernization

Stockpile Major Modernization activities are performed through a series of planned LEPs, Mods, and Alts supported by a strong set of science, technological, and engineering capabilities. **Figure 2–3** displays these plans, which fully reflect the priorities established and formally authorized by the Nuclear Weapons Council. Future activities are notional and reflect the current planning situation, which is subject to review as plans shift and circumstances change.

Currently, the long-term vision for the nuclear weapons stockpile seeks to build additional flexibility for the Nation to enable rapid response to unforeseen contingencies while incorporating features and technologies that enhance safety and security as appropriate and practicable. DOE/NNSA will

DOE/NNSA Warhead Modernization Activities

DOE/NNSA is currently executing the following warhead modernization activities:

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

incorporate flexibility-enabling design strategies and an advanced digital enterprise that promotes system modernization activities, as well as exercise capabilities through the Stockpile Responsiveness Program. These improvements will enhance the Nation's ability to counter adversaries' capabilities, stockpile aging, and variables associated with supporting U.S. hedge capabilities.

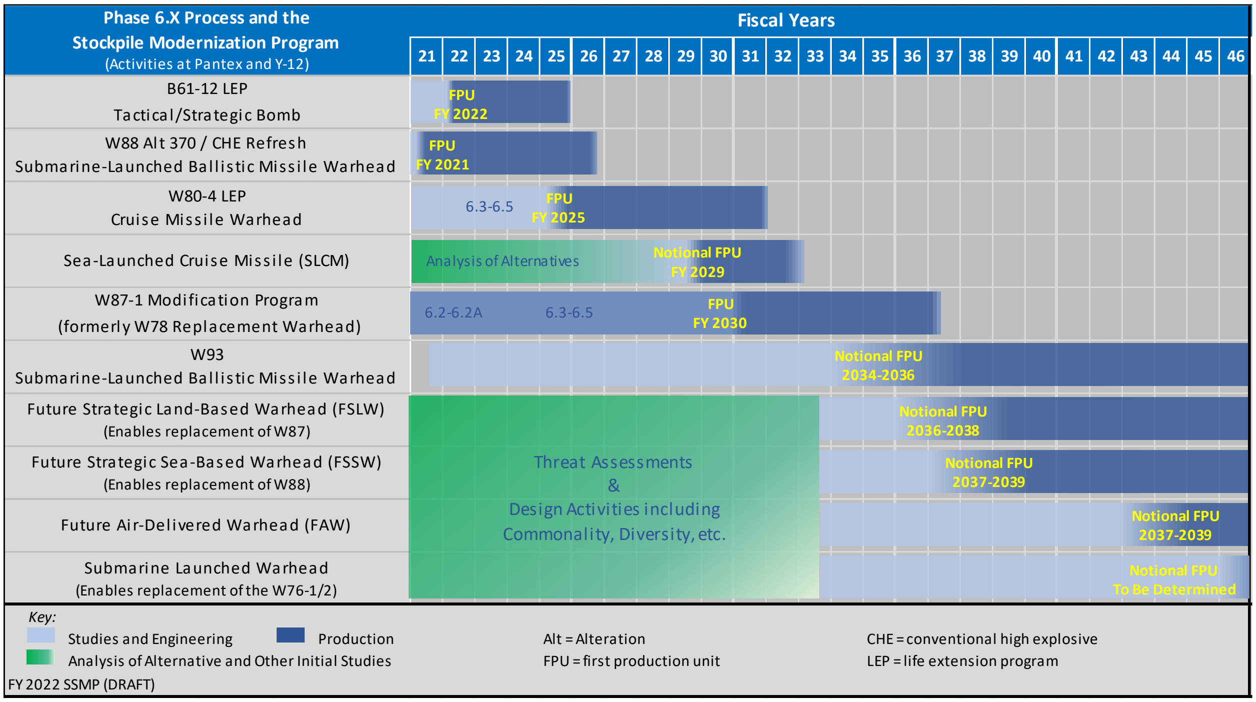


Figure 2–3. DOE/NNSA warhead activities

To meet requirements for the resilience of the U.S. nuclear deterrent, qualification- and certification-ready options for materials, components, and systems must be developed and matured ahead of time to be viable for consideration and available when needed to support Nuclear Weapons Council down-select decisions, development, and production. The activities that lead to this state of readiness depend on advanced scientific and engineering capabilities that support design, qualification and certification processes and improve the responsiveness of the nuclear security enterprise in terms of cycle time and digital design tools. These science-based supporting efforts are described in Chapter 4, "Stockpile Research, Technology, and Engineering."

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

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

The *Phase X Process* guidelines also supplement the existing Nuclear Weapons Council-approved Procedural Guidelines for the *Phase 6.X Process*, which define the framework for nuclear weapon refurbishment activities. The *Phase X Process* includes procedures for program study, development, production, sustainment, and dismantlement of nuclear weapons systems. The seven phases are, in sequential order: Concept Assessment; Feasibility Study and Design Options; Development Engineering; Production Engineering; First Production; Full-Scale Production/Sustainment; and Retirement, Dismantlement, and Disposal.

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

2.2.1.1 *Phase 6.X Process*

Nuclear weapons have been historically developed, produced, maintained, retired, and dismantled in a process known as the Nuclear Weapons Life Cycle (now Phase X Process). This process has not been exercised in its entirety since the end of the Cold War, with the United States executing only Phases 6 and 7 in recent decades. DOE/NNSA's Major Stockpile Modernization activities have instead been guided by the *Phase 6.X Process*, which was developed for non-routine Alts, Mods, and LEPs and starts from an existing warhead design, rather than being used to develop and field a complete warhead. The phases of this process are very similar to stages 1-6 of the life cycle. These phases, and the relation of the *Phase 6.X Process* to the Nuclear Weapons Life Cycle, are shown in **Figure 2–4.**

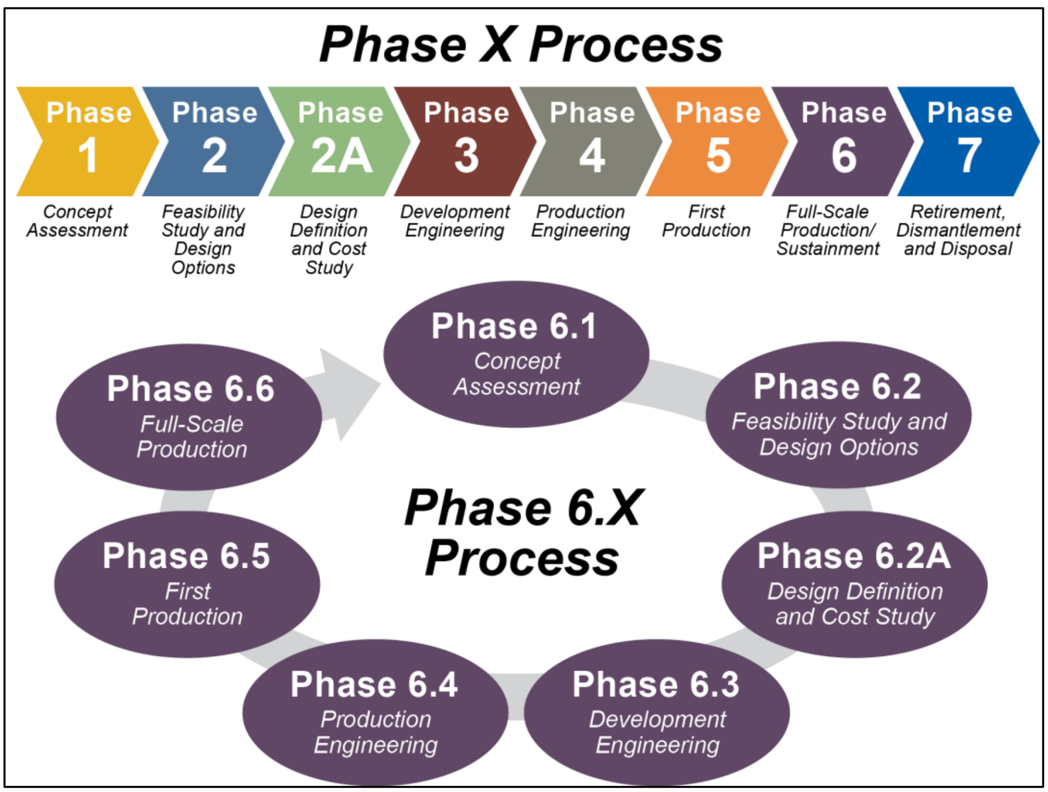


Figure 2–4. Phase X and the *Phase 6.X Process*

2.2.2 B61-12 Life Extension Program

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

An F-35A opens its bomb bay doors and drops a mock B61-12 at Sandia National Laboratories' Tonopah Test Range. It was the first of a testing series that will conclude with full-weapon systems demonstrations designed to increase confidence the bomb will always work when needed and never under any other circumstances.

2.2.2.1 Status

The B61-12 received authorization to enter Phase 6.5, *First Production,* in fiscal year (FY) 2021, and completed the first production unit in November 2021. The B61-12 LEP required re-planning to allow re-qualification of base metal electrode (BME)-affected components,[1] similar to the W88 Alt 370. The requalification efforts were completed in the first quarter of FY 2021, in accordance with the re-baselined plan.

2.2.2.2 Challenges and Strategies

Table 2–6 provides a high-level summary of B61-12 LEP challenges and the strategies to address each.

Table 2–6. Summary of B61-12 Life Extension Program challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Sustaining Steady State Production.	Close coordination between the design agency and production agency.	Continued process improvements within production modernization; address vendor/supplier fragility and supply chain challenges.

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 Program modernizes the arming, fuzing, and firing subsystem; improves surety; replaces the conventional high explosive and associated materials; and incorporates a lightning arrestor connector, trainers, joint test assemblies, and associated handling gear. The W88 Alt 370 conversion is scheduled to run concurrently with LLC exchanges of GTSs and neutron generators.

2.2.3.1 Status

The W88 Alt 370 received authorization to enter Phase 6.5 in FY 2021 and completed the first production unit in July 2021. The W88 Alt 370 required re-planning to allow re-qualification of BME-affected

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

components, similar to the B61-12. Requalification efforts were completed in the third quarter of FY 2021, in accordance with the re-baselined plan.

2.2.3.2 Challenges and Strategies

Table 2–7 provides a high-level summary of W88 Alt 370 Program challenges and the strategies to address each.

Table 2–7. Summary of W88 Alteration 370 Program challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Sustaining Steady State Production.	Close coordination between the design agency and production agency.	Continued process improvements within production modernization; address vendor/supplier fragility and supply chain challenges.

2.2.4 W80-4 Life Extension Program

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

2.2.4.1 Status

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

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

The W80-4 program office coordinated with DOE/NNSA's management and operating partners to develop standardized Earned Value Management practices and schedules across the sites. This allows implementation of a software tool to expedite Earned Value Management System data analysis.

2.2.4.2 Challenges and Strategies

Table 2–8 provides a high-level summary of W80-4 LEP challenges and the strategies to address each.

Table 2–8. Summary of W80-4 Life Extension Program challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Executing a coordinated DoD/NNSA development program.	Integrated milestones and streamlined oversight body.	Increased teaming with DoD.

2.2.5 W87-1 Modification Program

The W87-1 will be deployed alongside the W87-0 on the Ground-Based Strategic Deterrent (GBSD). It 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 and the only system to have not received a major refurbishment or upgrade. Critical W78 components continue to age, while the military requirements for the safety and security features of the W78 warhead have changed since the W78 entered the stockpile in 1979. The W87-1 Modification Program will meet DoD and DOE/NNSA requirements for performance, safety, and security and is slated to deploy as part of the GBSD by 2030.

2.2.5.1 Status

The Nuclear Weapons Council authorized a restart of Phase 6.2*, Feasibility Study and Design Options*, in September 2018. The program remains on track to deploy with the GBSD 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. The W87-1 Modification Program has started Phase 6.2A, *Design Definition and Cost Study*, activities and will seek Nuclear Weapons Council approval to enter Phase 6.3, *Development Engineering*, in the fourth quarter of FY 2022.

2.2.5.2 Challenges and Strategies

Table 2–9 provides a high-level summary of W87-1 Modification Program challenges and the strategies to address each.

Table 2–9. Summary of W87-1 Modification Program challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
All new manufacture of components.	Early manufacture of key components to mitigate risk of infrastructure delays. Close engagement between design agencies and production agencies to implement producibility reviews in design. Establish Inter-program requirement agreements between the W87-1 Modification Program and production modernization programs.	Timely installation of required production equipment. Risk mitigation for single-point failures in the manufacturing process. Develop a pit reuse backup plan and strategy.
Executing a coordinated DoD/NNSA development program.	Integrated milestones and streamlined oversight body.	Increased teaming with DoD contractor.

2.2.6 W93 Program

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

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

DoD is conducting an Analysis of Alternatives on an employment platform and a delivery platform for a nuclear-armed Sea-Launched Cruise Missile. To meet schedule requirements and fit within the existing nuclear security enterprise production footprint, the Nuclear Weapons Council issued notice of a preferred warhead solution, a W80-4-like variant, to minimize impacts to the strategic nuclear stockpile. However, the final selection will be determined at the conclusion of the Analysis of Alternatives. This program would need to start in FY 2022 with a Phase 6.2/6.2A-like effort to integrate with the W80-4. Major objectives in FY 2022 include assisting the Navy in defining operational requirements and translating those requirements into specific warhead performance characteristics that will define the extent of the warhead alteration.

2.2.8 Future Warheads

DOE/NNSA is coordinating with DoD to define the appropriate ballistic missile warheads to support threats anticipated in 2030 and beyond. These warheads currently include the Future Strategic Land-Based Warhead, the Future Strategic Sea-Based Warhead, the Future Air-Delivered Warhead, and a Submarine-Launched Warhead (for the W76-1/2) that will be needed in the 2040s. These plans are notional and may be subject to change.

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, policy, directives, weapon system complexity, and the availability of qualified personnel, equipment, and facilities. DOE/NNSA's current 5-year Dismantlement Plan balances these constraints while maintaining strict adherence to legislative, policy, and directive guidance. The WDD work scope includes management of retired nuclear weapon systems (e.g., managing safety concerns), characterization of weapon components, disassembly of weapons and components, and final component disposition (e.g., component reuse and material recycle and recovery). WDD activities occur across all sites in the nuclear security enterprise.

WDD Accomplishments

- *Trained production technicians at Consolidated Nuclear Security, LLC for future LEP work by providing experience with programs in dismantlement.*
- *Developed and refined canned subassembly dismantlement schedules at Y-12 to meet the material and component reuse demands of the B61-12, W80-4 LEPs, and highly enriched uranium program.*
- *Dismantled weapons on schedule and program remains on pace to eliminate the weapons that were in retirement at the end of FY 2008.*
- *Kept the size of legacy excess component inventories from growing and reduced storage constraints at the Pantex Plant.*

2.3.1 Status

DOE/NNSA continues to make significant progress on dismantling weapons and component disposition. WDD is on pace to completely dismantle the weapons that were retired at the end of FY 2008 by the end of FY 2022. In addition, DOE/NNSA has developed return schedules to remove retired weapons from DoD facilities while meeting DoD operational requirements. WDD continues to characterize components coming off the dismantlement line, and sites are eliminating excess component inventories on schedule.

2.3.1.1 Challenges and Strategies

Table 2–10 provides a high-level summary of WDD challenges and the strategies to address each.

Table 2–10. Summary of Weapons Dismantlement and Disposition challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
Increase component disposition at each site.	WDD is operating with no impact to stockpile operations.	Leverage the processing capabilities at each site and ensure other sites use these capabilities.

2.4 Production Operations

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

Production Accomplishments

- *Sustained base capabilities for multi-system operations and maintenance support to meet all LLC exchange GTS fills and surveillance deliverables*
- *Completed calibration services of over 1,200 critical equipment calibrations in support of production activities.*
- *Supported 240 LLNL engineering authorizations, 340 enterprise engineering authorizations, and 180 Product Realization Team meetings.*
- *Accepted over 79,000 SNL components at a 100 percent acceptance rate.*

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

Production Operations also serves as the demand signal for the modernization of production capabilities and capacity to improve efficiency and maintain manufacturing operations that will meet future requirements. The program requires close coordination with the Production Modernization and Advanced Manufacturing Development programs, which are charged with development and initial deployment of new or replacement manufacturing capabilities. It also heavily depends on required infrastructure modernizations (as discussed in Chapter 1, Section 1.4, and throughout Chapter 6) to ensure base capabilities with adequate capacities, space, and equipment are in place.

2.4.1 Status

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

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

2.4.1.1 Challenges and Strategies

Table 2–11 provides a high-level summary of Production Operations challenges and the strategies to address each.

Table 2–11. Summary of Production Operations challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Increasing production demand and expanding/modernizing manufacturing capacity causing increased demands on Production Operations base capabilities.	Production Operations supporting the Kansas City National Security Campus expansion, Pantex Plant projects to increase efficiency of operations, and Y-12 modernization efforts. Supporting site hiring.	Coordination of programmatic equipment replacement and maintenance requirements across Defense Programs so sustainment and modernization needs and shortfalls are well understood along with attendant risks and opportunities.
Need for expanded and improved enterprise capacity modeling and planning.	Production Operations maintains the Office of Stockpile Management's main modeling and analysis capability for enterprise capacity modeling, the Enterprise Modeling and Analysis Consortium.	Development of advanced and increasingly automated modeling to ensure capabilities are in place to meet current and future stockpile requirements.

Chapter 3
Production Modernization

3.1 Overview

The Department of Energy's National Nuclear Security Administration (DOE/NNSA) is focused on manufacturing nuclear weapons components of strategic interest that need replacement, revitalization, or modernization to meet stockpile requirements and maintain the Nation's nuclear deterrent. Some of these components, or their fabrication materials, can be obtained through managed supply chains while others must be uniquely produced by the nuclear security enterprise. Production of some of these components was reduced or stopped during the 1990s following the end of the Cold War. As DOE/NNSA continues to sustain the stockpile through warhead modernization activities, there is a greater emphasis on a responsive manufacturing infrastructure that improves production capability or existing capacity. New methods, approaches, and technologies will enhance throughput and efficiency. Production Modernization concentrates on the production capabilities of nuclear weapons components critical to weapon performance, including primaries, secondaries, radiation cases, and non-nuclear components, of which the manufacturing of such components has very tight tolerances.

Production Modernization encompasses four major subprograms, as illustrated in **Figure 3–1**, that sustain the Nation's nuclear weapons stockpile: (1) Primary Capability Modernization, (2) Secondary Capability Modernization, (3) Tritium Modernization and Domestic Uranium Enrichment, and (4) Non-Nuclear Capability Modernization.

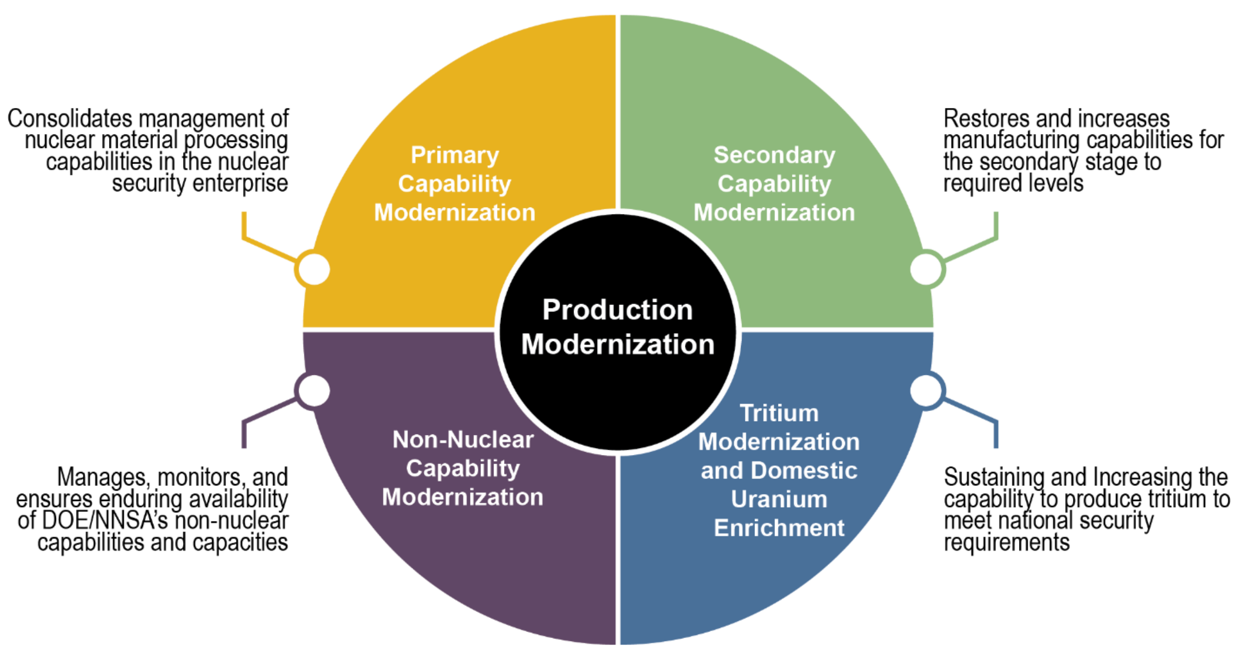


Figure 3–1. Production Modernization major subprograms

3.2 Primary Capability Modernization

The Primary Capability Modernization Program is responsible for restoring and increasing manufacturing capabilities for primary-stage nuclear materials to meet required levels in the nuclear security enterprise. Primary Capability Modernization consolidates the management of this material processing into two subprograms: (1) Plutonium Modernization and (2) High Explosives and Energetics Modernization.

3.2.1 Plutonium Modernization

The United States is restoring the capability to produce new primaries for nuclear weapons, including plutonium subcomponents such as pits. In May 2018, the NNSA Administrator provided Congress with DOE/NNSA's recommended alternative to produce no fewer than 80 pits per year (ppy) as required by the *National Defense Authorization Act for Fiscal Year 2018*. This recommended alternative was endorsed by the Nuclear Weapons Council. DOE/NNSA's recommended approach to meet pit production requirements is twofold:

- Continue to invest in the Los Alamos National Laboratory (LANL) to produce 30 ppy and
- 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 ppy.

This two-pronged approach will restore 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 risks that may affect operations at a single site.

Plutonium Modernization Major Accomplishments

- *Lawrence Livermore National Laboratory and LANL completed engineering evaluations for analytical chemistry processes in fiscal year (FY) 2020.*
- *Los Alamos Plutonium Pit Production Project and SRFFP achieved CD-1 approval in FY 2021.*
- *Savannah River National Laboratory and LANL established a Knowledge Transfer Program to begin building the pit production knowledge base at SRS.*
- *Kansas City National Security Campus for the first time supplied process prove-in non-nuclear parts to LANL to support FY 2020 pit builds.*

Recapitalizing the Nation's pit production capability to enable production of no fewer than 80 ppy addresses two major drivers:

- Department of Defense (DoD) and DOE/NNSA requirements to enhance warhead safety and security and
- Risk mitigation against plutonium aging through deliberate, methodical replacement of older existing plutonium pits with newly manufactured pits.

A small disk of plutonium metal at TA-55.

3.2.1.1 Status

Prior to completion of CD-1 analysis for SRPPF, the Nuclear Weapons Council certified[1] that DOE/NNSA remained on schedule to:

[1] 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 as of the last certification in 2021.

- Meet the military requirement of no fewer than 80 pits per year; and
- Produce 30 pits per year at LANL.

DOE/NNSA conducted a *National Environmental Policy Act* (NEPA) review of the recommended two-site solution described above. The NEPA strategy articulated a three-tiered approach to address the environmental impact of pit production activities, site-specific environmental impacts, and programmatic actions across the nuclear security enterprise. On November 5, 2020, a Record of Decision for the *Final Environmental Impact Statement for Plutonium Pit Production at the Savannah River Site in South Carolina* (DOE/EIS-0541) and the amended Record of Decision for the *Complex Transformation Supplemental Programmatic Environmental Impact Statement* (DOE/EIS-0236-S4) were issued.

In addition to dedicated pit production 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 infrastructure that supports the capability to manufacture and certify pits. These projects include the Chemistry and Metallurgy Research Replacement project, which maintains continuity in analytical chemistry and material characterization capabilities by transitioning these activities from the Cold War-era Chemistry and Metallurgy Research (CMR) facility to newer facilities. Programs are also conducting risk reduction activities in material recycle and recovery by removing the nuclear material inventory currently housed in the CMR facility.

3.2.1.2 LANL Plutonium Modernization

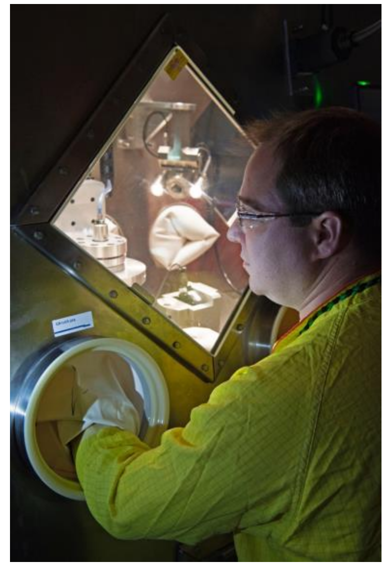
A modern, responsive, and resilient capability to process and handle plutonium is essential to assess and maintain the nuclear weapons stockpile. A responsive plutonium infrastructure requires proper storage facilities, safe and secure disposal pathways, and unique facilities for research and development (R&D) and design realization activities. Manufacture and surveillance of plutonium components, as well as experiments and analysis of plutonium, currently occur at LANL's Plutonium Facility (PF-4). Most plutonium processing for the nuclear weapons program (e.g., recovery, characterization, component fabrication, nondestructive analysis, and surveillance), as well as basic and applied research on plutonium, are conducted in this facility. Modernization activities concentrate on initiatives within PF-4, such as recapitalization of the equipment needed to restore PF-4's ability to produce War Reserve (WR) pits. PF-4 is currently the only DOE/NNSA facility authorized to produce pits for the enduring stockpile. Ongoing activities include projects funded by the Plutonium Modernization Program and line-item programs, such as the Los Alamos Plutonium Pit Production Project, which will increase the pit manufacturing capability to 30 ppy and maintain LANL as the Nation's Plutonium Center of Excellence for R&D.

Plutonium Facility (PF-4) at LANL.

Primary goals for Plutonium Modernization include:

- Maintain and modernize Technical Area 55 (TA-55) PF-4 to provide 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 ppy production rate.

- Increase the workforce required for the pit production mission to manufacture pits; maintain and operate facilities; provide security for pit production activities and materials; and provide a broad range of support functions.
- Provide acceptable components and support for the experiments and evaluations specified by LLNL in the Pit Certification Plan.
- Advance the science and engineering required to mature production processes to meet Lawrence Livermore National Laboratory (LLNL) design agency specifications for plutonium pit production.



Glovebox work in the TA-55 machining area.

To meet these goals, workforce increases are needed. Therefore, DOE/NNSA must hire, train, qualify, and retain additional pit production personnel to meet the requirements. This increased workforce will need additional support, such as infrastructure investments for operations support, waste management, offices, parking, training, etc.

To support pit production and other vital plutonium missions, DOE/NNSA will transition to 24/7 facility availability at PF-4 to enable enhanced execution of programmatic work, facility maintenance, equipment installation, and construction activities. DOE/NNSA will also continue modernizing LANL's reliable waste management capabilities to safely and efficiently disposition radioactive waste.

Plutonium Modernization also supports manufacturing of precision plutonium devices for science-related evaluation. The data collection and analysis from this evaluation supports sustaining an overall healthy feedstock supply chain that will support plutonium processing for the nuclear weapons program as necessary to maintain a ready nuclear deterrent.

3.2.1.3 SRS Plutonium Modernization

The former MFFF, is a Security Category 1/Hazard Category 2 structure that provides an opportunity to achieve pit production in an existing facility designed to meet stringent security and safety requirements for plutonium operations. Initial modernization activities include repurposing and transitioning the MFFF into a safe, secure, compliant, and efficient pit production facility, the planned SRPPF. Development of new facilities and security infrastructure, as well as establishment of a new program office at SRS to sustain an enduring pit production goal of 50 plutonium ppy, are also underway. Enhanced conceptual design efforts for the proposed SRPPF are continuing to use knowledge gained from LANL, LLNL, and other sites. The Critical Decision (CD)-1 (*Approve Alternative Selection and Cost Range*) package detailing the conceptual design and estimated cost range was approved in fiscal year (FY) 2021.

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

- Complete five inter-related construction subprojects;
- Hire and train the workforce necessary to establish and sustain the SRS pit production mission;
- Begin production operations upon CD-4 (*Approve Start of Operations*) to enable delivery of a first production unit pit;
- Establish the institutional systems at SRS necessary to build WR pits;
- Establish and manage SRS pit production interfaces across the nuclear security enterprise; and
- Re-establish a secure supply chain to support the SRS pit production mission.

The SRPPF project is supported by a Plutonium Pit Production Analysis of Alternatives (AoA) completed in October 2017 and the Plutonium Pit Production Engineering Assessment completed in April 2018. Both efforts informed DOE/NNSA's selection of a preferred alternative on May 10, 2018, to continue to invest in LANL for the capability to produce 30 ppy in 2026, and to repurpose existing facilities at SRS to produce a capability of 50 ppy. Based on information developed to support the CD-1 milestone, DOE/NNSA has determined that the required 50 WR ppy production rate at SRS will not be achieved by 2030.

Pending future acquisition milestones, three factors are needed to further inform the achievable date for 50 WR ppy capacity at SRPPF. First, DOE/NNSA must better define the timeframe to accomplish CD-4. DOE/NNSA must then identify the amount of time it will take for SRPPF to produce the first WR pit at the facility after achieving CD-4. Finally, DOE/NNSA must establish the period necessary for SRPPF to achieve the required production capacity of 50 WR ppy after demonstrating the ability to produce WR quality pits.

The following milestones and activities will inform the dates associated with the factors above and allow DOE/NNSA to narrow down potential timelines for 50 WR ppy at SRPPF:

1. Completion and approval of SRPPF's CD-2 (*Approve Performance Baseline*) acquisition milestone. This indicates that the project's design is 90 percent complete and will identify when CD-4 can be achieved.
2. Continuing coordination with LLNL, LANL, and the ongoing W87-1 Modification Program's Pit Production Realization Team to find ways to reduce the time needed to produce the first WR pit at SRPPF after CD-4, based on knowledge gained at LANL from parallel production efforts at PF-4.
3. Capture efficiencies and use lessons from production experience at LANL as they ramp from 1 WR ppy to 30 WR ppy to inform how best to minimize the time required for SRPPF to scale from 1 WR ppy to 50 WR ppy.

Additionally, further design activities conducted in support of CD-2 may identify multiple opportunities to accelerate achieving the required production capacity. Establishing required SRPPF pit production capacity as close as possible to 2030 remains a high priority and is required for sustaining the effectiveness of the Nation's nuclear deterrent.

The proposed pit production mission will need a skilled workforce at the site. Estimates indicate that design and construction activities will require approximately 2,000 staff. Manufacturing 50 ppy at SRS will require more than 1,600 production staff. These early estimates will continue to be refined as the project's design matures.

A multi-year training and qualification process will be undertaken to ensure the necessary people, processes, procedures, and commodities are in place to meet the minimum 50 ppy requirement at SRS. Essential to this process will be the transition of an existing facility into the SRS Training and Operations Center, beginning with design work in FY 2021. The Training and Operations Center will enable unclassified and classified training in a safe environment, as well as high-fidelity surrogate material training aimed to qualify the personnel and procedures ultimately used to build and handle pits in the SRPPF. The Training and Operations Center will also advance final design by serving as a test bed for selected engineering equipment and to demonstrate systems integration. LANL and LLNL are supporting the training rotation pipeline for the SRS pit production mission through a knowledge transfer program initiated in FY 2020 with Savannah River National Laboratory. This knowledge transfer program will form the foundation of the Training and Operations Center knowledge and experience base.

3.2.1.4 Enterprise Plutonium Support

DOE/NNSA manages numerous facilities that house plutonium handling, processing, R&D, characterization, experimentation, 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 and design realization activities.

Enterprise Plutonium Support includes activities that enable programmatic objectives across the enterprise, including production of non-nuclear components, certification activities, management of the Product Realization Team, material management activities, radioisotope thermoelectric generator production and surveillance, subcritical plutonium experiments, and pit certification.

3.2.1.5 Challenges and Strategies

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

Table 3–1. Summary of Plutonium Modernization challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Timely integration of infrastructure and workforce investments in alignment with W87-1 pit Production Realization Team schedule to re-establish required pit production capabilities and capacity.	Continue to invest in LANL plutonium facilities to meet pit production milestones – achieving the first production unit milestone in 2023, then completing the Los Alamos Plutonium Pit Production Project to increase production capacity to 30 ppy.	Streamline engineering evaluations and certification activities to support this schedule.
Repurposing of the former Mixed Oxide Fuel Fabrication Facility at SRS to achieve a production rate of 50 ppy.	Implement a tailored approach for the SRPPF project to achieve CD-1, CD-2, and CD-3A (*Long Lead Procurements*), in order to support producing 50 WR ppy. Use knowledge transfer from LANL and LLNL subject matter experts to support workforce development at SRS to achieve pit production mission objectives.	Re-establish the supply chain for weapons-related components and commodities needed to support the 50 ppy mission.
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 stockpile-to-target sequence normal environments. Establish equipment, experimental platforms, and systems to evaluate additional normal and abnormal environments that pits could experience.	Leverage the ongoing investment in the Enhanced Capabilities for Subcritical Experiments Program to demonstrate the certification uncertainty achieved with one-point and multi-point safety.

3.2.2 High Explosives and Energetics Modernization

The High Explosives and Energetics Modernization program addresses the modernization of high explosives (HE) science and production facilities and the qualification of explosive, pyrotechnic, and propellant materials for the nuclear security enterprise. This program is not only responsible for HE materials, but also the network of associated activities, such as the HE and Energetics business processes, infrastructure, production, and supply chain. This network and its subsequent critical energetic materials are utilized across five management and operating (M&O) sites: the Pantex Plant (Pantex), Sandia National Laboratories (SNL), LANL, LLNL, and the Nevada National Security Site. Each site maintains multiple dispersed facilities engaged in Stockpile Research, Technology, and Engineering and Production Operations.

Energetic materials are an enduring requirement for each weapon system in the existing stockpile. In addition to existing stockpile sustainment needs, currently planned warhead modernization activities, such as limited life component (LLC) exchanges, and future modernization activities will continue to have a substantial demand for energetics. DOE/NNSA meets HE demands for nuclear weapon sustainment and modernization through investment in development of reliable production capabilities, such as safe and secure facilities, integrated infrastructure, effective logistics (handling, storage, and delivery), and ensuring a reliable supplier base.

High Explosives and Energetics Modernization Accomplishments

- *Implementing projects to modernize production and design facilities (HE Science and Engineering; HE Synthesis, Formulation, and Production; and Energetic Materials Characterization).*
- *Completing qualification and production of development batches to support life extension program HE production schedules and demands*
- *Developed supply chain continuity of operations models and risk registers to inform risk mitigation decisions.*
- *Enhanced safety and viability of storage and shipping energetic materials, including testing to characterize hazards for Department of Transportation compliance*
- *Continued to identify and address risks to non-nuclear energetic material supply chains*
- *Re-establishing production capability and processes for critical energetic materials*
- *Updated IHE Qualification definitions to provide consistency across nuclear enterprise*
- *Provided subject matter expertise for DoD HE supplier with installation of stainless steel filter press and environmental mitigation upgrades*

3.2.2.1 Status

Most of the current facilities in the HE enterprise were built more than 70 years ago. These aging facilities lack the electrical infrastructure needed to meet mission requirements and have safety and security limitations.

DOE/NNSA is currently planning three major programmatic line-item construction projects for HE:

- The HE Science and Engineering Facility at Pantex will consolidate 15 aging facilities into three new, efficient facilities to conduct science, technology, engineering, and production activities in weapons assembly/disassembly and HE. It will hedge against current HE production and testing capability gaps.
- The HE Synthesis, Formulation, and Production project at Pantex 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 that will hedge against current HE production and testing capability gaps.

High Explosives Science and Engineering Facility Conceptual Design

High Explosives Synthesis, Formulation, and Production Conceptual Design

- The Energetics Material Characterization Facility at LANL will consolidate 18 inadequate and outdated facilities to analyze and periodically qualify HE parts going into or coming from stockpile systems. This critical capability will identify solutions for problems with HE identified through stockpile returns and aging studies. It will also produce energetic materials for detonator assemblies and advance the development of HE formulation and explosive components for the future stockpile. The facility will create a single capability for the evolution of components and materials from early concept and prototype design to high-volume production within a single location and provide internal production capability for mark-quality non-nuclear explosive components and materials to augment the commercial supplier base.

> ***Material Characterization and Aging***
>
> *DOE/NNSA laboratory researchers have recently confirmed that the explosive called PETN (Pentaerythritol tetranitrate), when stabilized with a polysaccharide coating, is resistant to changes in particle shape, size, and structure that can degrade detonator performance over time. PETN is a common initiating explosive used extensively in commercial detonators and in the U.S. nuclear stockpile, but batch-to-batch variability has made it difficult for us to definitively show how it responds to aging. When stabilized with a polysaccharide coating, it exhibits little to no change in powder characteristics during aging at elevated temperatures, in both free-flowing powder as well as when pressed into low- density commercially prepared detonator pellets.*

- Additionally, ongoing investment in Light-Initiated High Explosive capabilities at SNL and LLNL will provide the ability to conduct testing of mockup devices with live main charges in safe and effective modern facilities. These investments provide HE qualification capability to hostile impulse requirements.

Future infrastructure investments may include consolidation and modernization of existing facilities critical to providing required HE R&D capabilities for main charges, boosters, and detonators in a modern, enhanced safety and security environment. DOE/NNSA will continue to pursue projects to mitigate known issues with the limited commercial component supplier base and provide onsite production of energetic materials and components in the stockpile (actuators, igniters, detonators, timers, rocket motors).

HE and Energetics Modernization activities will also include the following:

- Manage the HE and energetics supply chain risk portfolio to ensure a healthy infrastructure exists to maintain, manufacture, and deploy mark-quality HE and energetics in support of weapons production.
- Provide guidance for energetics surveillance, weapon response, transportation, containers, and explosive/electrical environments.
- Define and monitor the qualification standards of HE and energetic material.
- Support the future of HE and energetics development, production, component design and manufacturing, testing, and qualification.

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 or retirement of senior personnel, DOE/NNSA must actively develop a sustainable workforce to perform these operations competently and safely in the future. More detail on DOE/NNSA's workforce strategies can be found in Chapter 7 of this report.

3.2.2.2 Challenges and Strategies

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

Table 3–2. Summary of High Explosives and Energetics Modernization challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Controlling risks posed by aging HE facilities and equipment awaiting upgrades or replacements 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. Keep aging equipment available for warhead modernization and current stockpile systems through rigorous maintenance programs and integrated equipment recapitalization planning across the nuclear security enterprise. Find creative solutions to maintain facilities past their useful life. Make short- to medium-term recapitalization investments where reasonable.	Construct the HE Synthesis, Formulation, and Production building, the High Explosives Science and Engineering Facility, the Energetic Materials Characterization Facility and the Energetic Manufacturing Science and Technology Facility. Employ creative methods to mitigate obsolescence issues, such as using additive manufacturing to produce parts. Stand up production enclaves at design laboratories to enable more efficient response to the emerging deterrent.
Maintaining qualified vendors for low-volume, high-quality outsourced components to sustain a viable and reliable domestic supplier base.	Establish clear requirements for Nuclear Enterprise Assurance. When necessary, use in-house capabilities to restore mission schedules at risk. Exercise suppliers to maintain proficiency on a more frequent schedule between procurement and continued technical exchanges.	Strategic joint-agency collaboration to identify systemic industrial base solutions to strengthen domestic supplier base options. Explore novel synthesis routes and manufacturing techniques to enable U.S. manufacture of explosive precursors.
Developing sufficient supply chain capacity for energetic materials in current and future life extension programs and alterations.	Exercise initiatives within the Defense Programs for Energetic Materials. Refresh HE formulation, synthesis, and machining capabilities at Pantex. Identify, assess, and perform risk-informed activities to understand, characterize, and develop better methods to produce and qualify materials more fully.	Analyze and apply lessons learned from Defense Programs initiatives for energetic materials for broader implementation across the enterprise along lines of effort such as design for manufacturing, and requirements and capacity integration.
Ensuring that requirements for energetic materials are adequately identified, preserved, and documented.	Document the detailed processes necessary for the synthesis and formulation of energetic materials for a repeatable material specification that yields the required engineering and performance requirements through efforts with the NNSA Energetics Coordinating Committee.	Document the technical basis for future process parameter choices and rationale for specific requirements in the specifications. Improve understanding and control over material specifications and manufacturing to improve reliability and repeatability and increase lot acceptance. Develop techniques to computationally assess manufacturing with computational fluid dynamics, computational chemistry, machine learning, and artificial intelligence. Develop techniques to reprocess out-of-spec material to meet requirements.

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Planning for material shortfalls for legacy WR HE due to a lack of robust plans and processes to control inventories.	Collaborate with DoD and industrial partners to institute a more routine process to exercise synthesis and formulation of energetic materials. Completion of TATB/PBX-9502 specification will improve plans and processes to enhance inventory control.	Preserve and enhance in-house production for items such as WR detonator powder production.

3.3 Secondary Capability Modernization

The Secondary Capability Modernization Program is responsible for restoring and increasing manufacturing capabilities for the secondary stage to required levels in the nuclear security enterprise. This includes ensuring the availability of strategic materials and other sub-component streams necessary for the secondary stage, as well as modernizing the facilities and operations required to process these materials, fabricate them into parts, and assemble the final components. The areas of focus include: (1) Uranium Modernization; (2) Depleted Uranium Modernization; and (3) Lithium Modernization.

3.3.1 Uranium Modernization

Uranium Modernization upgrades enriched uranium operations to ensure the delivery of secondary components needed to maintain the stockpile and support Naval Reactors and Nonproliferation programs. To execute this mission, Uranium Modernization is phasing out mission dependency on Building 9212 at the Y-12 National Security Complex (Y-12) by the end of 2025 through:

- Relocating Building 9212's enriched uranium capabilities into existing facilities as well as the new Uranium Processing Facility;
- Leveraging these relocations to develop and deploy new technologies into existing facilities and the Uranium Processing Facility to reduce cost, improve worker safety, and enhance manufacturing processes for nuclear weapon materials; and
- Investing in the reliability of key systems to sustain casting, machining, metal purification systems, assembly, and analytical chemistry capabilities.

Uranium Modernization Achievements

- *Achieved the "In the Dry" milestones for Uranium Processing Facility's Salvage and Accountability Building and the Personnel Support Facility Building.*
- *Completed Casting Parameters Optimization Plan for casting parts.*
- *Met purified highly enriched uranium metal production goal.*
- *Produced the first production-quality uranium metal "button" using a depleted uranium surrogate on the newly installed electrorefining demonstration system.*
- *Approved Critical Decision 2/3, established the cost and schedule baseline and start of installation for the Calciner project.*

3.3.1.1 Status

DOE/NNSA manages and operates Y-12, which is home to the Nation's primary uranium processing and storage infrastructure, including a laboratory that supports uranium activities. Building 9212 contains the most hazardous enriched uranium operations but does not meet modern nuclear safety and security standards because it is more than 70 years old. As part of the aforementioned relocation strategy, new production technologies will be deployed, and existing processes will be simplified or eliminated to increase the overall safety and efficiency of enriched uranium operations. During the transition period, efforts to reduce material-at-risk will continue.

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

While the Uranium Processing Facility is constructed and undergoes startup activities, Y-12's Process Technology Development Department will relocate processes and deploy new technologies that will fully enable phasing out mission dependency on Building 9212. New technology deployments will include electrorefiner, calciner, and direct chip melt projects, which will reduce cost and improve manufacturing processes for nuclear weapon materials. These new technologies will also improve existing capabilities in enduring facilities by reducing the number of production processes, reducing risks, and improving personnel safety. Ultimately, installation and operation of these systems in existing facilities will allow the current aqueous-based chemical purification and high-hazard metal conversion processes in Building 9212 to be shut down. Early technology maturation, such as for direct electrolytic reduction, is funded by Uranium Modernization. When the technology is sufficiently mature, the development and deployment of equipment is pursued through capital line item acquisition and major item of equipment processes, as appropriate. This technology development and maturation process has generated three current major items of equipment acquisitions. The major items of equipment include:

- Electrorefining is an electrochemical metal purification system designed to provide a replacement capability for the current metal purification process. This capability, located in Building 9215, along with the calciner process in Building 9212 (see below), will replace the current high hazard wet chemistry process located in Building 9212.
- A calciner uses a dry thermal treatment process to convert low-equity enriched uranium liquids to a dry stable form for storage. This capability will process remaining material in Building 9212 before operations there are shut down. The calciner, located in Building 9212, along with the electrorefining capability in Building 9215 (see above), will enable the shutdown of the current high-hazard wet chemistry process in Building 9212.
- Direct Chip Melt is the recovery of enriched uranium machine tool chips/turnings by collecting and remelting them in furnaces. This capability, located in Building 9215, will replace the current high-hazard practices of transferring chips to Building 9212, then cleaning, briquetting, and storing them there.

Note: DOE/NNSA has already relocated its 2MeV radiography capability from Building 9212 to another location.

DOE/NNSA will perform its enriched uranium metal purification in Building 9215 using the electrorefining process, which will come online in the 2023 timeframe. Uranium Modernization will continue to fund the purification of metal in Building 9212 until the electrorefining process is fully operational, at which point the hazardous wet chemistry, conversion, and reduction operations in Building 9212 will be shut down.

Uranium Modernization continues to optimize Y-12's Building 9212 resources to supply the current stockpile with purified enriched uranium metal through 2024. The program provides a comprehensive storage capability to support a steady supply stream of material through peak production periods. It also enables enriched uranium material de-inventory activities to increase safety, establish target working inventory levels for the production facilities, and optimize composition of the inventory. The program, partnering with DOE/NNSA's Office of Safety, Infrastructure, and Operations, is sustaining uranium facilities with an Extended Life Program. These efforts allow safe and secure continuation of operations, including those relocated from Building 9212, in existing facilities through 2040 and into the future.

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

3.3.1.2 Challenges and Strategies

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

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

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Integrating new technologies into operations.	Operate full-scale prototype systems in development before operations.	Use Operational Release Plans to identify issue and streamline the transition to operations.
Executing process relocations with multiple timelines without interruption to operations.	Develop integrated schedule, risk plan, and life-cycle cost estimate.	Bridge key capability gaps through partnership with commercial vendors and partnerships with other DOE national laboratories.
Preparing Building 9212 for disposition and demolition in shortest achievable timetable.	Begin deactivating systems and removing material immediately and maintain a 15+ year schedule.	

3.3.2 Depleted Uranium Modernization

DOE/NNSA has a long-term, increasing requirement for high-purity depleted uranium (HPDU) feedstock to meet national security needs. The capability to produce, process, and handle depleted uranium supports several key missions within the nuclear security enterprise, from providing components for life extension programs (LEPs) to downblending HEU to low-enriched uranium (LEU).

Depleted uranium is required for nuclear component production to maintain and modernize the stockpile through modernization programs. Depleted uranium is manufactured 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 Modernization Achievements

- *Restarted binary rolling operations at Y-12*
- *Completed primary and secondary melts at the off-site development VAR, with in-specification results*
- *Restarted the depleted uranium weld box*
- *Completed 60 percent design of depleted uranium tetrafluoride (DUF_4) conversion line for new high-purity depleted uranium production*
- *Completed Depleted Uranium Capability Study*

Depleted uranium is also required for stockpile surveillance. Nondestructive and destructive testing are performed for depleted uranium components in full assembly and part forms as part of surveillance data collection for ensuring confidence in the stockpile. Depleted uranium is also used as a surrogate material for component testing, such as flight and ground tests, that would otherwise be too hazardous.

3.3.2.1 Status

Depleted Uranium Modernization was established in FY 2021 by consolidating the depleted uranium portions of the previous Uranium Sustainment program and other programs of interest. Depleted uranium capabilities include feedstock procurement, restarting and maintaining both alloying and manufacturing processes, and investing in new key technologies. In the early 2000s, the reuse of materials, low-demand signals, and prioritization of other activities caused these capabilities to lapse. The Depleted Uranium Modernization program enables the restart of these capabilities so that DOE/NNSA will meet imminent mission requirements. Even though much of this work was previously performed under multiple programs, steady-state production demands a dedicated Depleted Uranium Modernization program to execute a comprehensive strategy to ensure that DOE/NNSA can meet programmatic requirements.

DUF_6 Conversion Processes

The Depleted Uranium Modernization program’s goal is to reestablish a reliable supply of HPDU before the current inventory is exhausted by developing a uranium hexafluoride (DUF_6) to uranium tetrafluoride (DUF_4) conversion line at the DOE’s Office of Environmental Management Portsmouth site DUF_6 Conversion Facility. The Depleted Uranium Modernization program is also restarting depleted uranium alloying capabilities and maintaining existing manufacturing processes. This includes restarting alloying production equipment at Y-12, modernizing component and machining capabilities, training operators, developing procedures, and supporting LANL and LLNL with process qualification activities. Collectively, these activities enable successful manufacturing of binary components.

Along with the wrought and machining capability issues, Y-12’s current alloying process is inefficient and leads to large amounts of material waste and excessive costs. DOE/NNSA is developing new technologies to replace these aging capabilities and provide a more efficient and cost-effective means of producing binary components and allowing DOE/NNSA to meet future production demands. For example, Direct Casting, intended to replace current alloying component manufacturing activities, significantly reduces risks of equipment failure, decreases material waste, and improves process efficiency. The Depleted Uranium Modernization program is also pursuing new technologies for material reuse and recycling, such as electron beam cold hearth melting and additive manufacturing of uranium alloys. These new technologies will significantly reduce risks to the production of depleted uranium and depleted uranium-alloyed components in the future stockpile.

DOE/NNSA’s Manhattan Project-era facilities continue to experience age-related failures that present significant risk to mission delivery and personnel safety. Restarting and sustaining depleted uranium processing capabilities requires targeted resources to address the risk associated with aging equipment. Sustaining these capabilities necessitates continued training and development of subject matter experts to produce components and resolve technical issues associated with these complex processes.

3.3.2.2 Challenges and Strategies

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

Table 3–4. Summary of Depleted Uranium Modernization challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
There is currently no capability to produce HPDU, and a steady supply requires significant investments in long-term capabilities.	Purchase limited commercial HPDU supplies remaining and invest in feedstock capabilities to ensure a steady stream of HPDU in the future.	Stand up a long-term HPDU conversion capability and invest in recycling technologies to reduce overall HPDU demand.
Depleted uranium alloying capabilities have lapsed and need to be restarted and modernized to support future stockpile needs.	Invest in maintenance of the legacy alloying processes. Plan to purchase additional equipment to reduce the strain on legacy equipment and processes.	Deploy new alloying production technologies to improve efficiency and recycling capabilities.
Current component manufacturing capabilities rely on aging equipment and have limited capacity to meet future stockpile needs.	Identify bottlenecks and develop bridging strategies to fulfill near-term mission requirements should new technology not be employed in the immediate future.	Invest in new component manufacturing technologies to produce component technologies more efficiently.
Current depleted uranium facilities have insufficient floor space to support future stockpile demand.	Identify opportunities to meet capacity within existing space using process improvements and upgraded equipment.	Evaluate long-term depleted uranium investment to meet future stockpile demands.

3.3.3 Lithium Modernization

DOE/NNSA requires specialized, weapon-specific forms of lithium for stockpile sustainment and is the sole-source provider for these materials. In addition to providing lithium for the nuclear weapon enterprise, it supplies the Department of Homeland Security, the DOE Office of Science, and other customers through the Strategic Partnership Program process. DOE/NNSA manufactures lithium materials into precision nuclear weapon components that meet stringent specifications to support warhead modernization programs and joint test assembly requirements, as well as to support tritium-producing burnable absorber rods (TPBAR) production for tritium modernization.

> ***Lithium Modernization Achievements***
>
> - *Completed qualification of reactor operations for B61-12 processing.*
> - *Completed planning and execution of additional bird bath installation.*
> - *Maintained the lithium material supply to meet Defense Programs mission and customer deliverables.*
> - *Continued Lithium Processing Facility design work and long lead procurement in preparation for CD-3A approval in 2022 and CD 2/3 approval in 2025*

Lithium Modernization activities include:

- Producing and maintaining the lithium material inventory to meet mission requirements and customer deliverables;
- Purifying and converting lithium materials to lithium hydride and/or lithium deuteride;

- Recapitalizing process equipment and performing risk reduction activities to sustain process capabilities; and
- Developing, maturing, and deploying lithium purification and production technologies in support of the Lithium Processing Facility.

Lithium is currently provided via a recycling process that relies on retired weapons dismantlement feedstock to supply material for processing. Nondestructive and destructive testing are performed for lithium components in full assembly and part forms as part of surveillance data collection for ensuring confidence in the stockpile.

3.3.3.1 Status

DOE/NNSA created a lithium strategy to ensure sufficient lithium processing capabilities (raw materials to finished assemblies) are available to meet near- and long-term requirements. The strategy includes:

- Sustaining the current Manhattan Project-era infrastructure and equipment until transition to the Lithium Processing Facility;
- Increasing the usable supply of lithium by dismantling and recycling lithium components using small-scale technologies to purify and convert lithium; and
- Designing and constructing the Lithium Processing Facility to house lithium processing capabilities by 2031.

A new facility is critical to the long-term strategy for lithium supply. Currently, aging infrastructure and antiquated equipment present risks to mission delivery that could affect the ability to meet stockpile requirements. The current lithium facility has housed lithium processing for more than 75 years. The historical processes are very corrosive in nature and have accelerated degradation of the facility. Structural issues due to chemical contamination pose safety and environmental concerns and must be replaced.

In addition to being well beyond operational design life, the facility and its processes are oversized for today's mission and do not meet current codes/standards. The program will execute recapitalization projects and risk reduction activities to ensure that the current lithium processing capability is sustained until the Lithium Processing Facility is operational. Modernization activities include developing the plan for bridging operations and transitioning from the existing facility to the new Lithium Processing Facility.

Lithium Processing Facility Conceptual Design

DOE/NNSA periodically updates the Lithium Strategy Document and has also developed the Lithium Technology Maturation Plan. DOE/NNSA is maturing technologies that will make lithium purification and processing safer to workers, more efficient, and less impactful to surrounding infrastructure. For example, an Automated Lithium Electrolysis Cell will increase efficiency in lithium metal processing and reduce risk to workers by using better construction materials for the cell body and anodes (less maintenance), provide in-process purification methods (better quality), and improve remote salt feed and metal harvesting techniques (improved safety). These technologies will be included in the Lithium Processing Facility.

DOE/NNSA established a technology development laboratory support to expand lithium technology maturation. Technology Readiness Assessments will be conducted as needed to assess the strengths and weaknesses of identified technologies.

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 necessitate continued training and development of subject matter experts to produce lithium components and resolve technical issues associated with these complex production processes.

3.3.3.2 Challenges and Strategies

Table 3–5 provides a high-level summary of Lithium Modernization challenges and the strategies to address them.

Table 3–5. Summary of Lithium Modernization challenges and strategies

	Strategies	
Challenges	*Current Strategy Being Implemented*	*Future Strategies Needed*
Meeting manufacturing deliverables using existing aging and degraded facilities.	Sustain current operations in the legacy lithium facility to meet near-term stockpile needs. Reestablish a small-scale purification capability and restart some legacy processing capabilities to supplement recycling activities. Plan and prioritize recapitalization projects and risk reduction activities to keep facilities and process equipment functional until the Lithium Processing Facility is operational.	Design and construct the Lithium Processing Facility. Continue to maintain legacy processing lines of effort through identified facility lifecycle extension projects until the Lithium Processing Facility is fully operational.
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.
Sustaining the supply of recycled lithium in the face of potential shortages.	Restart a small-scale 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.	Finalize development of Material Cell Equipment Refurbishment project to recapitalize equipment that processes salvage solutions, converts lithium chloride to lithium metal, and converts the metal to lithium hydride.
Sustaining lithium production with current inefficient processes.	Develop and mature lithium process technologies to introduce efficiencies into the current process and prepare for insertion in process facilities.	Further develop small scale wet chemistry resulting in purifying legacy material not suitable for the Direct Materials Manufacturing process.
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 adaptive solutions to maintain facilities past their useful lives.	Future projects include electrical, utility upgrades, and other identified structural life extending efforts. Optimize the design of Wet Chemistry setup for the Lithium Processing Facility.

3.4 Tritium Modernization and Domestic Uranium Enrichment

Tritium Modernization and Domestic Uranium Enrichment is responsible for producing tritium and supplying unobligated LEU to support national security needs.

3.4.1 Tritium Modernization

Tritium is a strategic material and due to the rate of radioactive decay, must be replenished periodically via LLC exchange. Tritium inventories are closely managed to meet replacement requirements and other national security needs.

Since FY 2003, DOE/NNSA has produced tritium by irradiating TPBARs in the Watts Bar Nuclear Plant Unit 1 (WBN1), which is operated by the Tennessee Valley Authority (TVA). Beginning in FY 2020, tritium production activities expanded to include Watts Bar Unit 2 (WBN2). TPBARs that are irradiated in the WBN1 and WBN2 reactors use unencumbered and unobligated LEU as fuel (i.e., LEU that is free of peaceful use restrictions, as discussed in more detail in Section 3.4.2). Once the TPBARs are irradiated, they are transported to SRS, where the tritium is extracted, stored, and loaded into gas transfer system (GTS) reservoirs that meet weapon system military specifications, increase system margins, and support weapon system reliability. In addition to tritium produced at TVA, additional tritium is recovered from previously filled GTS reservoirs and returned to SRS where the contents are recycled.

Tritium Modernization Achievements

- *WBN1 began irradiation of the maximum allowable TPBAR quantity, as permitted by Nuclear Regulatory Commission (NRC) license, in June 2020.*
- *WBN2 began its first-ever irradiation cycle of TPBARs in November 2020.*
- *TVA received Best Estimate Loss of Coolant Accident License Amendment Request approval from the NRC in February 2021, allowing more efficient and safer TPBAR core management.*
- *A new diffuser/stacking system at the Tritium Extraction Facility began operation, increasing capacity and decreasing waste gas processing.*
- *Contracts were awarded to begin site preparation and process building design for the Tritium Finishing Facility Project, which will replace the 1950's-era facility that processes GTS.*

Long-term tritium production schedules based on detailed computational models and annual inventory reconciliations are carefully managed to ensure the tritium inventory is sufficient to meet the needs of the active stockpile as well as required reserve amounts. Production schedules also take into consideration the material that is regularly recovered and recycled from returned reservoirs, including those from weapon dismantlement.

While most of DOE/NNSA's tritium capability activities focus on stockpile requirements, it also includes tritium gas processing R&D, GTS life storage, helium-3 recovery, and stockpile surveillance.

3.4.1.1 Status

Tritium Production

The Tritium Modernization Program operates the national capability for producing tritium and must increase capacity to meet added national security requirements.

The tritium production goal, independently certified by the Nuclear Weapons Council in 2015 as requested by Congress, increases tritium production capabilities by nearly 65 percent at TVA by 2025. This increased production requirement necessitates the use of two reactors with 18-month operating cycles. WBN1 has produced tritium since 2003 and is operating at the maximum licensed TPBAR irradiation rate permitted by the Nuclear Regulatory Commission (NRC). In November 2020, WBN2 began its first-ever 18-month tritium production cycle and is expected to reach the maximum allowable rate in early FY 2024.

To support DOE/NNSA's near- and mid-term tritium needs, as well as improving confidence that production targets will be met even in the event of unplanned reactor outages, TVA is preparing a 20-year license extension amendment that will increase the allowable production rates for both reactors.[2] While DOE/NNSA is confident that the TVA reactors will meet or exceed tritium production needs throughout their operating lifetime, the Tritium Modernization Program anticipates and plans for the long lead time required to establish new production methods. The Tritium Modernization Program is actively monitoring viable production alternatives, as well as trends in the civilian nuclear regulatory environment, to ensure supplies will continue to meet long-term needs.

As the demand for tritium continues to rise, DOE/NNSA must increase efforts to mitigate risk to production plans.

Tritium Processing at SRS

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

After being irradiated, TPBARs are transported to the Tritium Extraction Facility at SRS, where tritium is extracted by cutting and heating the rods. The processes to produce and extract tritium require unique, specialized equipment. Once the tritium gas is extracted, GTSs are then filled to meet DoD specifications. **Figure 3–2** illustrates the overall tritium processing flow. To recycle tritium from returned GTSs, the gas content is unloaded and then processed to remove any impurities. Helium-3, a byproduct resulting from the naturally occurring radioactive decay of tritium, is separated from the remaining tritium contents. The recycled tritium gas partially replenishes tritium inventory and can be reused in future GTS fills.

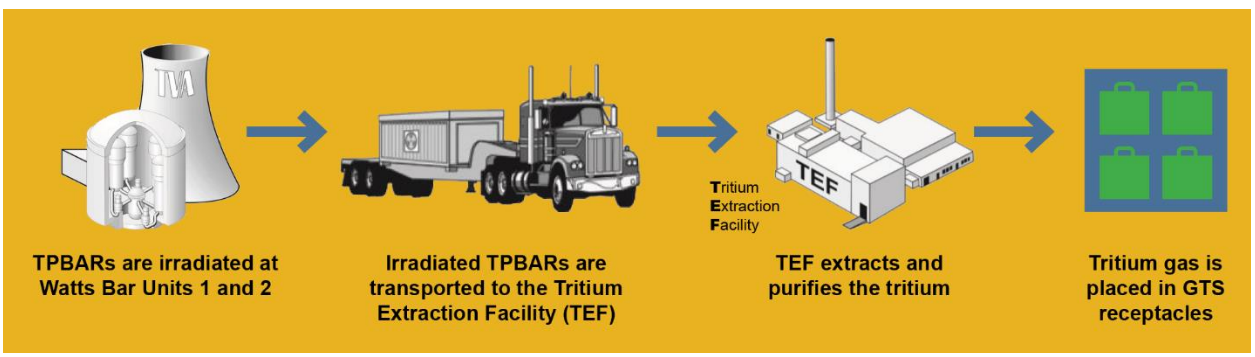


Figure 3–2. Tritium processing flow

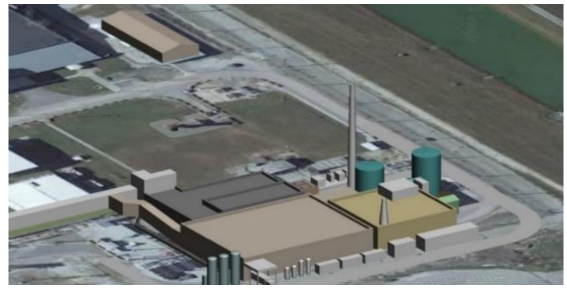
Various tritium extraction and purification processes, along with supporting functions, are performed in the H-Area Old Manufacturing facility, H-Area New Manufacturing facility, and the Tritium Extraction Facility at SRS. The Tritium Finishing Facility is a capital line-item project to construct a modern facility to replace the H-Area Old Manufacturing facility.

While DOE/NNSA has the tritium processing capabilities and capacity to meet foreseeable workload requirements, the facilities that house the processes were built in the 1990s. DOE/NNSA is currently monitoring the health of equipment, infrastructure, waste gas processing, and other facility attributes to

[2] Reactor operating lifetimes are regulated by the NRC. WBN1 is currently licensed to operate through 2035 and TVA WBN2 through 2055.

meet program deliverables and is developing a plan to maintain and recapitalize the facilities to meet processing requirements and other delivery schedules. The plan focuses on both the need to maintain the facilities themselves and the need to ensure maintenance of the supply chain, which includes unique vendors and tritium R&D capabilities.

The Tritium Finishing Facility line-item project, along with several minor construction projects, will replace the critical capabilities of the existing 60-year-old manufacturing building that operates 24/7 for GTS operations. The Tritium Finishing Facility achieved CD-1 in 2019, initiated design activities in 2020, and is on schedule to be completed by FY 2031.



Proposed Tritium Finishing Facility at SRS.

Tritium extraction operations at SRS are keeping up with the growing demand for tritium needs. DOE/NNSA has the workforce capability to meet planned workload and mission deliverables.

3.4.1.2 Challenges and Strategies

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

Table 3–6. Summary of Tritium Modernization challenges and strategies

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

3.4.2 Domestic Uranium Enrichment

> ***Domestic Uranium Enrichment Major Accomplishments***
>
> - *Identified additional unobligated LEU, extending the LEU need date to 2044*
> - *Oak Ridge National Laboratory successfully operated its small centrifuge in a demonstration cascade configuration*

Enriched uranium contains higher concentrations of the fissile uranium-235 isotope than natural uranium. DOE/NNSA requires enriched uranium at varied enrichment levels for tritium production, nonproliferation, and the Naval Reactors Program.

The Domestic Uranium Enrichment program is responsible for ensuring a reliable supply of enriched uranium is available to support U.S. national security needs. Since the 2013 closure of the Paducah Gaseous Diffusion Plant, near Paducah, Kentucky, the United States has lacked the capability to produce enriched uranium free of peaceful use obligations (i.e., unobligated). While commercial LEU sources exist, they carry peaceful use obligations and are therefore unusable for defense missions.

Mission needs for enriched uranium are currently fulfilled via the United States' remaining HEU stockpile (including downblending HEU to produce LEU where needed), which is a finite and currently irreplaceable source.

3.4.2.1 Status

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

- **Downblend HEU to LEU to extend the tritium fuel need date to 2044.** DOE/NNSA has identified existing unobligated and unencumbered material to power the TVA reactors through 2044. Much of the material is HEU "scrap," which is unattractive for use by other programs. Downblending activities will continue through FY 2025. This effort maintains continuous operations at the only commercial downblender, which would otherwise close in the absence of feed material. However, because the HEU inventory is finite and, at present, irreplaceable, downblending is a temporary solution.
- **Develop enrichment technology options.** Following an analysis of available enrichment technologies, DOE/NNSA determined that centrifuge technologies have the highest technical maturity and lowest risk. DOE/NNSA is funding centrifuge R&D efforts at Oak Ridge National Laboratory.
- **Execute an acquisition process to deploy an enrichment technology.** Because of the finite nature of the HEU inventory, the United States will eventually need a new uranium enrichment capability. DOE/NNSA approved CD-0 for this capability in December 2016. DOE/NNSA expects to conclude an AoA and make a final technology downselect in the mid-2020s.

3.4.2.2 Challenges and Strategies

Table 3–7 provides a high-level summary of Domestic Uranium Enrichment challenges and the strategies to address them.

Table 3–7. Summary of Domestic Uranium Enrichment challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Enrichment technologies are complex and difficult to develop and deploy.	DOE has invested in two centrifuge technologies to provide optionality and contingency. DOE/NNSA continuously assesses its inventory to identify any additional unobligated enriched uranium that may provide additional development time or margin to the LEU need date.	Continue developing multiple centrifuge technologies in order to provide additional operational data and reduce long-term deployment risks.
Sources of unobligated LEU are finite and limited.	DOE/NNSA continuously assesses its inventory to identify any additional unobligated enriched uranium. Recently identified materials have resulted in a 3-year extension of the LEU need date.	Establish a reliable source of unobligated enriched uranium.

3.5 Non-Nuclear Capability Modernization

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

The Non-Nuclear Capability Modernization program manages a portfolio made up of the following component categories:

- Cable Assemblies
- Electronic Assemblies
- GTSs
- Lightning Arrestor Connectors
- Mechanisms
- Microelectronics Packaging
- Neutron Generators
- Power Sources
- Polymers
- Radiation Hardened Microelectronics
- Testers

Non-Nuclear Capability Modernization Accomplishments

- *Developed Federal Microsystems Plan to assure trusted microelectronics are available for integration into our systems.*
- *Executed initiation of DOE Order 413.3b Capital Acquisition process for Power Sources Capabilities.*
- *Started Short-term Expansion Plan to increase development and production capacity of non-nuclear components*
- *Initiated COTS (Commercial Off-the-shelf) Transformation Initiative to address commercial product integration challenges.*
- *Developing production enclaves to accelerate the transition of design to production for future programs.*

Non-Nuclear Capability Modernization activities include:

- Procurement of equipment to meet non-nuclear component design, qualification, and manufacturing capacity requirements;
- Efforts to increase in capacity and capability of non-nuclear component manufacturing within the nuclear security enterprise and extend and strengthen the trusted supplier base;
- Sustainment of DOE/NNSA's capability to produce trusted microelectronics;
- Recapitalization of critical capabilities for the design, production, and qualification of nuclear weapon electrical and mechanical systems;
- Modernization of capabilities with a fragile vendor base such as Power Sources program deliverables;
- Reduction of component manufacturing costs through introduction of modernized processes and technologies; and
- Development of a pre-qualified and trusted inventory of commercial parts to avoid delays in integrating commercial off-the-shelf (COTS) components.

Subject matter experts at the production facilities work with the national security laboratories early in the design phase to provide production perspectives on material selections and designs to enhance producibility of components. The national security laboratories define the component testing requirements 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.

DOE/NNSA has made progress in developing rapid prototyping and advanced manufacturing capabilities that have the potential to accelerate design definition, manufacture, qualification, and acceptance while reducing production issues and space while delivering reliable products at lower costs.

3.5.1 Status

Production sites are facing capacity shortfalls in production and development of components due to increased weapon modernization requirements and scope. The increased workload has resulted in a growth in the Kansas City National Security Campus (KCNSC) M&O workforce from 2,200 to more than 5,000 employees since 2014. DOE/NNSA is adding additional production capacity through leasing at KCNSC, as well as shifting production to other DOE/NNSA sites while simultaneously increasing the supplier base for commercial component production. Off-site office space has been leased to meet the increased office employment. KCNSC is leasing an additional 275,000 square feet of space for manufacturing and is in the process of adding 175,000 square feet to meet the near-term weapon modernization mission. Additional space will be required for long-term manufacturing requirements. To accelerate the transition from design to production, LLNL and KCNSC have partnered on the development of a polymer enclave. Construction for the enclave started in FY 2020 and is expected to complete in FY 2022

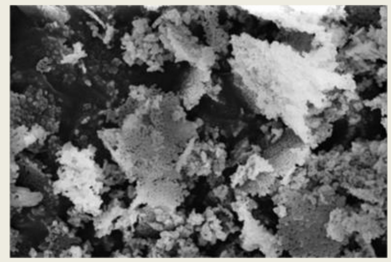
Non-Nuclear Capability Production Success

SNL, which has both design agency and production agency roles in the nuclear security enterprise, delivered nearly 40,000 non-nuclear parts, components, and technologies in FY 2020 to support all stockpile system maintenance activities and LEPs. KCNSC continues to produce or procures the majority of non-nuclear components for the nuclear security enterprise.

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 facility at SNL that primarily houses the DOE/NNSA power sources capability is a shipping/receiving warehouse converted in 1949. Severe degradation of this facility led to an AoA that determined the need for a long-term replacement while exploring use of other SNL facilities, such as the Agile Facility, on a temporary basis. The same 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 rapidly aging beyond fitness for mission use. MESA has an ongoing extended life program that must be fully funded to sustain MESA's capabilities through 2040. In addition, plans are in development for sourcing and manufacturing required microelectronics well past 2040.

Magnesium Oxide Development Addresses a Legacy Material Supply Challenge

Sustained R&D efforts at SNL have led to a mechanistic understanding of legacy magnesium oxide (MgO) performance within thermal batteries. Legacy MgO has a unique nanoscale structure, critical to its function, and the supply is limited. In FY 2019, the team demonstrated the ability to design and synthesize MgO materials with similar nanoscale structures and demonstrated their function in prototype batteries.



Scanning electron micrograph of microstructure in porous magnesium oxide

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 as full participation from each of the DOE/NNSA sites.

The concern with aging capabilities extends to major environmental test facilities utilized for the qualification and assessment of non-nuclear components in their extreme environments to high reliabilities not required for commercial products. The majority of these facilities, including the Annular Core Research Reactor, are decades old and, similar to production facilities, have suffered from obsolescence and deferred maintenance over the years. These facilities must remain operational to assure that the qualification of non-nuclear components does not become critical path for the modernization programs.

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

3.5.2 Challenges and Strategies

Table 3–8 provides a high-level summary of Non-Nuclear Capability Modernization challenges and the strategies to address them.

Table 3–8. Summary of Non-Nuclear Capability Modernization challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Increased Scope and Complexity: Workload projections to produce non-nuclear components for the program of record exceed existing equipment and infrastructure capacity. Manufacturing space was sized for fewer, less-complex weapon systems.	DOE/NNSA will develop options for additional space or more efficient use of existing space. Capital acquisition planning is underway to determine the most prudent solutions to provide increased production capacity at both SNL (for Power Sources) and KCNSC. Additionally, production enclaves at design laboratories allow increased capacity.	The MESA complex at SNL fulfills an enduring need for radiation-hardened microelectronics. A Federal Management Plan will implement processes to validate sustainment and modernization needs, identify potential funding gaps, and develop mitigation strategies to ensure MESA capabilities continue to meet stockpile sustainment and modernization needs through 2040.
Integration of New Technologies: As new manufacturing techniques are developed, qualified, and accepted, new production capabilities are required to support manufacturing involving different materials, multi-function machines, additive manufacturing, and other new approaches. Space for the new capabilities is required in addition to current equipment until legacy technologies can be retired.	The Capability-Based Investments program is providing interim relief for some of the critical equipment needs related to these key product lines. Additionally, funds are committed to bring new polymer advanced manufacturing capabilities online by FY 2022.	The Non-Nuclear Capabilities Program will work continue collaborating with the Research, Development, Test, and Evaluation Program Office to identify promising technologies that could/would be committed to future modernization programs if sufficiently mature, and fund them to higher technology readiness levels (TRL) and manufacturing readiness levels. Pushing these technologies across the "valley of death" (i.e., mid-range TRLs) will enable improvements in stockpile safety, security, use control, and reliability, while minimizing the schedule, performance, and cost risk to the identified modernization program.
Material Availability: Some material supplies are limited to only those quantities remaining from legacy programs, yet continue to be in demand by weapons programs. Vendors have lost the capability, capacity, or interest to produce more of these of materials.	Current efforts for managing these critical materials consist of establishing a central database for at-risk materials and providing transparency of the supply chain status by industry experts.	Supply chain analysis and studies will examine supplier network risks for non-nuclear components and provide recommended policy actions, production activity practices, and material solutions to improve supply chain resiliency. These efforts also coordinate across DOE/NNSA to prioritize supplier risks, develop enterprise-wide mitigation strategies, and leverage available policy tools.
Vendor Implications: Risks in the available supplier base and the need to produce more classified components is driving a need for additional in-house production capability while continuing to identify and qualify additional suppliers.	The program will support the development and replacement of non-nuclear component material identified for use. The program will then engage on activities to modernize DOE/NNSA's industrial capacity for its implementation.	Early engagement with design requirements in order to research potential new qualified sources. Determine alternative contracting methods to purchase goods and services from qualified sources quicker and more efficiently. Baseline capabilities at the design agencies to quickly fulfill unexpected needs.

Chapter 4 Stockpile Research, Technology, and Engineering

4.1 Overview

The Stockpile Research, Technology, and Engineering (SRT&E) Program is central to maintaining a credible deterrent and ensuring the safety, security, and effectiveness of the Nation's nuclear stockpile. SRT&E is responsible for research, development, qualification, certification, testing, and evaluation support to stockpile sustainment, stockpile modernization, warhead production, and the future nuclear security enterprise. The program also ensures the science, technology, and engineering proficiency of the Department of Energy/National Nuclear Security Administration (DOE/NNSA) workforce for the future and helps maintain the readiness of its infrastructure to support near-term and future workloads.

The drivers for SRT&E include (1) sustaining the deployed stockpile; (2) enabling the future nuclear deterrent; (3) assessing and mitigating threats to the deterrent; and (4) developing modern materials and design and manufacturing options for the nuclear security enterprise. The science-based SRT&E program sustains the deterrent in the absence of nuclear explosive testing and advances DOE/NNSA's understanding of nuclear weapon functionality through science, technology, and engineering research.

Key activities such as advanced modeling and simulation capabilities, subcritical and hydrodynamic experiments, high energy density (HED) physics experiments, and test flights of high-fidelity simulators provide the capabilities to underwrite current and future nuclear stockpiles. Enhanced experimental and simulation capabilities are required to recreate, interrogate, and provide data on materials and physics at weapon-like conditions to address these focus areas. Capabilities developed under SRT&E provide data essential to stockpile modernization and production and help recruit, train, and retain the next generation of stockpile stewards.

Major Stockpile Research, Technology, and Engineering Program Accomplishments

- *Conducted first-of-its-kind radiography on a centrifuge to evaluate and validate novel design and surety technologies under high G-force loads expected in future weapon environments.*
- *Ported and demonstrated existing and next-generation Integrated Design Codes/ weapons performance codes on new architecture for the Sierra supercomputer in preparation for use on NNSA's first exascale computer, El Capitan.*
- *Combined artificial intelligence with machine learning and high performance computing to expedite assessments of the National Ignition Facility Inertial Confinement Fusion Ignition and High Yield hydrotests for a life extension program.*
- *Nightshade A, a subcritical experiment executed at the U1a facility, provided key data to underwrite the performance of the evolving stockpile.*
- *Measured material properties for newly cast, 10-year, and 30-year naturally aged plutonium to inform updated pit lifetimes and pit production requirements.*
- *Successfully executed a plutonium equation-of-state experiment at higher pressure and accuracy than previously possible at the Z pulsed power facility (Z).*
- *Used additive manufacturing to fabricate a high explosive that was transferred to the W87-1 program in FY 2021, leading to reduced costs and manufacturing times.*
- *Completed three-dimensional, end-to-end simulation of a warhead encountering combined hostile environments to assess effect on subsequent weapon performance.*

For more than 25 years, the program has pioneered, developed, and deployed capabilities to provide DOE/NNSA with important, high-fidelity data to maintain and modernize the stockpile and associated workforce. SRT&E's world-class capabilities provide a hedge against prospective and unanticipated risks and prevent technological surprise, and it is critical to enabling technical assessment of the stockpile without nuclear explosive testing.

4.2 Strategic Program Goals

The initial Stockpile Stewardship Program established 20 years ago focused largely on nuclear explosive package experimental science and simulation, namely low energy density science (primaries), HED science (secondaries), modeling and simulation (making use of the experimental data), and high performance computing (HPC) (to run the weapon models in the timeframes and detail needed). This approach can now be applied to the needs of the future nuclear security enterprise in warhead component production and timely non-nuclear component design and certification. While the Stockpile Stewardship Program has made great advances in nuclear weapon science, engineering, simulation, and computing, challenges still remain and grow with an uncertain geopolitical future, enduring and emerging threats, and the aging of the stockpile itself.

The strategic program goals of SRT&E are still applicable as DOE/NNSA embarks on the next 20 years of Stockpile Stewardship. SRT&E continues to apply Stockpile Stewardship Program capabilities to address present needs and prepare for the requirements associated with an uncertain future. SRT&E advances capabilities for improved understanding of weapon performance and demonstrates new technologies and production processes as viable options for the future stockpile. Development of these capabilities well before their needed insertion in the stockpile is required to understand risks that such insertions would introduce due to aging, changing legacy processes, and evolving threats. These capabilities:

- Drive program plans within SRT&E (Section 4.3).
- Align with the 10-year program outlook in the Stewardship Capability Delivery Schedule (SCDS) (Section 4.2.2).
- Drive a new approach to Weapons Activities Line Item Planning (formerly capital acquisition planning) (Chapter 6, Section 6.2.2).
- Reaffirm the importance of Academic Programs to encourage weapon-relevant research and develop a pipeline research and development (R&D) scientists and engineers with weapon-related education and training (Section 4.3.6).

Looking to the future, SRT&E will continue to implement and develop capabilities to address issues facing the nuclear security enterprise. As part of an enterprise-wide strategy, SRT&E will take leadership in three areas:

- Fostering an environment of innovation aimed at improving our understanding of the stockpile and serving as the proving grounds for new ideas.
- Applying SRT&E capabilities to enable a more modern and efficient production complex.
- Investing in the next generation to lead the nuclear security enterprise by equipping them with the knowledge, judgment, and state-of-the-art scientific and computing capabilities to achieve the mission.

Accomplishing these goals requires some fundamental changes in the way the nuclear security enterprise is managed, including directly addressing three major obstacles to success:

- **Risk avoidance** has become ingrained in the culture of the nuclear security enterprise due to the high-risk, high-consequence nature of DOE/NNSA's mission. This has created an environment that can inhibit both innovation and attempts to do things differently, even if the changes would produce a more resilient and responsive nuclear security enterprise.
- **Prioritization** is a persistent issue. Because modernizing production infrastructure is currently the highest priority to meet Department of Defense (DoD) requirements, SRT&E is deferring some investments.
- **Lack of a common understanding of shared mission across the management and operating sites** is partly driven by the fact that sites are not incentivized to work together on common goals, as they are rated primarily on individual contributions through seven different prime contracts with DOE/NNSA.

To advance an improved approach, SRT&E will employ internal and external outreach, communicate the common vision for the future of the enterprise more effectively, codify strategies and plans, and enable appropriate risk-taking.

4.2.1 Stewardship Capability Delivery Schedule

The SCDS aligns SRT&E programs with mission objectives, coordinates efforts across Defense Programs, and communicates with internal and external stakeholders. DOE/NNSA and the national security laboratories, plants, and sites use the SCDS to guide capability development (**Figure 4–1**) in four key focus areas. These focus areas reflect the advances necessary for mission delivery, as well as what is required to achieve objectives in an integrated manner.

- **Stockpile Sustainment** guides the efforts that support the needs of the current U.S. nuclear stockpile, such as material aging studies and improving warhead assessment experimental, modeling, and simulation capabilities.
- **Future Deterrent** develops responsive technologies, architectures, and processes that reduce cycle times for future weapon development.
- **Threat Mitigation** develops and matures technologies and experimental capabilities to simulate and mitigate combined and emerging reentry and hostile environments that future weapons may encounter.
- **Modern Materials and Manufacturing** develops advanced materials and ways to manufacture materials and components that are robust to hostile environments, extend lifetimes, minimize risk of material obsolescence, and reduce production life cycle time and cost.
- New to the SCDS from its last appearance in the Stockpile Stewardship and Management Plan (SSMP) is a milestone in FY 2022 under Modern Materials and Manufacturing that covers Special Materials. The topic area and timeframe needed were developed in conjunction with Production Modernization, allowing SRT&E to shift near-term focus to meet an enterprise need. The Hostile Survivability Baseline milestone was also delayed to the second quarter of FY 2021 due to the in-person work restrictions responding to COVID-19. The SCDS provides a guiding framework while still maintaining a flexible and dynamic look at the needs of the enterprise to revise objectives in consultation with internal and external stakeholders. Successful accomplishment of SCDS objectives requires strong partnerships across Defense Programs.

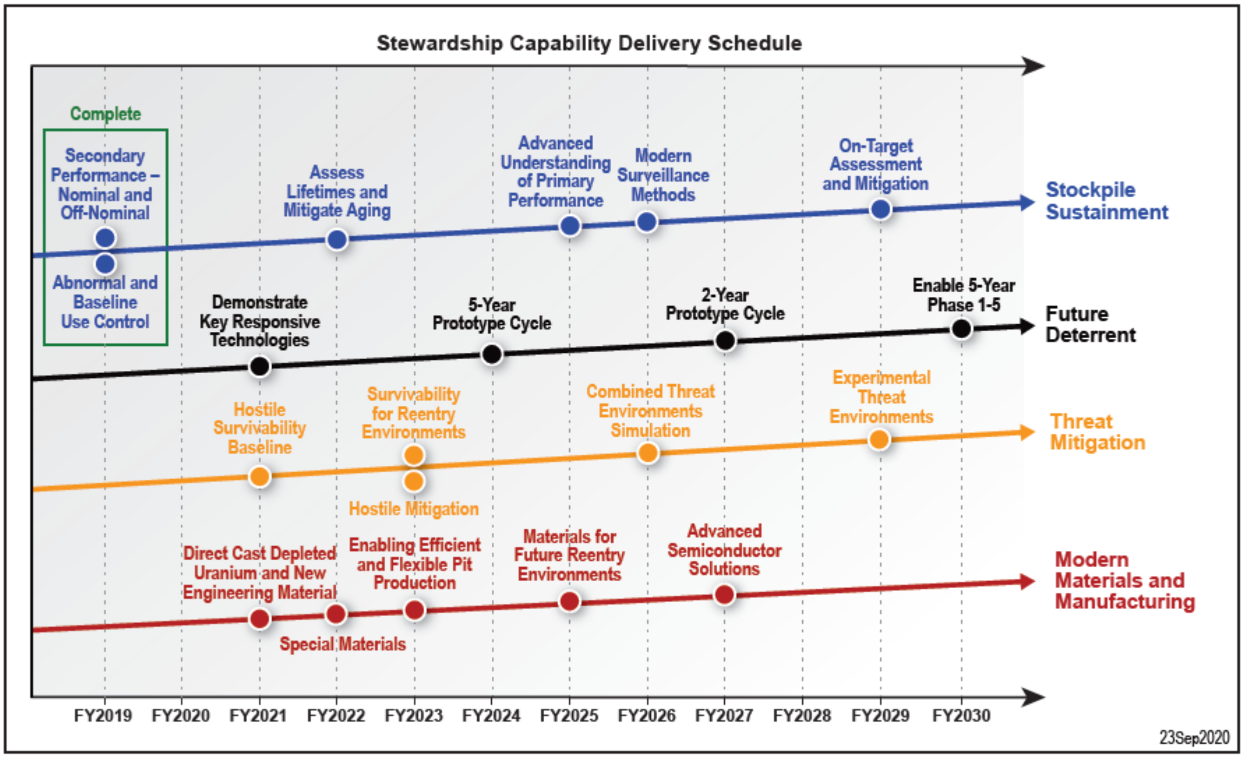


Figure 4–1. Stewardship Capability Delivery Schedule – the four key focus areas needed to address mission delivery

4.2.2 Enduring Drivers for Stockpile Research, Technology, and Engineering

Responsible stockpile stewardship demands computational, experimental, and testing capabilities, as well as continuous development of a qualified workforce to implement these capabilities. They are essential for stewardship of the current stockpile and must be enhanced to improve understanding of nuclear weapons performance to support the effectiveness of our nuclear deterrent into the future. Enhancing capabilities to prepare for the future also allows the nuclear security enterprise to remain responsive with an ability to adapt to changing geopolitical environments as needed, as well as attract, train, and retain the requisite stockpile expertise in the workforce.

4.2.2.1 Sustaining and Assessing the Current Stockpile

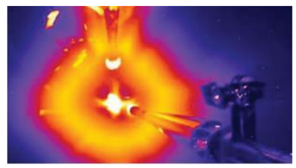
The status of the current stockpile is monitored through continuous, multi-layered assessments of the safety, security, and effectiveness of each U.S. nuclear weapon system. As explained in Section 2.1.2.1, the annual stockpile assessment process evaluates the safety, performance, and reliability of weapons based on physics and engineering

> ***Advanced Technologies for Stockpile Surveillance***
>
> *The Weapon Technology and Manufacturing Maturation Program is developing sensor technologies and embedded sensor systems for in situ surveillance and enhanced future system capabilities.*
>
> *Some devices under development:*
>
> - *A low-power thermal sensor that provides temperature vs. time data to understand aging and overall system health. The data will be used in predictive aging models.*
> - *A pressure sensor and a displacement sensor for shock and vibration measurement that works with the embedded sensor processor electronics to understand the internal and external operational environments seen by the weapon system.*

analyses, experiments, and computer simulations. Assessments further evaluate the effect of aging on performance and quantify performance thresholds, uncertainties, and margins. These evaluations depend on all available sources of information, including surveillance, non-nuclear hydrodynamic tests, subcritical experiments, materials evaluation, modeling and simulation, and enhanced surveillance techniques. These assessments rely on new advances in tools, including computational and experimental advances. Continuous assessment involves assembling a body of evidence to assess performance at the part, component, subsystem, and system levels to determine whether all the required performance characteristics are met. The processes combine data and theories with simulations of nuclear weapons to inform expert judgement and arrive at conclusions. DOE/NNSA uses expert judgment to combine data, theory, experiment, and simulation and arrive at conclusions. This process is underwritten by extensive peer review. SRT&E brings together experimental and modeling tools to evaluate current performance and study uncertainties around those baselines. Some of the many sources of information derived from SRT&E activities are depicted in **Figure 4–2**.

Subcritical testing is crucial to certification in the absence of nuclear test

Hydro testing: DARHT's (Dual-Axis Radiographic Hydrodynamic Test) electron accelerators create magnetic fields that focus and steer a stream of electrons



High energy density science capabilities test weapons in hostile environments

Surveillance activities such as joint test assembly flight tests and non-destructive testing provide essential data

Superfuge, a 29-foot arm centrifuge used for assessment of combined environments

Materials testing and evaluation: X-ray photoelectron spectroscopy instrument provides rapid, high-sensitivity chemical analysis of the near-surface region of samples

Testing complements modeling and simulation

Figure 4–2. Weapon assessments rely on many sources of information from Stockpile Research, Technology, and Engineering

Weapons scientists and engineers are crucial to every aspect of the assessment process. The overall assessment philosophy and approach involves quantification of weapon characteristics and a deep understanding of the multi-physics mechanisms driving weapons performance under a variety of conditions. The laboratory teams responsible for each weapon system and its assessment are comprised of scientists and engineers who are deep technical experts in multiple physics areas relevant to weapons physics and who review both historical and new data. Several mechanisms exist to ensure that each national security laboratory has full and complete access to all relevant weapons data to support these assessments. These mechanisms include regular exchanges of electronic documents and databases between sites and several peer-to-peer data-sharing options. In addition, DOE/NNSA sites are consolidating and digitizing historical weapon data to ensure it is available to future weapon designers. The assessments and conclusions in the Annual Assessment Reports are reviewed by independent reviewers, federally mandated Red Teams (subject matter experts from the other national security laboratories who are appointed by their Laboratory Directors), program managers, senior laboratory management, and the Laboratory Directors. Specific results related to the stockpile systems are included in the latest *Report on Stockpile Assessments*.

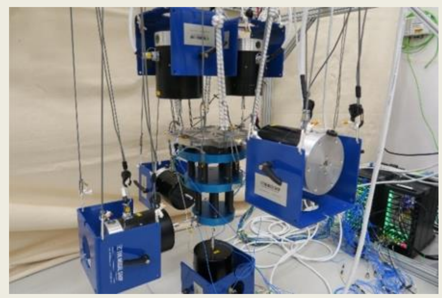
The assessment process can be at least, if not more, complicated than the initial certification process, as scientists and engineers must reconcile what was fielded in reality with what was intended in the design.

4.2.2.2 Ensuring the Future Stockpile

The evolving international and increasingly cross-domain security environment, as well as the aging of the stockpile, drive requirements for life extension programs (LEPs) and potential modern replacements for existing stockpile systems. Ensuring the resiliency of the U.S. nuclear deterrent requires qualification- and certification-ready options, from materials through components to systems, to be matured and available when needed for down-select decisions, development, and production. This maturation demands advances in qualification and certification methodologies, improvements to the responsiveness of the nuclear security enterprise, improved integration with DoD, and development of new and emergent capabilities for the qualification and certification processes.

4.2.2.3 Qualification

SRT&E collaborates with Stockpile Management to steward, advance, and qualify nuclear weapons components, subassemblies, and integrated systems to meet the military characteristics across the stockpile-to-target sequence (STS) environment requirements (e.g., normal, abnormal, and hostile environments specified in the STS). These qualification activities are defined in qualification plans and use experimental and modeling/simulation capabilities. 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.



Enhanced Vibration Testing in Laboratory Supports Qualification

National security laboratory researchers have been rapidly progressing the state of the art in multi-axis and multi-input vibration testing. Technology maturation has resulted in increased test capabilities demonstrated on laboratory tests of High Operational Tempo Sounding Rocket Program (HOT Shot) payloads as well as mock RB system and subassembly hardware from the Joint Technology Demonstrator program. Advances made in 2019 and 2020 milestones in multi-axis flight simulation has further increased capabilities by enabling new and improved test design methods.

DOE/NNSA is developing a series of high-cadence technology development capabilities intended for full system testing in relevant environments that are cost-effective tools for technology maturation. These tools allow for more rapid development of future technologies and deployment of weapon systems. Initial data shows demonstrators help increase TRL/MRL[1] and are effective at transferring technology to the end users. DOE/NNSA is collecting additional data to confirm initial findings. Technology funded by the Advanced Manufacturing Development subprogram has benefited from demonstrators, and demonstrators have been particularly useful for growing the acceptance of additive manufacturing in the enterprise.

Current demonstrator projects provide opportunities for cross-enterprise collaboration and optimization. The Joint Technology Demonstrator (JTD) is a United States and United Kingdom strategic collaboration dedicated to the design and execution of joint, integrated system demonstrations supporting new safety, security, and advanced manufacturing technologies. The primary goal of the JTD collaboration is to build and sustain core capabilities throughout the United States and United Kingdom nuclear weapon

[1] TRL/MRL refers to Technology Readiness Level and Manufacturing Readiness Level, as defined in Appendix F.

enterprises in the design, manufacture, ground testing, and assembly of flight-ready hardware. The Air Force has realized the benefit of JTD and has created the opportunity for a flight test in FY 2022. This joint JTD follow-on demonstrator is called the Air Force NNSA Demonstration Initiative.

DOE/NNSA achieves desired timelines by adopting flexible architectures for adaptability and agility, developing tight design agency/production agency collaboration from early activities for increased responsiveness, and applying advanced accelerated methods for qualification and certification. Understanding what works and what does not are identified in the course of the "build, test, break" cycle.

As new manufacturing technologies are inserted into the production enterprise, qualification of complex components and materials produced presents new challenges. To ensure that advances in manufacturing do not result in complex, costly, and lengthy acceptance processes, new inspection technologies such as in-line metrology and born-qualified processes are being developed by the SRT&E program. In addition, new measurement techniques are being developed and deployed to more fully characterize products to enable predictive assessments of stockpile performance over time.

4.3 Stockpile Research, Technology, and Engineering Elements and Status

SRT&E elements play a major role in the full range of stockpile activities. The high-level FY 2021 accomplishments in the sidebar on page 4-1 are the result of using the program's experimental, modeling, and simulation capabilities to design weapon subsystems and quantify their expected performance for the weapon program of record. These capabilities enable the nuclear survivability qualification of several components. The five major elements that enable Stockpile Stewardship are the Assessment Science program, the Inertial Confinement Fusion (ICF) Ignition and High Yield program, the Advanced Simulation and Computing (ASC) program, the Engineering and Integrated Assessments program, and the Weapon Technology and Manufacturing Maturation program. These elements are illustrated in **Figure 4–3**.

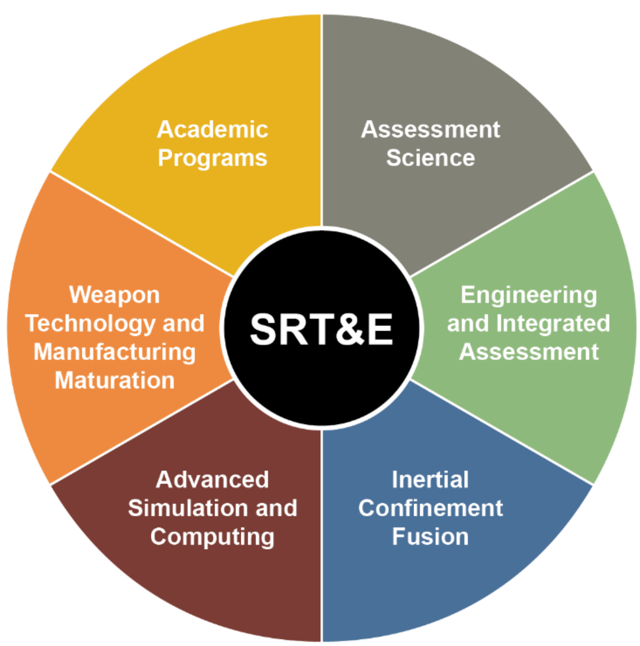


Figure 4–3. Subprograms in Science, Research, Technology, and Engineering

4.3.1 Assessment Science

The Assessment Science program provides the knowledge, expertise, and experimental toolkits needed to maintain confidence in the nuclear stockpile in the absence of nuclear explosive testing. Capabilities developed and maintained by the Assessment Science program support the entire nuclear security enterprise providing (1) the scientific underpinnings required to conduct annual assessments of weapon performance and certification of LEPs; (2) the scientific insight necessary to inform our understanding of the effects of surveillance findings to assure that the nuclear stockpile remains safe, secure, and effective; and (3) the core technical expertise required to be responsive to technical developments and geopolitical drivers. Assessment Science also facilitates the assessment of current weapon and weapon component lifetimes, development and qualification of modern materials and manufacturing processes, concepts for component reuse, and modern safety concepts for sustainment.

This program performs experiments to obtain the materials and nuclear data required to validate and to understand the physics of nuclear weapons performance. Science program experiments and data analyses also facilitate evaluations of safety, security, and sustainment concepts without the need for additional nuclear explosive testing. These activities serve to develop, exercise, and maintain the expertise and competence of the nuclear weapon design, engineering, and assessment community. Each subprograms links to other areas within Weapons Activities. Those linkages are described in **Figure 4–4**.

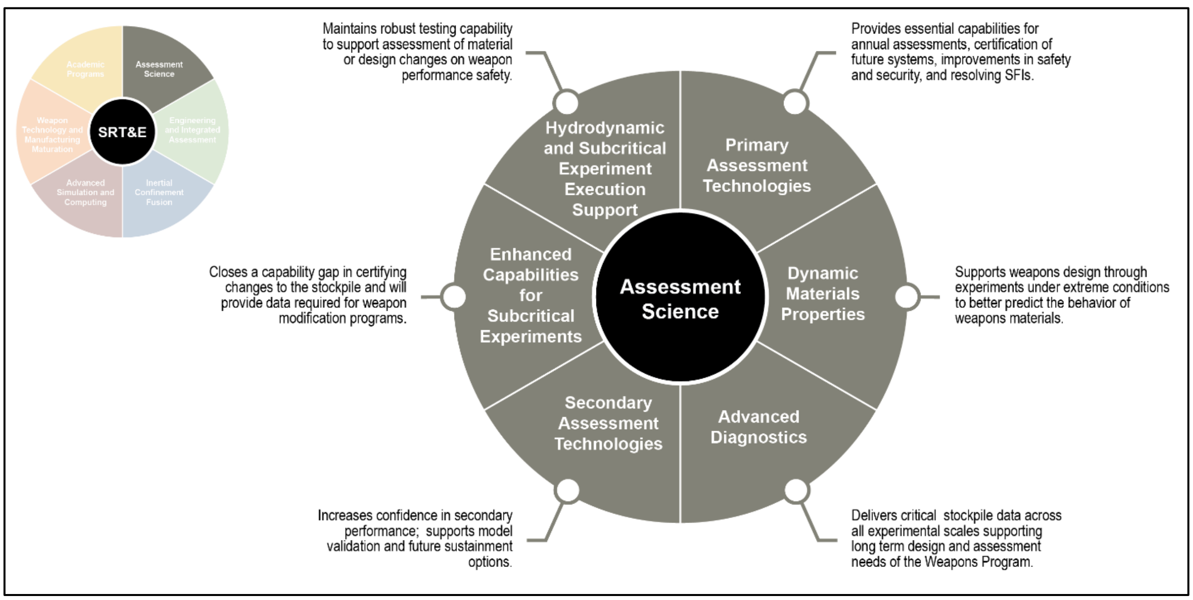


Figure 4–4. Assessment Science linkages to Weapons Activities

Primary Assessment Technologies provides foundational capabilities for annual assessment of stockpile primaries, certification of future sustainment programs, improvements in primary safety and security, and resolution of significant finding investigations (SFIs). It also designs and executes subcritical experiments that provide essential data to underwrite the performance of the evolving stockpile. This subprogram improves predictive ability by developing common models to quantify uncertainties in predictions; supports experimental platforms to validate weapons physics models; incorporates experimental data to improve modeling of boost, plutonium aging, and manufacturing variances; and enables threat-informed design and assessment advances.

Dynamic Materials Properties develops and maintains the experimental capabilities needed to describe and predict the behavior of weapon materials in extreme environments. The subprogram provides the experimental data and assessment of special nuclear material (SNM), metals, conventional/insensitive high explosives (HE), polymers, and foams under dynamic conditions. It furthers understanding of how fundamental material behavior affects nuclear weapon performance. The subprogram advances understanding of how plutonium aging and manufacturing methods of plutonium and HE impact weapon performance. It also maintains capabilities to expand pressure, temperature, and strain rate regimes and advances characterization methodologies of these high-interest materials, leading to reduction of uncertainties in performance models.

Advanced Diagnostics establishes tomorrow's tools for delivering stockpile data that matter. It develops revolutionary diagnostics and methodologies for hydrodynamic, subcritical, gas gun, and other dynamic experiments that subject materials to strong shocks and high strain rates. It provides next-generation driver technologies that can create dynamic experimental conditions relevant to the stockpile. It also incorporates novel data analysis techniques that push the boundaries of what can be learned from dynamic experiments.

Secondary Assessment Technologies provides capabilities that increase confidence in the assessment of stockpile secondaries and enables a broad range of sustainment options and resolution of SFIs. It uses past nuclear explosive test data and a variety of experiments to develop and validate physical models, expand the domain of validity of modeling tools, and qualify experimental platforms to meet the needs of current and future modernization programs.

Enhanced Capabilities for Subcritical Experiments (ECSE) closes a capability gap in the ability to certify changes to the stockpile, including aging, modern manufacturing technologies, modern materials, and evolving design philosophies. Data from the ECSE program helps underwrite certification of the W87-1 Modification Program, as well as future annual assessments and modernization programs. **Figure 4–5** shows one of the capital investment elements of ECSE, the Advanced Sources and Detectors "Scorpius" accelerator. The U1a Complex Enhancements Project line item is preparing the underground U1A Complex (U1A) to receive this major item of equipment in order to provide advanced diagnostics for subcritical testing.

Hydrodynamic and Subcritical Experiment Execution Support enables execution of prioritized experiments through the National Hydrodynamic Test Plan and the National Subcritical Plan to deliver critical data in support of modernization programs, stockpile maintenance, experimental science, and global security. The subprogram allows assessment of potential effects from design changes, material substitutions, or component changes associated with LEPs, alterations (Alts), or modification programs (Mods) on weapon performance and safety.

4.3.1.1 Status

The Assessment Science program is increasing its resource allocation toward large-scale integrated experiments while preserving a balanced portfolio of focused experiments to underwrite the performance of the evolving stockpile. Enduring experimental priorities include hydrodynamic experiments and subcritical experiments that fully utilize ECSE upon delivery, as well as materials science platforms to investigate the effect of material changes on weapon performance. These priority experiments will also use new capabilities that leverage DOE's investment in world-class advanced light sources[2] and in situ aging and manufacturing experiments on hazardous and SNM at the Los Alamos Neutron Science Center neutron diffraction and proton radiography facilities. These strategic priorities enable the assessment

[2] Advanced lights sources, such as synchrotrons and X-ray free-electron lasers operated by the DOE Office of Science, are devices designed to emit exceptionally brilliant and penetrating light that allow diagnostic imaging of nuclear weapon implosions and other weapon-related phenomena.

The planned **Scorpius electron accelerator** will utilize a linear induction accelerator to radiograph the late stages of implosion of a nuclear weapon. The imaging will allow scientists to see what is happening to the plutonium inside a subcritical weapon during the late stages of implosion, informing annual certification of the stockpile and validating computer models.

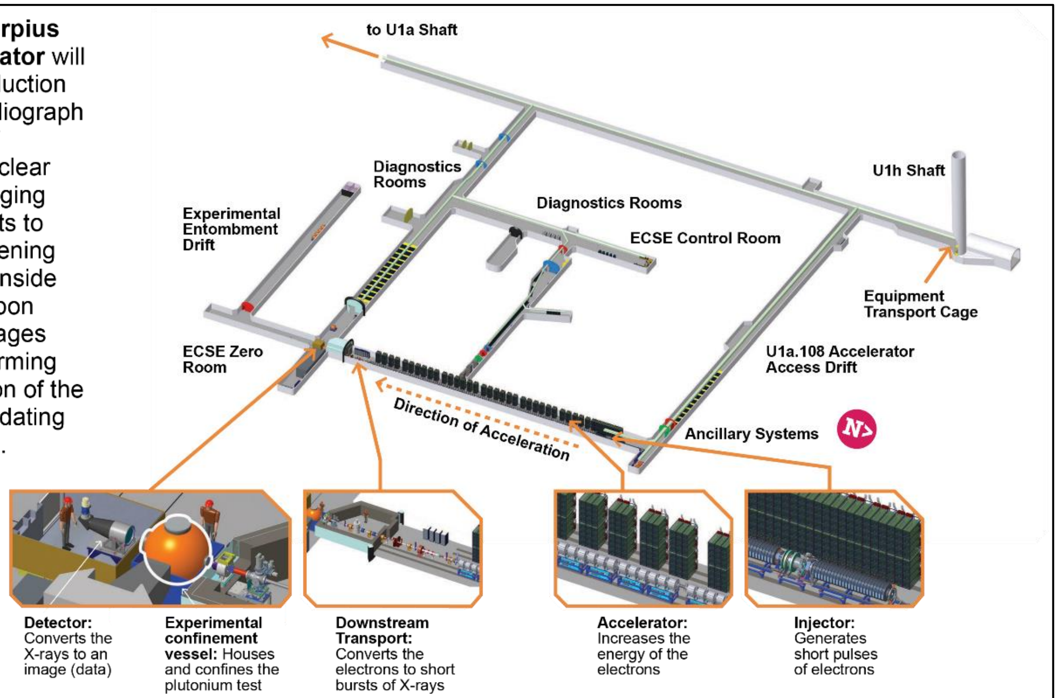


Figure 4–5. Advanced Sources and Detectors "Scorpius" Layout at U1a Complex

program to establish a robust, forward-leaning effort that considers potential future needs and investigates design concepts for potential new technologies. These efforts improve understanding of how manufacturing processes and subsequent material properties affect performance, which in turn help identify flexible capabilities to produce parts with better efficiency, reliability, flexibility, and control.

4.3.1.2 Challenges and Strategies for Assessment Science

Table 4–1 provides a high-level summary of Assessment Science challenges and the strategies to address them.

Table 4–1. Summary of Assessment Science challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
Meeting Evolving Stockpile Requirements for Nuclear Deterrence Stewardship must provide the tools to promptly assess performance issues, including SFIs, aging, and evolving threat environments to underwrite the surety and effectiveness of the stockpile without underground nuclear tests.	Provide capabilities to support stockpile assessments, LEP reuse, and surety decisions. Achieve a robust understanding of weapons' physics supported by a full range of experiments, including boost; radiation transport; hydrodynamics; plasma, nuclear, and material properties; and platform and diagnostics development. Conduct subcritical experiments to inform LEP options, assess aging effects, inform safety choices, provide needed data on the hydrodynamics of implosions, and underwrite stockpile performance.	Conduct experiments and analyses to resolve the principal remaining uncertainties to achieve a predictive capability. Enhance efficiencies in experimental operations to reduce fielding time and number of experiments required for assessment and certification. Establish domestic and global partnerships to leverage strategic scientific investments to realize capabilities.

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Modernizing Through Science and Engineering Improve our understanding of how material aging and manufacturing processes affect system performance to identify material replacement requirements and flexible capabilities to produce parts with better efficiency, reliability, flexibility, and control.	Understand the effects of aging (in particular, aging plutonium) on weapon performance through execution of the National Plutonium Aging Strategy, studies on aging, canned subassemblies, and evaluations of new materials and processes through Production Science partnerships on plutonium, uranium, HE, and non-nuclear materials. Deliver high-pressure materials property data at weapon-relevant regimes to understand how the manufacturing process and the subsequent material structure and properties affect performance to enable the broader enterprise to quickly adopt new technologies and improve material tolerances to increase efficiency of production. Deliver world-class experimental capabilities to support hydrodynamic testing, dynamic plutonium experiments, nuclear science, materials' characterization, and HED physics.	Invest in production-oriented R&D testbeds to accelerate evaluation of cutting-edge technologies for the production mission.
Prepare for an Uncertain Future The 21st century threat environment is evolving rapidly; accurate assessment of the effect of these threats and development of mitigation options are key to a resilient U.S. nuclear deterrent. A responsive R&D enterprise includes the development of options for LEPs, modern replacements, and tailored deterrence options that are certification-ready.	Invest in a core suite of flexible experimental capabilities that enable access to weapons-relevant regimes at a variety of scales from small focused to large integrated experiments that provide weapon designers with the capabilities required to respond to a rapidly evolving threat environment.	Deliver certification-ready options for LEPs and the future stockpile to inform down-select decisions. Enable assessment and certification of these options via sufficient range of experiments. Increase coordination with other Government stakeholders to consider how potential new technology concepts would affect the strategic deterrence balance.

4.3.2 Engineering and Integrated Assessments

The Engineering and Integrated Assessments Program is responsible for ensuring system-agnostic survivability in present and future STSs and ensures a responsive nuclear deterrent through collaborative partnerships, proactive integration, and assessments. This program supports four key mission areas (1) strengthening the science, technology, and engineering base by maturing advanced technologies for insertion in future weapon modernizations; (2) providing tools for qualifying weapon components and certifying weapons without nuclear explosive testing; (3) supporting annual stockpile assessments through improved weapons surveillance technologies and warhead component aging assessments; and (4) providing capabilities that accelerate the nuclear weapons acquisition process and strengthen the ability of the United States to respond to unexpected developments that could threaten nuclear security. Engineering and Integrated Assessments subprogram linkages to Weapons Activities are shown in **Figure 4–6**.

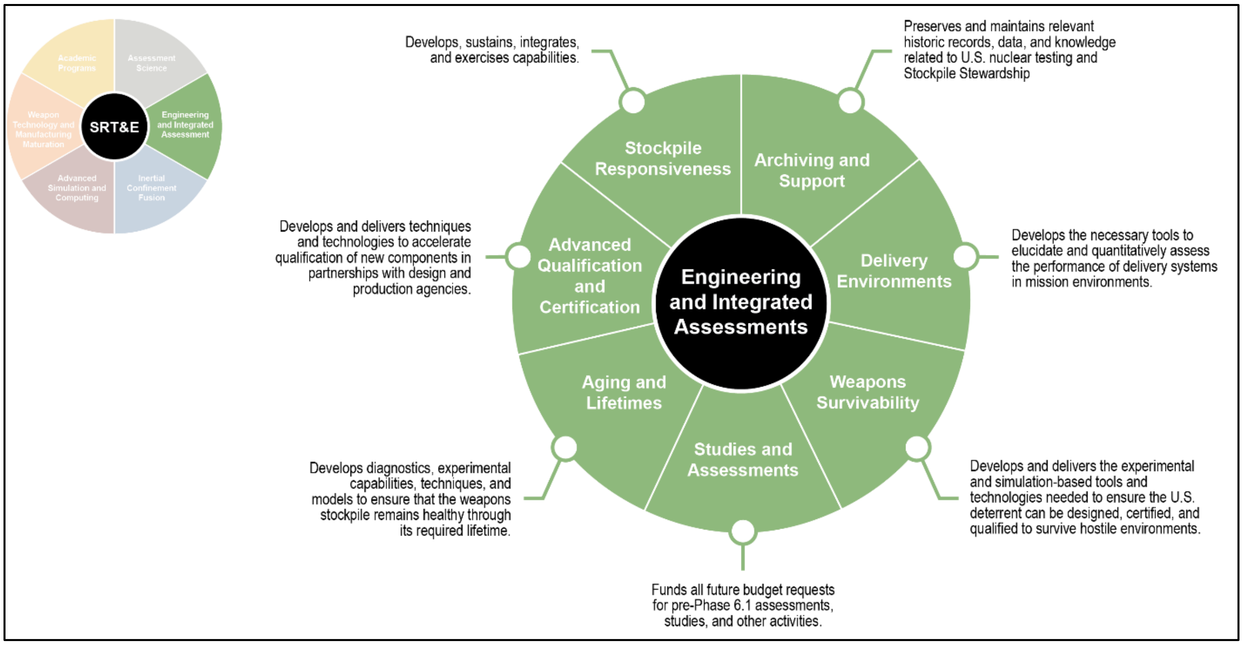


Figure 4–6. Engineering and Integrated Assessments linkages to Weapons Programs

Archiving and Support preserves and maintains relevant historic records, data, and knowledge related to U.S. nuclear testing and Stockpile Stewardship, providing targeted studies, independent reviews, and multi-system assessments that support the annual assessment process. It maintains program management and the infrastructure needed to support R&D capabilities and activities across the enterprise.

Delivery Environments ensures weapon survivability in normal and abnormal environments for future and current stockpile to target sequences. In doing so, the Delivery Environments Program predicts and models system responses to future environments and delivery platforms while addressing failure and survivability margins. The Delivery Environments Program works closely with interagency partner such as DoD and the Intelligence Community to support informed mission execution.

Weapons Survivability develops and delivers the experimental and simulation-based tools and technologies needed to ensure the U.S. nuclear deterrent now and into the future can be designed, certified, and qualified to survive hostile environments. The scope includes developing scientific and engineering models for understanding radiation effects; improving laboratory radiation sources and diagnostics to support code validation and hardware qualification experiments; generating experimental data to validate scientific and engineering models; understanding radiation-hardened design strategies; and evaluating candidate and evolving stockpile technologies for radiation hardness capabilities in a generalized, weapon-relevant configuration.

Studies and Assessments funds all future budget requests for Phase One weapon development and scoping study activities, including the current Sea-Launched Cruise Missile study, Analyses of Alternatives, cost estimation, and schedule development.

Aging and Lifetimes develops diagnostics, experimental capabilities, techniques, and models to predict the effects of weapon aging and ensure the weapons stockpile remains healthy through its required lifetime. It provides insight on the chemical compatibility of reused legacy materials and components with new materials introduced to modernization programs in non-nuclear components and materials, HE in the nuclear explosive package, plutonium for pits, canned subassemblies and cases, and polymers and adhesives in the nuclear explosive package systems.

Advanced Certification and Qualification (ACQ) develops tools and methods to ensure that there is a certification path for stockpile systems and components in the absence of additional nuclear explosive testing. It does this by integrating computing, science, technology, and engineering advancements to facilitate certification of future life extensions and other warhead needs. ACQ has moved from understanding the certification basis for the legacy stockpile to developing certification methodologies for the evolving stockpile, including planned LEPs and potential future systems. Further, ACQ is exploring alternative paths to the qualification of components and systems to accelerate the introduction of newly developed technologies into LEP planning.

Stockpile Responsiveness develops and exercises 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, and strengthens integration between DoD and DOE/NNSA. This program explores the art of the possible by using potential responses to future threats to explore the acceleration of design, engineering, testing, production, and qualification methodologies that could increase responsiveness of the nuclear weapons complex. Detailed information on the Stockpile Responsiveness Program can be found in Appendix D of the SSMP.

4.3.2.1 Status

The tools, technologies, methods, and data developed within the Engineering and Integrated Assessments Program ensure the viability and success of ongoing modernization programs and the rapid certification and qualification of future weapon systems. Success depends on diverse, highly qualified staff throughout the complex; close coordination and cooperation between weapon designers, weapon engineers and production agencies; partnerships with ongoing modernization and surveillance programs, and close coordination with the programmatic and technical efforts ongoing throughout the SRT&E portfolio.

The program continues to rapidly increase access to historical records and data that are imperative for the certification of new weapon designs without the benefit of underground nuclear testing by indexing and digitalizing existing records. In concert, the program continues to expand experimental and diagnostic capabilities to collect data that inform models being developed for lifetime predictions and ensure the survivability of weapon systems due to technical advancements of U.S. adversaries.

As the United States begins potentially exploring new weapon capabilities, the nuclear security enterprise will be undertaking the first new weapon development program since the end of the Cold War through the W93’s Concept Assessment Phase.

To ensure the success of new acquisition programs and reduce the associated time and cost, the Engineering and Integrated Assessments Program is developing methodologies, computational tools, and technology development capabilities to advance the technical readiness and manufacturability of weapon systems and components. These include ground and flight testing capabilities; tools to improve combined environment testing; facilities to evaluate hostile radiation exposures; quantification of uncertainties for engineering models; digital design; engineering and manufacturing tools; embedded sensing; and diagnostics. All of these will be available to the next generation of weapon designers and engineers.

4.3.2.2 Challenges and Strategies for Engineering and Integrated Assessments

Table 4–2 provides a high-level summary of Engineering and Integrated Assessments challenges and the strategies to address them.

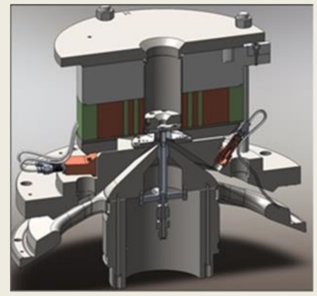
Table 4–2. Summary of Engineering and Integrated Assessments challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Experienced nuclear weapon design and production agency personnel, some going back to the underground nuclear test era, are leaving the workforce. Transferring knowledge and skills from one generation to the next must be done in the coming few years before staff turnover is complete.	Execute the Archiving and Data Management Program responsible for the preservation of knowledge and expertise derived from U.S. nuclear testing, Stockpile Stewardship efforts following the testing moratorium, and making past, present and future collections accessible to the nuclear security enterprise workforce of today and tomorrow. Stockpile Responsiveness exercises will be used to develop expertise outside of the programs of record to address challenges and problems posed by DoD.	Complete archiving of national laboratory and production agency holdings in ways that make information searchable and useful for future stockpile stewards. Conduct design/build/test cycles to exercise joint design and production agency teams outside of the modernization programs.
The nuclear weapon stockpile is aging and made of materials that may no longer be produced or are hazardous to handle. Newly produced weapons have anticipated lifetimes measured in decades.	Execute the Aging and Lifetimes program to develop non-destructive evaluation (increase data on weapon materials of interest) to minimize effects to the stockpile, analyze materials of interest to modernization and surveillance stakeholders, and leverage relationships with other DOE/NNSA programs to obtain data and information as needs arise.	Establish a robust effort on embedded sensing to provide an opportunity to mitigate risks in a rapidly changing environment.
Environments associated with nuclear explosions cannot be completely replicated in the laboratory, and the number of nuclear tests that the United States conducted to understand these environments is of diminishing relevance.	Determine weapon material effects by developing improved radiation and hostile environment experiments across a range of reactor, explosive, and HED facilities, improving testing, modeling, and simulation capabilities and developing technologies and system designs for enhanced survivability in evolving environments.	Establish a combined radiation effects experimental capability to provide a basis for high fidelity modeling and simulation.
Aging equipment, facilities, and infrastructure used to simulate the environments nuclear weapons experience (normal, abnormal, hostile, and combined environments) may not be sufficient to meet future STS needs.	Expand investment in new and existing test and experimentation facilities to support the current and future stockpile. Fill the gap between what modeling and simulation can accomplish today with what it needs to do tomorrow, to include experimental validation and verification.	Develop modeling, simulation, and experimental capabilities to assess warhead performance as delivered.

4.3.3 Inertial Confinement Fusion

The ICF program delivers HED capabilities and expertise that support research and testing in the laboratory of materials and radiation under the extreme conditions produced inside a detonating nuclear weapon. Its twofold mission is to meet immediate and emerging needs for HED data on materials and properties under HED conditions to support the deterrent of today and advance the R&D capabilities necessary to meet those needs for the deterrent of the future. The ICF program enables access to and data delivery from the HED regime through: (1) the design and execution of complex physics experiments to improve our integrated, as well as, fundamental understanding of properties and processes in the HED regime; (2) the development of instrumentation to diagnose physics phenomena at the extreme temperature, pressure, and density conditions relevant to nuclear weapons performance; and (3) the development and operation of experimental facilities capable of reaching those conditions.

The ICF program leverages its experimental design expertise, computational modeling capabilities, diagnostic technology, target engineering and fabrication infrastructure, and national HED facilities to ensure high-fidelity experimental capabilities and data are available to support a range of DOE/NNSA missions. Its capabilities are used by program partners to assess and certify the existing stockpile, inform design decisions for current LEPs, investigate hostile nuclear environments, and support DoD research.



Cutaway Diagram – Z Beamlet Transport Tube

Key technologies developed and maintained at the national security laboratories for ICF and HED/pulsed power weapon science applications have been combined in recent experiments to achieve a record-breaking, order-of-magnitude increase in neutron output on Z, a key standard by which fusion efforts are judged. By combining ICF and magnetic confinement fusion technologies, researchers have made giant strides towards one day, on an appropriate facility, reaching multi-Mega Joule fusion yields in the laboratory, a critical capability for science driven stockpile stewardship.

The ICF program supports DOE/NNSA's long-term R&D mission by developing the knowledge and capabilities necessary to reach controlled thermonuclear fusion in the laboratory. Reaching a burning plasma[3] platform and eventually producing high fusion yield[4] will open the door to a range of important weapons physics that has been unreachable since the cessation of underground nuclear testing, with significant knowledge and capability development at each step along the path from burning plasma to ignition and high yield. This is among DOE/NNSA's most high-risk, high-reward research efforts; not only does it attract, train, and challenge some of the Nation's best physicists and engineers, it also represents an important component of DOE/NNSA's preparation to meet the stockpile science challenges of the 2030s and beyond. ICF subprogram linkages to Weapons Activities are shown in **Figure 4–7**, followed by brief subprogram descriptions.

HED and Ignition Science for Stockpile Applications supports R&D in HED physics and maintains global preeminence in HED science by identifying, maturing, and delivering next-generation tools and experimental platforms to enable weapons science studies. It addresses immediate and future weapon science needs by developing platforms and delivering data for current certification and qualification efforts and prepares for future capability needs through advanced platform development. It pursues thermonuclear fusion and eventual high yield to provide access to weapons phenomena and energy densities that have been inaccessible since the cessation of underground testing. The subprogram develops expertise and tools for partner programs to experimentally measure dynamic material properties, fluid and plasma hydrodynamics, hydrodynamic instability-induced mix, burn, boost, and radiation transport. It produces unique environments relevant to nuclear weapon outputs and hostile radiation conditions.

ICF Diagnostics and Instrumentation establishes new diagnostics, experimental capabilities, and support systems for use at the national HED facilities to execute experiments studying matter under extreme HED conditions. It develops and deploys transformational diagnostics, such as two-dimensional high-resolution velocimetry and time-resolved neutron spectrometry, to acquire high-fidelity data during HED experiments. It also leverages advanced neutron and fast X-ray diagnostics from the National Ignition Facility (NIF), engineering them for enhanced capabilities within the Z environment.

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[3] A burning plasma is one in which most of the plasma heating comes from fusion reactions involving thermal plasma ions. A plasma enters what scientists call the *burning plasma regime* when the self-heating power exceeds any external heating (DOE Office of Science website).

[4] High fusion yield is a release of fusion energy in excess of 100 megajoules from an ICF target. This is three orders of magnitude greater than today's best performing experiments.

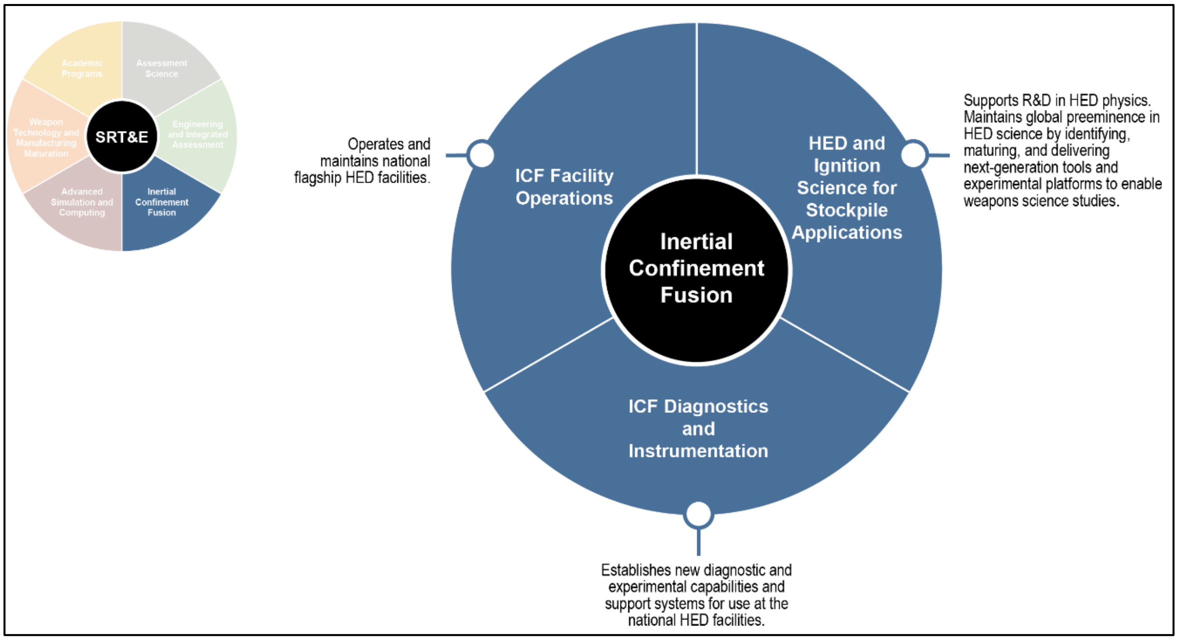


Figure 4–7. Internal Confinement Fusion linkages to Weapons Activities

ICF Facility Operations operates and maintains national flagship HED facilities and conducts R&D for long-term sustainment of facilities and capabilities.

4.3.3.1 Status

The ICF program is rebalancing its experimental portfolio to incorporate the findings and recommendations of two studies that were completed in FY 2020. DOE/NNSA's ICF 2020 review assessed the program's proximity and scaling to ignition, and the congressionally mandated JASON Defense Advisory Group review assessed the ICF program's value to the stewardship mission. These studies reaffirmed the enduring need and value of HED and ignition research and concluded that the ignition threshold may be beyond current experimental capabilities. Recommendations included a research program focused on resolving key gaps in physics understanding to optimize scientific progress over the next decade. Taking these recommendations into account, the enduring priorities of the program are to enhance and deliver the HED capabilities needed to create and diagnose weapons-relevant conditions so that they may be used to address challenges in the nuclear modernization, assessment, and survivability missions, as well as to produce controlled thermonuclear fusion in the laboratory to meet the stockpile science challenges of the 2030s and beyond.

HED flagship facilities are crucial to DOE NNSA's mission to ensure the reliability and safety of our current and future nuclear stockpile. The facilities allow scientists to study materials and processes under conditions similar to those produced by the detonation of a nuclear weapon. They also produce key data used to validate physics models in computer simulations.

The National Ignition Facility (NIF) generates temperatures of more than 180 million degrees Fahrenheit and pressures of more than 100 billion Earth atmospheres, causing hydrogen atoms in the target to fuse and release energy in a controlled thermonuclear reaction.

The Z machine uses high magnetic fields associated with electrical currents to produce high temperatures, high pressures, and powerful X-rays for research in high energy density science.

The OMEGA laser delivers pulses of energy to targets and measures the resulting nuclear and fluid dynamic events.

DOE/NNSA's Flagship High Energy Density Facilities

4.3.3.2 Challenges, and Strategies for Inertial Confinement Fusion

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

Table 4–3. Summary of Inertial Confinement Fusion challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	***Future Strategies Needed***
Enable Sustainment and Modernization by Providing Access to Timely Experimental Data Assessment, certification, LEPs, and Mods require access to high fidelity experimental data at extremes of pressure and temperature to promptly address performance issues, resolve SFIs, and inform design decisions in the absence of underground nuclear tests.	Execute experiments targeting key aspects of material properties and complex hydrodynamic flows in the HED regime using novel diagnostics to acquire data that benchmarks our models of the behavior between radiation and materials. Provide intense X-ray and neutron sources that can be used to support the design and qualification of components of U.S. systems to meet nuclear survivability requirements.	Develop and pursue an integrated investment strategy to sustain existing HED capabilities and provide ongoing and timely access to experimental HED needs by the program of record.
Meet Evolving Stockpile Requirements for Nuclear Deterrence Stewardship must invent and provide the tools to promptly assess performance issues, including SFIs, aging, and evolving threat environments to underwrite the surety and effectiveness of the stockpile without underground nuclear tests.	Pioneer new diagnostic technologies, experimental platforms, and analytical tools to meet emerging assessment needs by making new and higher fidelity data available in HED regimes of interest.	Develop new driver technologies and facility capabilities to provide access to energy densities necessary to emerging radiation effects and assessment science needs.
Modernizing Through Science and Engineering Improve our understanding of how material aging and manufacturing processes affect system performance to identify material replacement requirements and flexible capabilities to produce parts with better efficiency, reliability, flexibility, and control.	Execute focused materials experiments at HED facilities to provide precision data on material properties at regimes that were previously only accessible by theory or models to enable future assessments and certification of device performance in the absence of underground nuclear tests.	Generate the full range of nuclear weapon environments within experimental facilities, including sustainment and development of existing Office of Experimental Sciences facilities to reach the critical portions of the weapons physics parameter space, investment in next-generation facilities to reach weapons physics regimes beyond current capabilities, and development of novel facility instrumentation and advanced diagnostics to measure within these regimes with high fidelity.
Prepare for an Uncertain Future The 21st century threat environment is evolving rapidly; accurate assessment of the effect of these threats and development of mitigation options are critical to a resilient U.S. nuclear deterrent. A responsive R&D enterprise includes the development of options for LEPs, modern replacements, and tailored deterrence options that are certification ready.	Develop an ignition platform to achieve controlled thermonuclear fusion in the laboratory that access a range of important weapons physics phenomena that have been unreachable since the cessation of underground testing to enable new design and certification capabilities.	Develop HED capabilities to address potential changes in STS environments (i.e., outputs and effects, thermal and mechanical environments), including development of experimental capabilities required for assessments, with increasingly more realistic source environments.

4.3.4 Advanced Simulation and Computing

The ASC program provides high-end simulation capabilities (e.g., modeling codes, computing platforms, and facility operational infrastructure) to meet the requirements of the Stockpile Stewardship Program. Modeling the complexity of nuclear weapons systems is essential to maintaining confidence in the performance of our stockpile without additional nuclear explosive testing. The ASC program provides the weapon codes that provide the integrated assessment capability supporting annual assessment and future sustainment program qualification and certification of the stockpile. It is a foundational capability that underscores the Stewardship Capability Delivery Schedule described in Section 4.2.1. ASC provides critical capabilities that help inform decision-making related to the sustainment of the nuclear stockpile in support of U.S. national security objectives and develops the toolkit to integrate measured data and scientific understanding. While the focus remains on the U.S. nuclear weapons program, the program also enables the use of HPC and simulation tools to support nonproliferation, emergency response, nuclear forensics, attribution activities, and many DoD non-nuclear missions, coordinating within NNSA and with many other Government agencies, including the Intelligence Community.

Lawrence Livermore National Laboratory has installed a new artificial intelligence accelerator into the Corona supercomputing cluster, allowing DOE/NNSA laboratory researchers to run scientific simulations for ICF and other high fidelity physics models very efficiently. The accelerator communicates with applications running on standard Corona nodes to train machine-learned models. These machine-learned models can then be employed in other simulations to efficiently replicate the original models. Initial results have indicated fivefold or more increases in processing speeds.

The ASC computing capabilities are the key integrating mechanism across the nuclear weapons program through the Integrated Design Codes (IDCs), which contain mathematical descriptions of the physical processes of nuclear weapons systems and functions. These IDCs use weapon-specific data as input to high-fidelity physics models that simulate performance and safety behaviors. The output is used to carry out design studies, maintenance analyses, annual assessment reports, sustainment and modernization programs, SFIs, and weapons assembly and dismantlement activities – all without additional nuclear explosive testing. The IDCs currently perform well for general mission-related activities. However, issues such as aging, potential new threats, and new manufacturing techniques require IDCs with enhanced-fidelity physics models that are able to leverage the latest technologies in HPC. This has driven the need to adapt current integrated design codes and build new codes to efficiently utilize the hardware capabilities anticipated in next-generation HPC systems.

ASC subprograms link to Weapons Activities as shown in **Figure 4–8** below, followed by brief subprogram descriptions.

Integrated Codes produces large-scale, validated IDCs that allow the performance of detailed nuclear weapons assessments without the need for additional explosive nuclear testing. IDCs and science codes are used for physics and engineering stockpile assessments to support concept studies, certification, maintenance analyses, LEPs, Alts, SFIs, and weapons dismantlement activities. This subprogram represents a repository of knowledge gained from experiments on DOE/NNSA's wide range of facilities, legacy nuclear explosive tests, and enhancements made to support the Stockpile Management program. It enables nuclear forensics, foreign assessments, and device disablement techniques related to nuclear counter-terrorism efforts and the study of nuclear weapons behavior in normal, abnormal, and hostile environments. The Integrated Codes subprogram is responsible for maintaining selected legacy codes and ancillary tools that support the weapons mission. It provides validated simulation capabilities that cover all of the relevant physics and maximize performance on existing and future computing architectures.

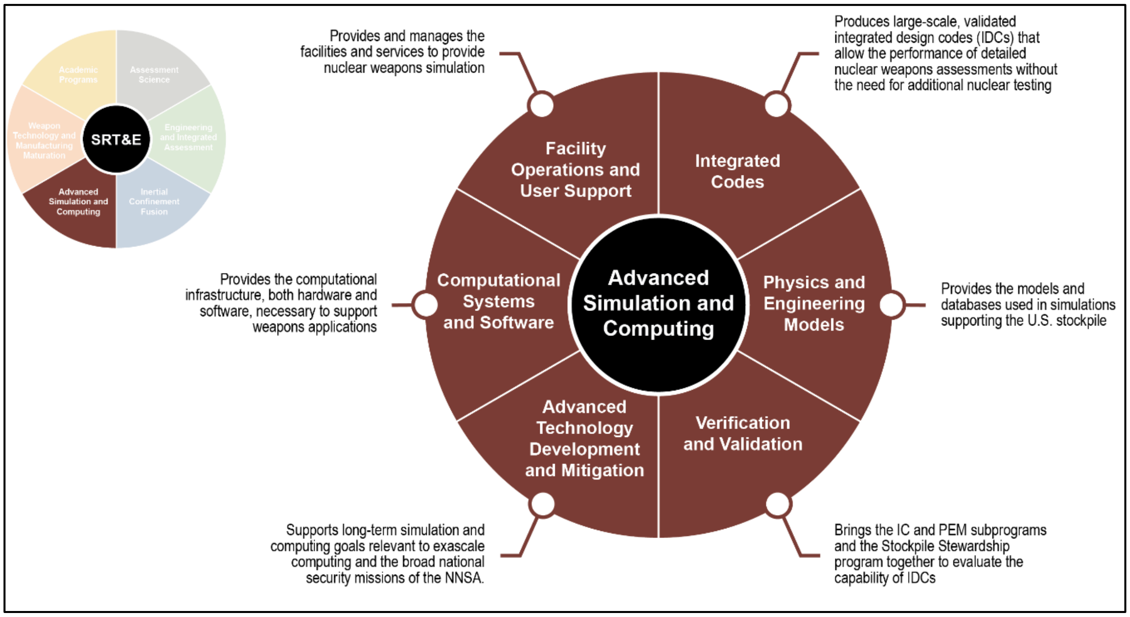
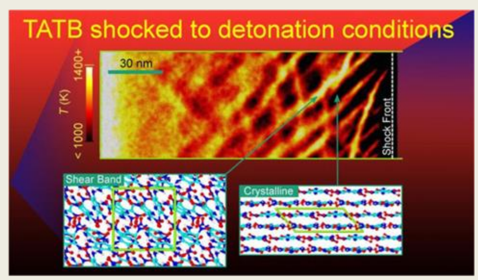


Figure 4–8. Advanced Simulation and Computing Linkages to Weapons Programs

Physics and Engineering Models provides the models and databases used in simulations supporting the U.S. stockpile. Models describe a wide variety of physical and engineering processes occurring in a nuclear weapon life cycle and are required for annual assessment; design, qualification, and certification of warheads in the stockpile; resolution of SFIs; and development of future stockpile technologies. The Physics and Engineering Models subprogram is closely linked to the Assessment Science program.

Verification and Validation brings the Integrated Codes and Physics and Engineering Models subprograms and the Stockpile Stewardship Program together to evaluate the capability of IDCs. It ensures that both science codes and IDCs are solving the equations accurately and that the models themselves are sufficiently precise for the intended application. It provides a technically rigorous and credible foundation for computational science and engineering calculations. The subprogram develops, exercises, and implements tools that provide confidence in simulations of high-consequence nuclear stockpile problems; ensures the integrity of modified and new codes that address major modifications to the stockpile; and exercises critical skills to support high levels of confidence in the future.



Advanced Modeling of Explosive Phenomena Reveals Complex Behaviors in TATB

Scientists have discovered a new mechanism for ignition of high explosives that explains the unusual detonation properties of triaminotrinitrobenzene (TATB), a form of insensitive high explosive. Current models revealed discrepancies between initiation and detonation regimes, indicating a gap in understanding of the underlying physics, specifically in the localized performance of materials under extreme stress. Scientists turned to quantum-based molecular dynamics simulation approaches and HPC and found an explanation for the gap in understanding of the models.

Advanced Technology Development and Mitigation includes projects that support long-term simulation and computing goals relevant to exascale computing and the broad national security missions of the DOE/NNSA and builds new IDCs aligned with emerging technologies to rapidly respond to the architectures of the future. It addresses three major challenges: responding early on to the radical shift in computer architectures; maintaining current IDCs; and adapting current capabilities as evolving computer technologies become increasingly disruptive to the broad national security missions of DOE/NNSA.

This subprogram focuses on long-term investment in Next-Generation Code Development and Application, Next-Generation Architecture, and Software Development and Interagency Co-Design.

Computational Systems and Software Environment builds integrated, balanced, and scalable computational capabilities and provides the stability to ensure productive system use and protect DOE/NNSA's investment in IDCs. It takes software developed by the Advanced Technology Development and Mitigation subprogram, reduces vulnerabilities by reducing the number of points at which an unauthorized user can enter or extract data, a process otherwise known as hardening, and prepares the software for larger-scale use in the ASC computing environment. It tracks future technologies beyond exascale – such as quantum, neuromorphic, and non-complementary metal-oxide-semiconductor-based computing techniques – and deploys testbeds for evaluation of potential hardware benefits to DOE/NNSA applications. It also provides the computational infrastructure, both hardware and software, necessary to support weapon applications.

Facility Operations and User Support provides and manages the facilities and services required to provide nuclear weapons simulation, including physical space, power, cooling and other utility infrastructure; local area/wide area networking for local and remote access; system administration; cybersecurity; and operations services. The subprogram also provides computer center hotline and help-desk services, account management, web-based system documentation, system status information tools, user training, trouble-ticketing systems, common computing environment, and application analyst support.

4.3.4.1 Status

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

HPC platforms are also evolving in response to the computer industry's movement toward heterogeneous computing, in which accelerators, such as graphics processing units, are combined with traditional central processing units to grow computing capacity. Recognizing the challenge that this evolution presents to current IDCs, several years ago DOE/NNSA started to design and develop a new generation of IDCs, requiring new capabilities in numerical methods, software design, and adaptable programming models to optimize the use of these emerging HPC technologies. The ASC program continues this work in preparation for DOE/NNSA's first exascale system, El Capitan, to be deployed at Lawrence Livermore National Laboratory (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 its own missions.

In addition to utilizing heterogeneous architectures, the computing industry has evolved new technology paradigms that are more energy efficient and have developed artificial intelligence and cognitive simulation (Cog-Sim) capabilities and infrastructure that greatly magnify the capabilities of traditional simulation. In response, the ASC program has introduced an Advanced Machine Learning Initiative to expand the use of artificial intelligence or Cog-Sim capabilities to better manage complexity in physics-informed simulations. This initiative will significantly increase efficiency, improve models to better match experimental data, and tighten the integration of multi-scale and multi-dimensional models, while addressing concerns with validation of these techniques and improved understanding of when new errors are introduced. The ASC program is driving efficiencies into the manufacturing process through ASC's Production Simulation Initiative. Efforts such as the Simulation First or "SimFirst" initiative at the Kansas City National Security Campus incorporates physics-based simulation into production operations to optimize solutions prior to full-scale manufacture.

As levels of detail increase in simulation codes, especially those with three-dimensional (3D) features, run times to reach solution increase dramatically. This presents an increasing challenge in providing timely support for mission and experimental needs. To address this challenge, DOE/NNSA continues to follow its clearly defined strategy of upgrading HPC platforms at regular intervals; however, evolution of these platforms creates increased demand on supporting infrastructure. Power, cooling, and mechanical requirements have grown dramatically with the introduction of exascale computing and are being addressed through minor construction projects and construction line items. The Exascale Computing Facility Modernization project is an example of such a construction line item that will upgrade the LLNL computing facility with increased power and cooling capability in preparation for the El Capitan system and subsequent exascale-class architectures. It will provide sufficient cooling and power to allow initial installation, as well as necessary overlap of the systems as they are sited and decommissioned. The nuclear security enterprise will continue to manage and coordinate code development and facility upgrades with system acquisitions to allow the use of HPC platforms for DOE/NNSA as the technology progresses into the exascale era.

4.3.4.2 Challenges and Strategies for Advanced Simulation and Computing

Table 4–4 provides a high-level summary of ASC challenges and the strategies to address them.

Table 4–4. Summary of Advanced Simulation and Computing challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
The changing stockpile is evolving away from as-tested designs through aging and LEPs.	Work with Stockpile Management, Assessment Science, Engineering, and Integrated Assessments, and Weapons Technology and Manufacturing Maturation programs to understand the physics of these changes, establish requirements, and continue efforts to improve modeling.	
The threat space is evolving, for which weapons must now be certified.	Coordinate with customers through the *Nuclear Posture Review* implementation to understand the new needs for threat response and to respond with credible simulation capabilities.	

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Improving the rate at which new modeling and simulation capabilities are provided to the Stockpile Major Modernization and Stockpile Sustainment programs. Enhancing the ability to simulate the effects of weapons effects, aging, and manufacturing changes.	Develop and implement a broader range of tools for rapid design, evaluation, and qualification of new materials. Develop models and databases in conjunction with experiments to improve the performance, reliability, and safety of weapons. Adapt weapon science codes to the most advanced computing architectures to reach time and spatial scales of greatest interest. Run IDCs and supporting codes on more powerful platforms to allow quicker time-to-solution for applications of simulation enhancements.	
Performing rapid evaluations of new materials and modeling additive manufacturing techniques requires advanced simulations.	Continue current efforts to model additive manufacturing processes and couple these with molecular dynamics and mesoscale modeling to enhance their utility. Develop machined-learned techniques that can capture these effects efficiently for routine use in part-scale simulations.	
Working with IDCs that are not effectively using advances that have emerged in commercial HPC architectures. Maintaining operation of current IDCs to deliver on near-term needs, while preparing the IDCs for future computing architectures.	Optimize current codes for advanced technology hardware.	Evolve HPC tools for a next generation of IDCs to achieve sophisticated programming models, software designs, and numerical algorithms. This will produce a more responsive simulation capability that responds more rapidly and efficiently to challenges.
Supporting exascale platforms with insufficiently structured and sized facilities and supporting infrastructure (space, power, and cooling).	Continue to execute the ASC platform strategy. Continually survey HPC vendors' facility requirements, identify gaps, and proceed with modernization or new infrastructure solutions to meet the utility demands of HPC.	

4.3.5 Weapon Technology and Manufacturing Maturation

The Weapon Technology and Manufacturing Maturation program is responsible for developing agile, affordable, assured, and responsive technologies and capabilities for nuclear stockpile sustainment and modernization to enable Defense Programs' mission success and the future success of the nuclear security enterprise.

Primary responsibilities of this program include:

- Developing enhanced technologies that both minimize the probability of unauthorized use and maximize reliability for authorized use;

- Lead technology and system demonstration efforts, with various mission partners, to speed development and improve acceptance of advanced technologies and processes into the stockpile and nuclear security enterprise; and
- Improve agility, effectiveness, safety, and efficiency in the design and manufacture of War Reserve components.

The Weapon Technology and Manufacturing Maturation program comprises three subprograms, whose elements and linkages are illustrated in **Figure 4–9**.

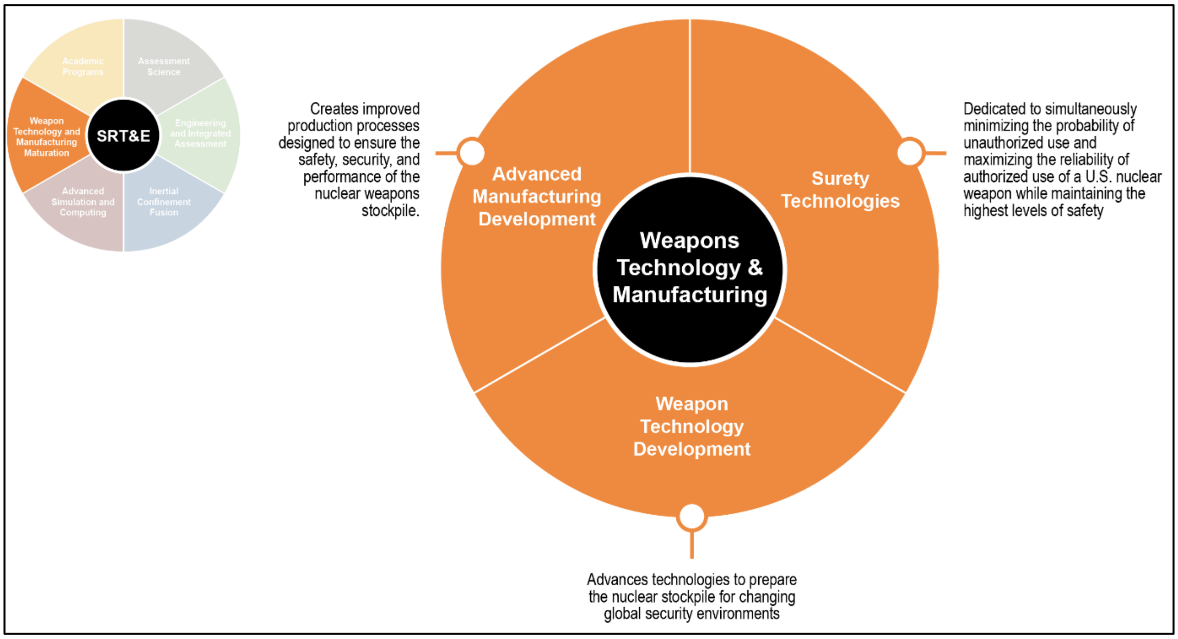


Figure 4–9. Weapon Technology and Manufacturing linkages to Weapons Programs

Surety Technologies is dedicated to simultaneously minimizing the probability of unauthorized use and maximizing the reliability of authorized use of a U.S. nuclear weapon while maintaining the highest levels of safety. Surety Technologies creates, develops, and matures advanced safety, security, and use-control or denial technologies to minimize the probability of an accidental nuclear explosion, given exposure to an abnormal environment. In the unlikely event that security fails and unauthorized access is gained, the technologies developed by this subprogram reduce the risk of an unauthorized nuclear yield to the lowest possible level.

Weapon Technology Development seeks to achieve an effective nuclear deterrent through proactive design and development of innovative weapon technologies. It develops technology insertion options to prepare the nuclear stockpile for changing global security environments and advances technologies from concept to a viable option ready for transition to a program of record.

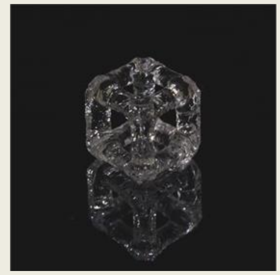
Advanced Manufacturing Development designs, develops, demonstrates, and transitions improved production processes, including tools, fixtures, parts, and materials designed to ensure the safety, security, and performance of the nuclear weapons stockpile. This development work benefits the nuclear security enterprise while maintaining the base capability to respond to emerging issues with the current stockpile and adapting new processes for follow-on use, with the objective to provide significant reductions in production time, material waste, and floor space. In accomplishing its mission, this program enables DOE/NNSA to meet DoD requirements while enhancing safety and security and remaining vigilant and responsive to evolving national security requirements.

4.3.5.1 Status

The tools, technologies, methods, and data developed within the Weapons Technology and Manufacturing Maturation Program ensure the viability and success of ongoing modernization programs and the implementation of advanced manufacturing techniques that streamline production. Success depends on diverse, highly qualified staff throughout the complex; close coordination and cooperation between weapon designers, weapon engineers and production agencies; partnerships with ongoing modernization programs, and close coordination with the programmatic and technical efforts ongoing throughout the SRT&E portfolio.

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. The themes of this plan are laid out in **Figure 4–10** and cover additive manufacturing, automation, intelligent production systems, and manufacturing processes to reduce production time, waste, and floor space requirements. Efforts across these themes directly improve the agility and responsiveness of DOE/NNSA's manufacturing infrastructure and 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.

Volumetric Additive Manufacturing (VAM)



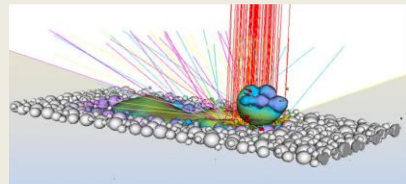
A complex structure in thiol-ene resin using VAM

VAM is a new technology that can complete 3D objects in a single photocuring operation without layering defects, enabling 3D printed polymer parts with mechanical properties similar to bulk material counterparts. DOE/NNSA researchers recently demonstrated the application of VAM using a focused 3D light source applied to a photosensitive thiol-ene-based resin, which then solidifies. Thiol-ene materials are believed to have potential for adhesives, electronics, and other weapon-relevant areas.

Figure 4–10. DOE/NNSA is pursuing advanced manufacturing areas for investments across capabilities that support a robust and resilient manufacturing capability

Emerging advanced technology solutions include an evolving, digital-based enterprise that uses 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.

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.



A laser interacting simultaneously with the melt pool and a large "spatter" of metal powder particles

This simulation shows a laser interacting simultaneously with the melt pool and a large "spatter" of metal powder particles. In this event, the laser power was above a threshold that expelled the spatter away from the scan track. This prevented formation of defects due to "laser shadowing," in which melted metal powder can block or eclipse the laser. Simulation provides clues to reduce defects in 3D printing.

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. The Weapons Technology and Manufacturing Maturation Program is developing methodologies, procedures, and technology development capabilities to advance the technical readiness and manufacturability of weapon systems and components more rapidly, which helps the nuclear security enterprise hedge against an uncertain future.

4.3.5.2 Challenges and Strategies for Weapon Technology and Manufacturing Maturation

Table 4–5 provides a high-level summary of Weapon Technology and Manufacturing Maturation challenges and the strategies to address them.

Table 4–5. Summary of Weapon Technology and Manufacturing Maturation challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Future warhead modernization efforts will require a range of components and materials to meet requirements not defined decades ahead of time.	Identify high-priority technologies in coordination with the end user and maintain frequent communication with relevant partners. Leverage resources from the United Kingdom, as authorized under the Mutual Defense Agreement, as well as other DOE/NNSA programs.	
HE and energetics need to be both safe and effective for future systems and are often challenging to produce in the quantities and qualities needed.	Collaborate with Stockpile Sustainment to continue work as planned. Continue development of alternative insensitive HE formulations based on new molecules.	Improve understanding and control over material specifications and manufacturing to increase reliability and reproducibility for higher lot acceptance.
Transitioning technology findings and benefits to other programs/end users.	Negotiate early and continually with program managers to ensure that interface requirement agreements are developed and approved, and the benefits are well understood.	
The radiation-hardened microelectronics infrastructure is aging and unsupported equipment likely will require investments to sustain the capability through 2040. This capability is needed to meet nuclear weapon requirements.	Address highest-risk infrastructure needs: already started 6- to 8-inch tool conversion to support production for future programs of record.	DOE/NNSA is addressing the strategic radiation-hardened microelectronics capability options through an Extended Life Program to sustain the capability through 2040 and beyond.

4.3.6 Academic Programs

The challenges of modernizing the nuclear stockpile demand a strong and diverse base of national expertise and educational opportunities in specialized technical areas that uniquely contribute to nuclear stockpile stewardship. The Academic Programs of SRT&E are designed to support academic programs in science and engineering disciplines of critical importance to the nuclear security enterprise, such as nuclear science, radiochemistry, materials at extreme conditions, HED science, advanced manufacturing, and HPC. The role of the Academic Programs is threefold:

- Develop the next generation of highly trained technical workers able to support its core mission.
- Maintain technical peer expertise external to the nuclear security enterprise for providing valuable oversight, cross-check, and review.
- Enable scientific innovation to enhance the nuclear security enterprise missions to strengthen the basic fields of research relevant to the DOE/NNSA mission.

Academic Programs enable diverse research and science, technology, engineering, and math (STEM) educational communities through a variety of methods of support to achieve program goals. Investments in consortia and centers of excellence assemble collaborative groups to tackle large questions through multi-disciplinary approaches and leverage preeminent scientists in the field. Research grants and focused investigatory centers support individual principal investigators to foster a vibrant community that is responsive to new breakthroughs by providing flexibility for new ideas, diversity, and career growth. Specific support to minority- and tribal-serving institutions prepares a diverse workforce of world-class talent through strategic partnerships. Fellowships provide graduate students with key opportunities to connect with DOE/NNSA missions and give participants direct experiences at nuclear security enterprise sites. User facilities open opportunities for academic partners to use DOE/NNSA's cutting-edge research facilities and push frontiers of current scientific understanding. Academic Programs comprises five subprograms illustrated in **Figure 4–11**.

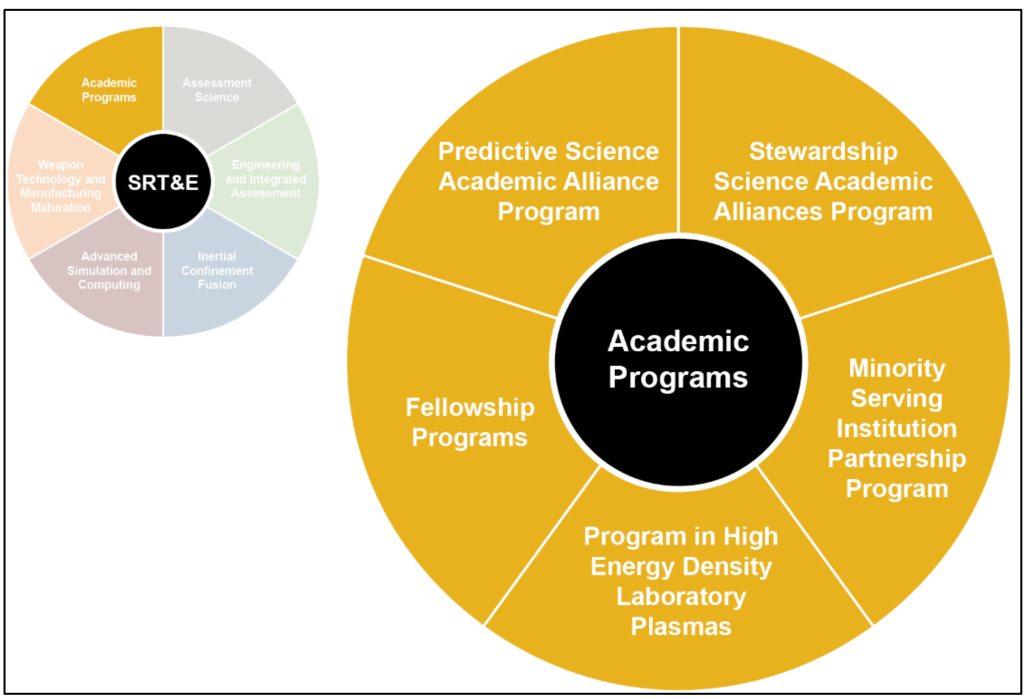


Figure 4–11. Components of Academic Programs

The **Stewardship Science Academic Alliances (SSAA) Program** supports scientific academic research programs to develop the next generation of highly trained technical workers to support its core mission and ensure a strong community of technical peers, external to the DOE/NNSA national security laboratories, who are capable of providing peer review and scientific competition to strengthen the basic fields of research relevant to the DOE/NNSA nuclear security enterprise.

SSAA funds both collaborative centers of excellence and smaller individual investigator research projects to conduct fundamental science and technology research of relevance to stockpile stewardship. Current technical areas include studies of materials under extreme conditions, low-energy nuclear science, HED physics, and radiochemistry. SSAA funding supports research at approximately 80 universities, including training of over 200 graduate students and post-doctoral researchers. A key element of both centers of excellence and individual investigator awards is the connection of students with the nuclear security enterprise. These opportunities are focused in technical fields critical to stewardship science to build a field of talented researchers and committed doctoral students sharing a common desire to advance science while affecting national security.

SSAA also funds the Stewardship Science Graduate Fellowship, the Computational Science Graduate Fellowship, and the Laboratory Residency Graduate Fellowship, with the goal of addressing workforce needs by directly connecting the highest caliber graduate students with the national security laboratories through providing financial support and ongoing scientific development opportunities to students pursuing a Ph.D. in fields of study that solve complex science and engineering problems critical to stewardship science.

DOE/NNSA's **Minority Serving Institution Partnership Program (MSIPP)** mission is to create and foster a sustainable STEM-pipeline that prepares a diverse workforce of world class talent through strategic partnerships between Minority Serving Institutions and the nuclear security enterprise. MSIPP supports Historically Black Colleges and Universities, Hispanic Serving Institutions, and Tribal Colleges and Universities. MSIPP aligns investments in university capacity and workforce development with the DOE/NNSA mission to develop the needed skills and talent for the nuclear security enterprise's enduring technical workforce and to enhance research and education capacity at under-represented colleges and universities.

This alignment is defined by the following crucial success factors:

- Strengthen and expand minority- and tribal-serving institutions' educational and/or research capacity in DOE/NNSA mission areas of interest;
- Target collaborations between minority- and tribal-serving institutions and the nuclear security enterprise

Minority-Serving Institution Partnership Program (MSIPP) 2020 Highlights

MISSION

Create and foster a sustainable STEM pipeline that prepares adiverse workforce of world-class talent through strategic partnerships.

MSIPP:

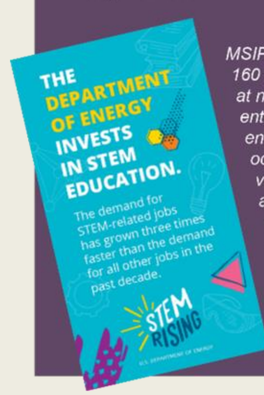
- Coordinates with **34** minority-serving institutions of higher learning in the U.S. and Puerto Rico.
- Sponsors **13** consortia that utilize the facilities and technology at DOE/NNSA's laboratories and sites.

In 2020, MSIPP:

- Supported **485** undergraduate/graduate college students and **146** faculty professional development activities.
- Sponsored **277** new courses and laboratories.
- Launched **8** new degree programs.
- Launched **9** new certificate programs.

Net result:

- More than **600** professional development activities.
- More than **200** on-campus student experiences.



MSIPP sponsored over 160 student internships at nuclear security enterprise and non-enterprise sites that occurred either virtually or remotely at NNSA sites or various institutions across the consortia in FY 2020.

that increase interactions to provide direct access to nuclear security enterprise resources for minorities and tribal citizens;

- Increase the number of minority-serving institution students who graduate with STEM degrees relevant to NNSA mission areas and have had exposure to career opportunities within the nuclear security enterprise; and
- Increase the number of minority graduates and post-doctoral students hired into the nuclear security enterprise's technical and scientific workforce.

HED states are central to many aspects of nuclear weapons; maintaining a strong HED academic community in this unique field is critical for future needs of a modern nuclear stockpile. The **Joint Program in High Energy Density Laboratory Plasmas (HEDLP)** is designed to steward the study of laboratory HED plasma physics by funding academic research of ionized matter in laboratory experiments where the stored energy reaches approximately 100 billion joules per cubic meter (i.e., pressures of approximately 1 million atmospheres).

The program has three primary elements: research grants, centers of excellence, and the National Laser User Facility Program.

- **Research Grants:** DOE/NNSA partners with DOE's Office of Fusion Energy Sciences to issue an annual joint solicitation for HED Laboratory Plasmas research. The coordination across agencies enables the support of a strong and broad academic presence in HED science, leveraging common interests while assuring that DOE/NNSA-specific interests in this area remain vibrant. Competitively awarded research grants are selected through the joint solicitation conducted in coordination with the DOE Office of Science.
- **Centers of Excellence:** The Joint Program in HEDLP funding also supports the HED centers of excellence selected under the competitive SSAA Centers process. Centers of excellence are an integrated multi-institutional collaborative effort focused on a central problem or theme. These centers work closely with nuclear security enterprise scientists and maintain a core set of academic expertise in key technical areas.
- **National Laser User Facility Program:** The Program provides access to the Omega Laser Facility (Omega) and Omega-EP lasers for academic partners in an openly solicited, peer-reviewed program. In addition to applying DOE/NNSA's unique tools to advance basic science, this and similar programs attract world-class scientists to DOE/NNSA through offering training to students in specific experimental skills, providing access to cutting edge facilities, and enabling innovative development of diagnostics and platforms by user facility partners.

For the three fellowship programs (the DOE/NNSA's **Stockpile Stewardship Graduate Fellowship,** the DOE's **Computational Science Graduate Fellowship,** and the DOE/NNSA's **Laboratory Residency Graduate**), DOE/NNSA has a long-term goal to cultivate the next generation of scientists and engineers to support the ASC and the broader Weapons Activities missions through academic alliance activities. These efforts establish academic programs for multidisciplinary simulation and experimental science and, through graduate fellowships, provide students an introduction to the national laboratories and their mission space, as well as build relevant experience for weapons code, science, and engineering development through open science applications. All of the fellowship activities are currently managed by the Krell Institute (the Computational Science Graduate Fellowship is jointly funded with the DOE Office of Science's Advanced Scientific Computing Research program.)

The **Predictive Science Academic Alliance Program** consists of participation by leading U.S. universities, focusing on the development and demonstration of technologies and methodologies to support effective

HPC in the context of science and engineering applications. The research performed by the universities in this program is discipline-focused to further predictive science and is enabled by effective extreme-scale computing. This focus on predictive science supports the DOE/NNSA need for expertise in verification and validation and uncertainty quantification for large-scale simulations.

All these efforts establish academic programs for multidisciplinary simulation science and provide students the relevant experience for weapons code development through open science applications.

4.3.6.1 Status

Academic Programs is a recent compilation of programs established in FY 2021 to bring together similar activities addressing the need for a strong and diverse base of national expertise and educational opportunities in specialized technical areas that uniquely contribute to nuclear stockpile stewardship. By combining these activities, DOE/NNSA gains coordination across programs, leverages strengths and addresses the needs of DOE/NNSA through interactions with academic partners.

4.3.6.2 Challenges and Strategies for Academic Programs

Table 4–6 provides a high-level summary of Academic Programs challenges and the strategies to address them.

Table 4–6. Summary of Academic Programs challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
Large numbers of retirements are expected across the nuclear security enterprise.	Attract and educate students through academic research in critical technical areas, graduate fellowships, and opportunities to conduct research on DOE/NNSA facilities.	
Increased need for specialized, weapon-relevant skillsets in the nuclear security enterprise.	Deploy centers, consortia, and grants to focus on identified technical areas of need and maintain an academic community of expertise and an educational pipeline for trained graduates familiar with the nuclear security enterprise.	Increase efforts to attract undergraduate students to these technical areas.
Lack of diversity in current nuclear security enterprise workforce.	Diversity, equity, and inclusion is now a program goal for all subprograms within Academic Programs, leveraging existing relationships developed through MSIPP/TEPP and establishing new connections with academia.	Partner with other DOE/NNSA academic programs and workforce recruitment and retention programs to ensure the workforce reflects the American public.

4.4 Nuclear Test Readiness

The United States continues to observe the 1992 nuclear test moratorium. DOE/NNSA maintains the readiness to conduct an underground nuclear explosive test, if required, to ensure the safety and effectiveness of the Nation's stockpile or if otherwise directed by the President. DOE/NNSA's evaluation of the response time has changed over the years, and the fundamental approach taken to achieve test readiness has also changed.

Nuclear test readiness covers a broad range of potential activities. Assessments of nuclear test readiness require a clearly defined technical basis and well-understood assumptions. Key considerations include the following:

- DOE/NNSA is required to maintain the capability to conduct a nuclear test within the timelines identified in National security presidential memorandum (NSPM)-31.
- Nuclear test response time depends on the specific details of the test.
- Assuring full compliance with domestic regulations, agreements, and laws related to worker and public safety and the environment, as well as international treaties would significantly extend the time required for execution of a nuclear test.
- DOE/NNSA assumes that a test would be conducted only when the President has declared a national emergency or other similar contingency and only after any necessary waiver of applicable statutory and regulatory restrictions.

Since FY 2010, there has been no funding specific to nuclear test readiness as a separate program. DOE/NNSA maintains test readiness by exercising capabilities and workforce at the national security laboratories and the Nevada National Security Site (NNSS) through the Stockpile Stewardship Program. Test readiness is a product of a robust, technically challenging science-based Stockpile Stewardship Program that exercises essential underground testing elements at NNSS, such as mining, as well as investments in both the personnel and infrastructure of the nuclear security enterprise.

Operations such as subcritical experiments at U1a are exercising some of the people, physical assets, and infrastructure required for an underground nuclear explosive test. These involve critical skills and formality of operations; including design, preparation, and fielding of advanced diagnostics; modern safety analysis; experimental execution; and recovery and analysis of the data. Subcritical experiments also exercise critical skills and concept of operations with respect to weapon design.

DOE/NNSA is continuing to leverage subcritical experiments for test readiness, as they are challenging, multi-disciplinary efforts that enhance the technical competency of the nuclear security enterprise workforce. DOE/NNSA will also leverage experiments on HED physics platforms such as NIF, Z, and Omega to preserve the capability for maintaining relevant measurement capabilities, such as prompt measurement of optical, X-ray, gamma-ray, and neutron flux from experiments with next-generation technologies similar to underground nuclear explosive test measurements. The Stockpile Responsiveness Program also contributes to ensuring the readiness of the workforce.

Some of the capabilities and technologies used during testing have been supplanted by newer technologies. It would be a significant challenge to regenerate some of the old technologies, as they are no longer available. The strategy to migrate to these technologies entails maintaining a key set of the historic capabilities to enable cross-calibration between the new capabilities and technologies available today. The test readiness strategy is to reconstitute underground testing elements when needed, rather than maintaining obsolete facilities and capabilities. DOE/NNSA assesses the current nuclear test readiness and complies with current Presidential directives and public law.

Chapter 5
Security

5.1 Overview

This chapter covers several aspects of security within the Department of Energy's National Nuclear Security Administration (DOE/NNSA): The Secure Transportation Asset (STA) program, the Defense Nuclear Security (DNS) program, and the Information Technology (IT) and Cybersecurity program. Together, these programs provide the safe and secure transportation of nuclear weapon assets, security of the Nation's nuclear materials, physical infrastructure, workforce, and information assets at DOE/NNSA Headquarters and its field offices, national security laboratories, nuclear weapons production facilities, and the Nevada National Security Site.

5.2 Secure Transportation Asset

5.2.1 Introduction

STA provides safe, secure transport of the Nation's nuclear weapons, weapon components, and special nuclear material (SNM) throughout the nuclear security enterprise to meet national security requirements and support DOE/NNSA missions. Nuclear weapon warhead modernization, limited life component (LLC) exchanges, surveillance, dismantlement, nonproliferation activities, and experimental programs rely on STA's safe and secure transport. STA is Government-owned and operated because of the control and coordination required and the potential security consequences of material loss or compromise.

Secure Transportation Asset Accomplishments

- *Completed more than 167 safe and secure deliveries.*
- *Completed the Test Article 1 Side Crash Test and delivered Test Article 2 for the Mobile Guardian Transporter.*
- *Executed vehicle sustainment efforts to ensure mission vehicles are upgraded and maintained to provide reliable mission support.*

STA's highest priority is Weapons Activities missions. It also provides secure transport for other DOE/NNSA programs and offices, such as the Nuclear Counterterrorism and Incident Response Program, Office of Naval Reactors, and the Office of Nuclear Energy, as well as the Department of Defense (DoD) and other Government agencies. STA has a record of 100 percent safe and secure shipments without compromise, loss of components, or release of radioactive material. This record is enabled by the core components of the STA security concept of specialized vehicles, secure trailers, specially trained Federal Agents, and leading-edge communication systems. To maintain that exemplary record, STA must continue to modernize the transportation assets and communication systems for convoy safety and security, and recruit and retain the Federal Agent and program staff workforce to meet mission capacity and customer requirements. While the Safeguards Transporter (SGT) fleet is beyond its original design life, STA is sustaining the capability through implementation of a risk-reduction initiative that is extending the life of the SGT until the replacement, known as the Mobile Guardian Transporter (MGT), becomes operational.

Mobile Guardian Transporter (Test Article)

5.2.2 Status

STA supports the workload by adjusting to unforeseen demands and changes in the security posture while maintaining a workforce and vehicle fleet capable of responding to the full security continuum. STA is investigating the integration of unmanned aerial and ground-based technologies to enhance secure operations by increasing awareness during emergency or off-normal events involving critical STA assets. This section discusses the various assets and personnel elements that comprise STA.

5.2.2.1 Vehicles

Modernizing and sustaining STA's vehicle assets require an integrated, strategic plan and a substantial investment for life cycle replacement. The STA strategy includes steady-state initiatives such as eliminating outdated vehicles, refurbishing operational vehicles to extend their useful life, and procuring new vehicles.

The process of identifying, designing, procuring, and manufacturing these vehicles takes several years. The current armored tractor and escort vehicle are being replaced by the Next Generation Armored Tractor (T4) and Escort Vehicle (EV4). STA continues to assess and refurbish vehicles to extend life cycles until replacements are available. Evaluating demands on vehicles is a continuous effort to keep pace with operational requirements.

5.2.2.2 Trailers

The trailer fleet is a critical asset for transporting nuclear cargo on public highways. The design, engineering, testing, production, and use of these trailers can span several decades. The design and construction features address public safety, unique cargo configurations, and protection systems. The SGT fleet began reaching its end-of-design life cycle in FY 2018, years before the first MGT will enter production. STA implemented risk-reduction initiatives to sustain its capability until the new MGTs are produced and operational.

Mobile Guardian Transporter Crash Test

In FY 2020, MGT accomplishments included the development of an Integrated Master Schedule that incorporated the System Integrator, design agency, and production agency; completion of Test Article 1 Side Crash Test; and delivery of Test Article 2. The data from the MGT crash test performed by Sandia National Laboratories (SNL) (photo on right) will be used for qualification of the transporter and to better understand cargo response in accident scenarios for years to come. Major planned activities for FY 2022 include delivery of the pre-production unit rolling chassis, completion of Test Article 2 assembly, and start of the pre-production unit assembly. The first production unit is scheduled for delivery in FY 2026.

5.2.2.3 Aviation

The fleet of Government-owned aircraft provides for the efficient and flexible airlift of LLCs, nuclear incident response elements, Federal Agents, joint test assemblies, training assemblies, and personnel and equipment associated with national emergencies and disasters. STA is required to maintain an aircraft on continuous alert with a six-hour response time to nuclear incidents. STA must also support evacuation and relocation of key personnel to maintain the continuity of Government operations.

These emergency response aircraft support the Nuclear Emergency Support Teams, which include the Joint Technical Operations Team, the Accident Response Group, and the Radiological Assistance program. The procurement of a third 737 aircraft, scheduled for delivery in FY 2022, will replace an aging DC-9 aircraft. STA's current fleet of two Boeing 737 aircraft are over 30 years old. A Business Case Analysis completed in FY 2018 recommends lifecycle replacement to ensure continued mission capacity. STA's goal is to begin replacement of these two 737 aircraft in FY 2027 and FY 2032, respectively.

Boeing 737-400

5.2.2.4 Communications

Reliable, secure, real-time communication is crucial to STA mission success. Essential communications include information that is obtained, analyzed, and disseminated for mission planning; continuous monitoring and updating of that information during mission execution; and continuous communication during convoy operations. These various tiers of communication must be executed seamlessly in real time, while balancing the evolving need for cybersecurity to ensure system reliability and integrity. STA is continually evaluating risk, researching emergent technologies, and implementing new tools and practices to keep up with on-going and developing threats. STA has shifted to a prioritized mobile network and is exploring solutions for the use of mobile classified communications in mission vehicles.

5.2.2.5 Training

Federal Agents receive training in full-scale emergency and tactical operational scenarios, tactical driving techniques, and a variety of weapons and explosives. Each Federal Agent Command has facilities and staff to refresh primary skills and accomplish the majority of qualification training. The Training Command at Fort Chaffee, Arkansas, supports basic to advanced training, including special weapons, tactical scenarios, and other general training covering all aspects of convoy operations, as well as an initial Nuclear Material Courier Basic training program for Federal Agent candidates. The Federal Law Enforcement Training Center, at Glynco, Georgia, provides a follow-on course for Federal Agents, emphasizing legal authorities and law enforcement concepts. Federal Agent law enforcement authority and specialized training are continually evaluated to respond to the dynamic operational environment.

New OST Logo

STA continues to recruit and retain the Federal Agent workforce to meet mission capacity and customer requirements. During the COVID-19 pandemic, STA's mission did not cease. STA's ability to effectively meet customer requirements proved STA to be highly dynamic and adaptable to the ever-changing environment.

5.2.2.6 Safety and Security

Validation Force-on-Force exercises are assessments designed to test STA's Active Security Doctrine and determine system effectiveness for the STA's Site Security Plan. The vulnerability assessment team designs, performs, evaluates, and documents the conduct of these assessments; the training and logistical staff support the execution of Validation Force-on-Force exercises and integrate them with the emergency command and control elements to provide the most realistic convoy scenarios possible. STA also executes safety studies and safety engineering for the Safety Basis, Nuclear Explosive Safety, and over-the-road safety issues. The Site Security Plan and the Documented Safety Analysis outline compliance with security and safety orders and regulations as related to nuclear operations within DOE/NNSA.

5.2.2.7 Liaison

STA maintains a liaison program with agencies and organizations that may be in contact with a convoy or must respond to an STA emergency. This interface extends across the United States, with a focus on primary and secondary convoy routes. The scope of the liaison function includes Federal, State, Tribal, and local agencies and involves interactions with law enforcement officers, firefighters, emergency and hazardous materials responders, dispatchers, and military personnel.

5.2.3 Challenges and Strategies

Table 5–1 provides a high-level summary of STA challenges and the strategies to address them.

Table 5–1. Summary of Secure Transportation Asset challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
The SGT fleet is beyond its design life and sustaining the SGT fleet involves challenges such as unavailable or obsolete parts, difficulty finding new manufacturers, the high cost of limited-run production, and meeting Nuclear Explosive Safety Study requirements.	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. Support SGT risk-reduction program.	Continue to evaluate, update, and replace STA assets as required to meet mission.

5.3 Defense Nuclear Security

5.3.1 Introduction

DNS leads, develops, and implements the DOE/NNSA security program to enable DOE/NNSA's nuclear security enterprise missions. DNS provides protection for DOE/NNSA personnel, facilities, nuclear weapons, and materials from a full spectrum of threats, ranging from minor security incidents to acts of terrorism, across all the sites of the nuclear security enterprise. In addition, DNS provides nuclear security expertise for a broad set of 21st-century national security needs, such as those in defense nuclear nonproliferation, homeland security, and intelligence, in line with its core mission. Employing more than 2,500 protective force officers, DNS secures SNM, classified materials, and more than 4,400 buildings in addition to protecting more than 62,000 personnel. The major elements of the DNS program are illustrated in **Figure 5–1**.

Defense Nuclear Security Accomplishments

- *Completed the upgrade of the security access system for the Device Assembly Facility at the Nevada National Security Site.*
- *Launched the fully developed Center for Security Technology, Analysis, Response, and Testing (CSTART) web portal, designed to better integrate the security community.*
- *Completed Interagency Acquisition to standardize the long gun (M27 Infantry Automatic Rifle) across the NNSA nuclear security enterprise.*
- *Reduced the personnel security clearance inventory by over 75 percent from more than 5,000 clearance actions to a daily average of approximately 1,300 clearance actions in less than 6 months (accomplished while implementing 100 percent telework operations due to the COVID-19 pandemic).*
- *Implemented the Uncleared HSPD-12 Program for all DOE/NNSA sites, granting 1,921 Personal Identity Verifications for Uncleared Contractors since September 3, 2019.*
- *Developed a Design Basis Threat Implementation Strategy that captures action items, risk acceptance, and site recommendations on risk acceptance/mitigation.*
- *Created a risk management framework strategy to mitigate and manage DOE/NNSA security risks.*
- *Ensured the ability of security operations to support all DOE/NNSA requirements through the COVID-19 pandemic by facilitating numerous contracts, policy, and logistical modifications.*

Figure 5–1. Defense Nuclear Security Program elements (excludes construction)

Dedicated and specially trained security professionals using an array of weapons and technologies address general and site-specific threats and carry out the physical security mission at each field location. Physical security includes the safeguards and security programs that provide the day-to-day secure environment necessary to implement DOE/NNSA's national security mission. DNS also provides facility clearances for contractor organizations that perform both classified and unclassified work; administers the classification program to ensure information is properly identified for appropriate handling and protection; and provides personnel security clearance processing and adjudication for the nuclear security enterprise. **Table 5–2** provides a brief description of each of these program elements for DNS.

Table 5–2. Defense Nuclear Security Program elements

DNS Element	*Description*
Protective Force	*Protective Force* officers are an integral part of a site's security posture and are trained in tactics and techniques necessary to protect NNSA sites. These forces are each site's primary front-line protection and consist of armed, uniformed officers.
Physical Security Systems	*Physical Security Systems* oversees counter unmanned aircraft systems, intrusion detection and assessment systems, performance testing and certification/recertification, access control systems, barrier and delay mechanisms, canine explosive detection programs, and tactical systems.
Information Security	*Information Security* provides classification guidance, technical surveillance countermeasures, operations security, classified matter protection and control, and administration of special access programs.
Personnel Security	*Personnel Security* includes access authorizations, badging, portions of the Human Reliability Program, classified and unclassified visits, and foreign national assignments. Encompasses administrative support for the site clearance process, including security clearance determinations at each site.

DNS Element	*Description*
Material Control and Accountability	*Material Control and Accountability* controls and accounts for special and alternate nuclear materials through measurements, quality assurance, accounting, containment, surveillance, and physical inventory. Management of the Local Area Nuclear Material Accountability Software application, as well as training and operational support, is provided to DOE/NNSA sites and facilities.
Security Programs Operations and Planning	*Security Program Operations and Planning* manages development of budgets; responses to audits and information requests; review of Site Security Plans; security planning and assessment, including vulnerability/risk assessments; and performance testing and assurance. It also includes security incident and reporting management, security surveys and self-assessments, activities related to deviation requests, and control of security technology transfer activities and supports facility clearance processing and Foreign Ownership, Control, or Influence determinations for security contracts.

5.3.2 Status

5.3.2.1 Center for Security Technology, Analysis, Response, and Testing (CSTART)

This initiative uses a team approach working with SNL, Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), other DOE national laboratories, DoD, and the Nuclear Regulatory Commission (NRC) to achieve enterprise-wide solutions to security challenges. CSTART developed a comprehensive on-line portal allowing and improving critical information sharing across the entire physical security program and to collaborate with other Government agencies in identifying additional opportunities for improvement and joint initiatives.

5.3.2.2 Counter Unmanned Aircraft System

DNS is focused on addressing the threat posed by unmanned aircraft systems and the need for effective countermeasures, which is among DOE/NNSA's top security priorities. DOE/NNSA's first counter unmanned aircraft system (CUAS) platform (the first within DOE) was deployed at LANL in December 2017 and achieved full operational capability on October 31, 2018. Remaining Category I[1] facilities are actively working to deploy the CUAS platform. The Nevada National Security Site achieved initial operating capability in September of 2020. DNS continues to work closely with Departmental security counterparts and interagency partners, including the Department of Homeland Security, the Federal Aviation Administration, DoD, the Department of Justice, and appropriate congressional stakeholders to maintain an effective CUAS capability.

5.3.2.3 Security Infrastructure Revitalization Program

The Security Infrastructure Revitalization Program (SIRP) addresses physical security infrastructure across DOE/NNSA, identifying a prioritized list of physical security refreshes and upgrades as part of a life cycle management plan across the nuclear security enterprise. SIRP project requirements were derived from the data obtained during a detailed condition assessment completed at each DOE/NNSA facility. The condition assessment identified the oldest systems and systems with the highest risk for failure and assessed these systems' contributions to the overall security posture. Condition assessment surveys were used to calculate risk values that established a baseline and demonstrated reduction in risk based on proposed upgrades. This provided a method by which to compare various upgrade options that support cost-effective implementation decisions across the enterprise.

[1] A Category I facilities store or process Category I quantities of SNM or credible rollup quantities of SNM to a Category I quantity.

5.3.2.4 Design Basis Threat Implementation

DOE Order 470.3, *Design Basis Threat*, establishes the baseline threat characterization against which the NNSA security program is developed and implemented. The design basis threat (DBT) draws on information from a variety of sources, including the Intelligence Community's Nuclear Security Threat Capabilities Assessment. An update to the DBT required NNSA to assess its security posture and make appropriate adjustments. DNS, in coordination with DOE/NNSA management and operating (M&O) contractor partners and field offices, developed an implementation plan and completed the analysis in December 2020. DNS is leading the effort to develop a comprehensive risk management framework that outlines physical protection for all DOE/NNSA assets and a risk mitigation plan for the nuclear security enterprise.

5.3.2.5 Departmental Collaboration

DNS participates in the Capital Acquisition process, the Integrated Planning Group, the Management Council, the Chief Security Officer Committee, and the Insider Threat Steering Committee to maintain close collaboration with other NNSA and DOE entities. Under one of the Security Roadmap initiatives, DNS revitalized collaboration with the NRC, Department of Homeland Security, the United Kingdom's Ministry of Defence, and DoD to identify opportunities for collaborating on respective nuclear security programs.

5.3.2.6 Personnel Security

DNS assumed responsibility for 98 percent of NNSA's clearances by transferring clearances held by the DOE Office of Environment, Health, Safety, and Security and the Savannah River Site. Despite implementing full telework operations due to the COVID 19 pandemic, DNS also reduced the personnel security clearance inventory backlog significantly. In addition, DNS recently upgraded its web-based program, the Clearance Action Tracking System (CATS), to enhance workflow and manage cases from cradle to grave. This system has been adopted by the Department as the adjudication system of record for clearance activities. As part of its paperless initiative, over 50,000 paper files are being scanned and uploaded into CATS. Clearance documentation received prior to CATS is being integrated into the system by contract partners.

5.3.3 Sustainment Investments

DNS has a process in place for funding operations and sustainment of safeguards- and security-related infrastructure, equipment, and facilities. During the annual programming process, M&O partners submit requests for funding these requirements, which include upgrades to/replacement of security infrastructure, security systems, equipment, and facilities. This routine Planning, Programming, Budgeting, and Evaluation (PPBE) process, accomplished in close coordination with NNSA's Office of Management and Budget, is essential to the protection of NNSA's critical missions. The FY 2022 Budget Request supports increased security needs associated with known mission growth in weapons programs across the NNSA nuclear security enterprise, including Pit Production at LANL; Kansas City National Security Campus floor space; updating and replacing proprietary security systems throughout the enterprise; and initial efforts to implement additional security requirements resulting from completed DBT analysis. This request includes funding for continued efforts to recapitalize security infrastructure through SIRP projects, which address high-priority security systems and related security infrastructure and equipment refresh needs. It also requests funding for the West End Protected Area Reduction project at the Y-12 National Security Complex (Y-12), which will install a new Perimeter Intrusion Detection and Assessment System (PIDAS) section while eliminating a much larger PIDAS section, reducing the Y-12 protected area by approximately 50 percent. In addition, DNS allocated funding for numerous equipment purchases related to security equipment modernization. These approvals funded weapons, ammunition, body armor, vehicles, radios, electronic security system components, software system upgrades, tactical casualty care kits, and other security-related purchases to improve, modernize, and maintain operations. Additional project information is available in Chapter 6, Section 6.5, and further funding information is available in Chapter 8, Section 8.8.

5.3.4 Challenges and Strategies

A major challenge for NNSA, as well as the Government more broadly, is identifying and addressing new and emerging security threats. Each threat is assessed and prioritized according to national security importance, taking into consideration the effectiveness of existing security measures. Through tactical and strategic planning and collaboration with counterparts, DOE/NNSA has developed several programs to meet these security challenges. As systems age and technology advances, meeting current and future challenges will remain an area of focus. In addition to these new threats, **Table 5–3** provides a high-level summary of various DNS challenges and the strategies developed to address them.

Table 5–3. Summary of Defense Nuclear Security Program challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Conversion of Personnel Security Files to electronic media.	Contract awarded to vendor to complete scanning and validation of files.	DNS must balance its workload, reviewing scanned files as other actions are completed on a case, and determine a funding source to purchase equipment (i.e., "high volume" scanners). Efforts are needed for a project team, through the execution of a Charter, to develop project scope, identify project tasks, and track/monitor milestones.
Address aging security systems and related critical security infrastructure and equipment.	Continuing support for recapitalization of the security infrastructure through critical SIRP projects.	Develop a life cycle management plan and incorporate it within the fiscal year PPBE process.
Implement modern security technologies, systems, analysis, testing, and response forces designed to address evolving national security threats.	Collaborating with other Government agencies, the NNSA Security Community, CSTART, and Physical Security Center of Excellence to identify ways to modernize the security program.	Develop and implement a security technology modernization plan designed to incorporate updated security technologies that enhance our capabilities across the NNSA nuclear security enterprise. Continue to collaborate with other agencies to modernize security technology to effectively address evolving threats.
Implementation of Trusted Workforce 2.0 [a]	Coordination across DOE to develop policy and implementation plans for the constantly changing investigative and adjudicative landscape.	As the Government moves to a more real-time vetting and adjudication model, there is a need for DNS and DOE to adjust to meet the needs of the changing landscape.

[a] Trusted Workforce 2.0 is a joint initiative between the Office of the Director of National Intelligence, DoD, and the Office of Personnel Management focusing on the "continuous vetting" of security clearance holders.

Increased weapons requirements have led to mission growth across the nuclear security enterprise, especially in the areas of weapon modernization and infrastructure investment and recapitalization. This mission growth drives increased security program resource requirements across every security discipline. For example, increases in site staffing result in additional personnel clearance action, and increases in square footage require additional personnel and physical security infrastructure; protective force support;

classified material protection and control; technical surveillance and countermeasures; classification program support; and programmatic management. **Figure 5–2** illustrates these requirements.

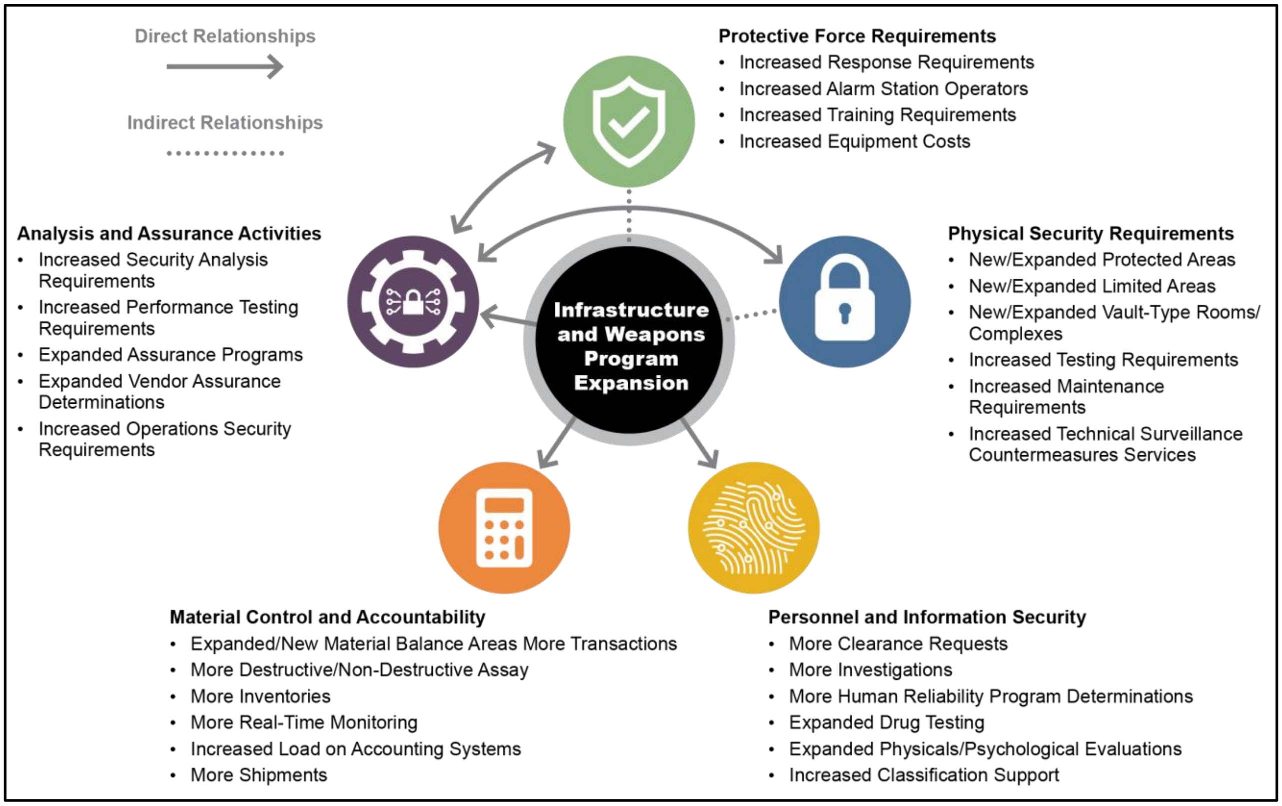


Figure 5–2. Increased weapons requirements

5.4 Information Technology and Cybersecurity

5.4.1 Introduction

DOE/NNSA's Office of the Associate Administrator for Information Management and Chief Information Officer (NNSA OCIO) is responsible for Federal information management, IT, and enterprise-wide cybersecurity for the NNSA. The IT and Cybersecurity program ensures and enables the availability of a secure infrastructure for mission activities and information sharing for DOE/NNSA and its partners within classified and unclassified environments to support mission activities throughout the entire nuclear weapon life cycle and across the entire nuclear security enterprise. The program is NNSA's primary method of implementing Executive Order 14028, "Improving the Nation's Cybersecurity," which makes prevention, detection, assessment, and remediation of cyber incidents a top priority. Services are provided through three offices: Cybersecurity, Policy and Governance, and Information Technology. These offices work in tandem to:

- Increase organizational efficiency and effectiveness.
- Protect classified and unclassified information assets.
- Enhance communication with internal and external partners.
- Ensure continuous monitoring, and support effective incident response.

- Ensure information is protected from unauthorized access and malicious acts that would adversely affect national and economic security.
- Comply with statutory requirements governing classified data protections and information assurance.

The IT and Cybersecurity program uses a risk management approach to protect information and information assets in the complex, global environment to ensure prudent prioritization of resources. Well-informed management decisions incorporate a systematic understanding of the risks inherent in the use of information systems. Full integration of risk into management processes will provide greater degrees of security, privacy, reliability, and cost-effectiveness for core missions and business functions.

> ***IT and Cyber Accomplishments***
>
> - *Assumed responsibility and oversight for IT and cybersecurity for the Emergency Communication Network.*
> - *Implemented Phase I of the IT Modernization Project by working closely with the Department and element CIOs and IT Managers to move to Windows 10 and Microsoft 365.*
> - *With DOE Chief Information Officer (CIO), implemented Phase I – IT Modernization Project.*
> - *Completed IT and cybersecurity budget re-baseline activities to ensure vital projects are funded appropriately.*
> - *Developed and implemented services and solutions to provide operational connectivity during COVID-19.*
> - *Coordinated with the IT services provider to deploy equipment and ensure telework capability for a remote workforce.*
> - *Built the foundation to leverage cloud technologies.*
> - *Upgraded and enhanced NNSA security and operations capabilities.*
> - *With DOE CIO, established DOE's Enterprise Architecture Framework, and Control System Working Group.*
> - *Oversaw restoration of three enterprise network monitoring sensors at both the Pantex Plant and Y-12.*

The NNSA OCIO must maintain and plan for an appropriately skilled and trained workforce to meet current and future mission needs. Recruiting, developing, and retaining top talent has been a continuing challenge in a competitive market for IT and cyber professionals. Many of the strategies described in Chapter 7 with respect to the workforce of the nuclear security enterprise are also deployed by the NNSA OCIO to continue to meet mission-driven demands for IT and cybersecurity services.

Along with other activities and initiatives, ongoing and planned projects in IT and cybersecurity are critical to the overall effectiveness of the nuclear security enterprise. The remainder of the section describes a few of those many efforts.

5.4.1.1 Transformations to Ensure Information Security and Cybersecurity Throughout the Nuclear Security Enterprise

Digital Transformation: The NNSA OCIO has embarked on a digital transformation effort that will:

- Improve, upgrade, and enhance the mission unclassified and classified logical infrastructure;
- Enable Artificial Intelligence and Machine Learning; and
- Perform IT and application modernization.

The goal of the transformation is to ensure that sufficient management, operational, technical operation, and safeguards are implemented throughout the nuclear security enterprise to maintain adequate protection of information and information assets. The digital transformation program has several responsibilities:

- Ensuring that IT investments and projects across NNSA are coordinated, have the necessary cybersecurity protection, and are in alignment with the NNSA Strategic Plan, DOE requirements and objectives, and national policies and standards.
- Ensuring that IT is acquired and information resources are managed in a manner that implements the policies and procedures of legislation, including the *Paperwork Reduction Act, Clinger-Cohen Act*, *Federal Information Security Management Act*, E-Government Initiative of the President's Management Agenda, and *Federal Information Technology Acquisition and Reform Act* (FITARA).
- Execute the priorities set forth by the President, the Secretary of Energy, and the NNSA Administrator, related to providing classified and unclassified services and associated cyber protections across the nuclear security enterprise, coordinate with external agencies, and collaborate with international partners.

Enterprise Transformation: Building on past organizational successes to modernize and strengthen an aging infrastructure, NNSA is also implementing an enterprise transformation initiative that will deliver a modern, reliable, comprehensive, secure computing environment that supports the enterprise and aligns with current and future IT service delivery models. With the managed services model, NNSA's networks will benefit from industry best practices and receive ongoing patching and monitoring. They will incorporate hardened configurations from a security perspective, fine-tuned settings for performance, and dynamic configurations to meet evolving business environments.

5.4.1.2 IT and Cybersecurity Program Elements and Initiatives

The IT and Cybersecurity program provides commodity IT, unified communications, collaboration, mission applications, and security tools. The program focuses on the development of integrated IT initiatives that provide an effective technology infrastructure and support to the NNSA nuclear security enterprise shared services. These initiatives will fundamentally redesign the IT and cybersecurity 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. The major elements of the IT and Cybersecurity program are illustrated in **Figure 5–3**.

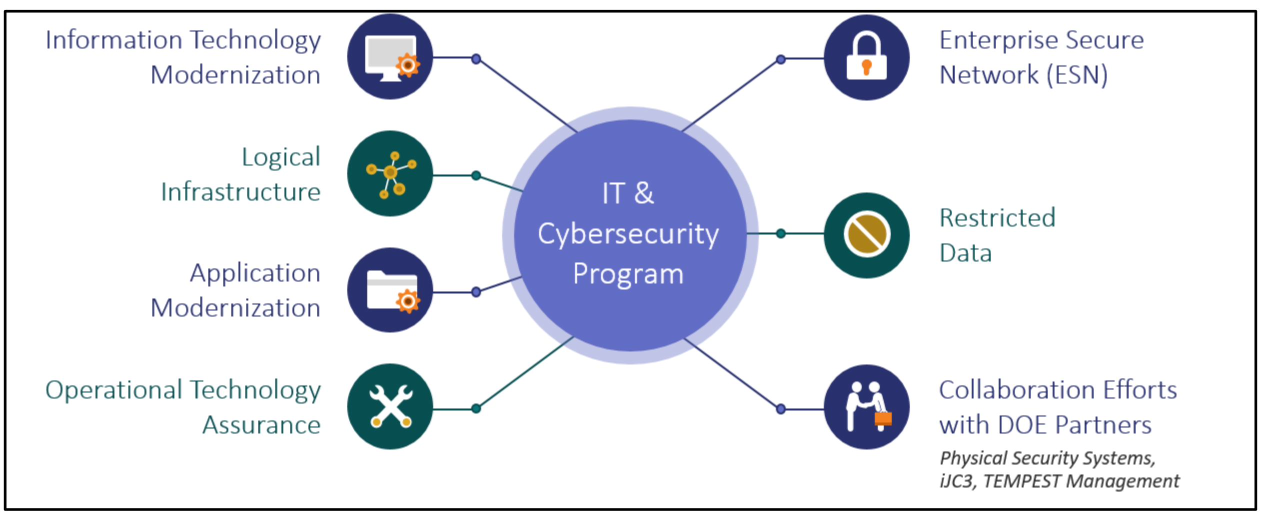


Figure 5–3. Information Technology and Cybersecurity Program elements

Table 5–4 provides a brief description of each of these program elements.

Table 5–4. Elements of the Information Technology and Cybersecurity Program

NA-IM Element	*Description*
Information Technology Modernization	An enterprise transformation initiative that will grow cloud services over time and deliver a modern, well-managed, secure computing environment that will eliminate many of the inefficiencies and performance degradations currently experienced by the workforce.
Logical Infrastructure	To improve and enhance the classified infrastructure for its Enterprise Secure Network.
Application Modernization	To perform application rationalization for mission IT applications. This evaluation of applications will be used to determine the best method of migration for current applications onto the modernized classified network.
Operational Technology Assurance	A methodology to secure the operational technology used in nuclear weapons production, testing, and facility control capabilities across the enterprise.
Enterprise Secure Network	Increases the capability, capacity, and responsiveness of the DOE classified infrastructure in direct support of the NNSA mission and the statutory requirements governing classified data protections and information assurance.
Restricted Data	Working collaboratively with other Government agencies (such as DoD and the Federal Bureau of Investigation) to identify interagency needs and opportunities for accessing, sharing, and leveraging Restricted Data (RD).
Federal IT Acquisition Reform Act (FITARA)	OMB Memorandum M-15-14, Management and Oversight of Federal Information Technology. The NNSA FITARA Implementation Framework, approved in September 2019, provides details on how NNSA will implement the Act in accordance with the OMB memorandum.
Collaboration Efforts with DOE Partners	Physical Security Systems – The application of technology to improve physical security. Integrated Joint Cybersecurity Coordination Center (iJC3) – provides 24/7 situational awareness of evolving cybersecurity threats, operational status, and associated risks to DOE mission essential functions. TEMPEST Management – To evaluate and mitigate technical risks to systems in support of its risk management oversight and control authorities.

5.4.2 Ongoing NNSA OCIO Activities

NNSA's OCIO continues to manage IT and cybersecurity projects designed to help reduce risks. Note that, while these efforts are projectized, they are not managed under the same acquisition policies as the line-item construction or minor construction projects discussed in Chapter 6. **Figure 5–4** illustrates a sampling of ongoing and completed IT and cybersecurity projects.

5.4.3 Planned NNSA OCIO Activities

NNSA's OCIO is planning the following activities in FY 2022:

- Modernizing the cybersecurity programs at the national security laboratories, plants, and sites.
- Strengthening the M&O cybersecurity operations along the defense-in-depth approach.
- Providing software and hardware enhancements and upgrades to the NNSA Security and Network Operation Center.
- Bolstering the enterprise network security posture by continuing to address known critical capability gaps at the Information Assurance Response Center.
- Initiating a modern cross-domain solution to replace the last legacy gateways currently in production.
- Expanding the application of Digital Rights Management/Data Loss Protection Technology.

Figure 5–4. Ongoing and recently completed information technology and cybersecurity projects

- Providing assistance to the operation of classified IT services and solutions, support weapons design and development.
- Deploying IT enhancements, including commodity IT services and solutions, that facilitate effective collaboration and information sharing necessary for NNSA Federal employees and support contractors to carry out the NNSA's mission.
- Overseeing the implementation of hardware and software licensing, maintenance, and refresh.
- Supporting field office IT services provisioned by M&O partners and overseeing the M&O partners' unclassified IT programs.
- Implementing the application modernization project and enterprise Voice over Internet Protocol (VoIP) as a service.
- Providing oversight of activities related to, and ensure agency compliance with, the provisions of FITARA.
- Enabling IT operations and maintenance of the critical infrastructures and networks.

5.4.4 Status

5.4.4.1 Significant Changes Since the Last Stockpile Stewardship and Management Plan

The NNSA OCIO has inherited the responsibility for the Emergency Communications Network from the Emergency Operations subprogram of the Nuclear Counterterrorism and Incident Response Program and other classified networks, as well as full-scope enhancements to the Enterprise Secure Network infrastructure, and additional IT modernization, with an emphasis on addressing risks related to software assurance and supply chain management. Due to the COVID-19 pandemic, the IT and Cybersecurity program had to adapt and rapidly pivot to accommodate a large portion of the workforce working from home and for extensive videoconferencing, including classified videoconferencing.

5.4.4.2 The Current and Future Anticipated Mission Requirements

In addition to the details provided in the introduction section, emphasis is needed for agility, as the required responses to the cyber environment require constant monitoring and response and demand increasingly advanced technology to protect information.

5.4.4.3 Current State of the Infrastructure

The infrastructure and related initiatives described in the introduction are aimed at modernizing the infrastructure to provide the best possible protection of information at the best level of service.

5.4.4.4 Current State of the Workforce

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

5.4.4.5 Technologies Deployed to Address Cybersecurity Threats

NNSA's IT and Cybersecurity program maintains management, operations, and technical security safeguards throughout the nuclear security enterprise for adequate protection of information assets. The workforce that develops, deploys, and uses the security tools listed in **Table 5–5** provides the first lines of defense against known adversaries and emerging threats.

Table 5–5. Technologies deployed or to be deployed to address Information Technology and Cybersecurity threats

Cybersecurity Framework Core Function	*Technology*
Identify	Enterprise Governance, Risk, and Compliance
	Center of Excellence Sensor Platform for Cybersecurity Intelligence
	Vulnerabilities Asset Management
	Supply Chain Management Center Solution
Protect	Multifactor Authentication Identity and Access Control Management Solution
	Encryption
	Firewalls
	Intrusion Prevention System
Detect	Network Monitoring
	Configuration Management

Cybersecurity Framework Core Function	*Technology*
Respond	Incident Response
	Enterprise Forensics
Recover	The nuclear security enterprise maintains overlapping cybersecurity technology capabilities that ensure defense-in-depth and continuity of operations at alternate locations.

5.4.5 Challenges and Strategies

The highly complex and global nature of the NNSA enterprise, coupled with limited resources, makes it critically important that information and information assets are secured, managed, and protected using a risk-management approach. As the cybersecurity threat landscape constantly evolves, it is critical for NNSA OCIO to keep up and adapt with the ever-changing IT and cybersecurity landscape and have the ability to respond rapidly to the evolving and most sophisticated threats.

Table 5–6 provides a high-level summary of the IT and Cybersecurity challenges and the strategies developed to address them.

Table 5–6. Summary of Information Technology and Cybersecurity challenges and strategies

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Ensuring purchased equipment is from the manufacturer, as designed, without modification.	Move toward centralized purchasing and equipment review before issuing equipment to the field will address current supply chain and software assurance issues.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies needed.
Insider Threat.	Work with counterintelligence on implementation of an insider threat program, concentrating first on the classified arena.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies needed.
Network Aging Infrastructure/IT Support.	• Improve network infrastructure by updating and enhancing networking equipment through public/private cloud services, managed services, software, and hardware enhancements. • Mature capabilities of aging infrastructures enterprise-wide to identify and alert concerning emerging threats. • Ensure faster development and implementation of these capabilities to counter such threats.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies needed.
Current network monitoring services restrictions.	Upgrade sites across the enterprise through deployment of new cybersecurity solutions.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies needed.
Not all buildings support network speeds that are fast enough for today's scientific computing and, with technology's reliance on computers, capacities are being exceeded across the NNSA complex.	Continued investment is needed in network communications systems and in the central networking and telecommunications facilities.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies needed.
Fill critical cybersecurity and IT vacancies across the enterprise.	Hiring a workforce that has the skillsets is included in NNSA's OCIO strategic principles in the 2017-2019 Strategic Plan:	The current strategy is sufficient. However, ongoing threat analysis will

Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
	"Principle 6: Invest in employee development to cultivate a high-performing workforce that will support NNSA's mission today and into the future."	determine whether further strategies needed.
Fulfill OMB guidance to consider and use cloud solutions in a secure manner.	Modernize current services by capitalizing on cloud technology to increase performance and strengthen security.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies needed.
Accommodate current and future teleworking needs across the NNSA complex.	Developed and implemented services and solutions to provide operational connectivity during COVID-19.	Continue planning efforts to ensure services and solutions are available to enable operational connectivity beyond COVID-19.
Artificial Intelligence/Machine Learning	• Develop an artificial intelligence/ machine learning strategy. • Improve supply chain security processes using business intelligence. • Unlock the power of data to make risk-based decisions. • Set policy for artificial intelligence and machine learning for the enterprise. • Seek technical applications to meet business/mission requirements.	The current strategy is sufficient. However, ongoing threat analysis will determine whether further strategies needed.

Chapter 6
Infrastructure and Operations

6.1 Overview

> ***Infrastructure and Operations Major Accomplishments***
>
> - *Completed the Expand Electrical Distribution System line item under budget, providing reliable, efficient electrical distribution to at Lawrence Livermore National Laboratory.*
> - *Completed construction of the Dual-Axis Radiographic Hydrodynamic Test Weather Enclosure, one of the first minor construction projects completed using DOE/NNSA's increased $20 million threshold for minor construction.*
> - *Completed construction of the Z pulsed power facility and Technical Area 4 Support Facility at Sandia National Laboratories to provide modern office and laboratory facilities.*

Infrastructure modernization is necessary to ensure a safe, secure, and effective stockpile; reduce the risk to mission; and improve employee, public, and environmental safety. The increased demand on the existing infrastructure due to multiple concurrent stockpile modernization programs and the need to advance science, technology, and engineering (ST&E) activities presents many complex challenges, particularly with an aging infrastructure that is failing at increasing rates. Despite these challenges, the Department of Energy's National Nuclear Security Administration (DOE/NNSA) has made significant progress in modernizing its infrastructure, eliminating excess facilities, and improving management practices. DOE/NNSA, with congressional support, has also increased the resources allocated to improving the condition and functionality of the infrastructure and disposing of unneeded facilities.

Figure 6–1 illustrates the size and scope of the DOE/NNSA nuclear security enterprise infrastructure that drive the challenges and strategies discussed in this chapter. Comprehensive asset management of this enterprise requires continuous, multi-level planning across the entire spectrum of asset types, resulting in balanced enterprise investment decision-making across the entire life cycle of asset management, as shown in **Figure 6–2**. Planning initiates the life cycle of an asset, followed by acquisition through new construction, lease, or purchase. The majority of an asset's life is spent in continuous sustainment through maintenance, repairs, and replacements-in-kind, with periodic recapitalizations to upgrade and extend the service life of the asset prior to disposition. These life cycle asset management activities are presented in the rest of this chapter.

Chapter 6 begins with a set of high-level, enterprise-wide challenges to lay the foundation for subsequent discussions. More specific challenges are contained in the discussions for each subsection, as appropriate. The asset management life cycle model shown in Figure 6–2 is used to frame the discussion for different types of investments across a variety of funding sources and sponsoring programs. Sections 6.2 through 6.6 each reflect the activities within the asset management model. Infrastructure planning and asset management, described in Section 6.2, enables effective operations by estimating future repair of and modernization investments in facilities as they age, forecasting facility replacement schedules, planning for new and replacement acquisitions, and anticipating the disposition needs and costs of excess facilities for completion in a timely manner. Sections 6.3 through 6.5 describe the different acquisition strategies and funding approaches necessary to build long-term infrastructure modernization programs, and Section 6.6 addresses the disposition of excess facilities. Programmatic equipment is discussed in

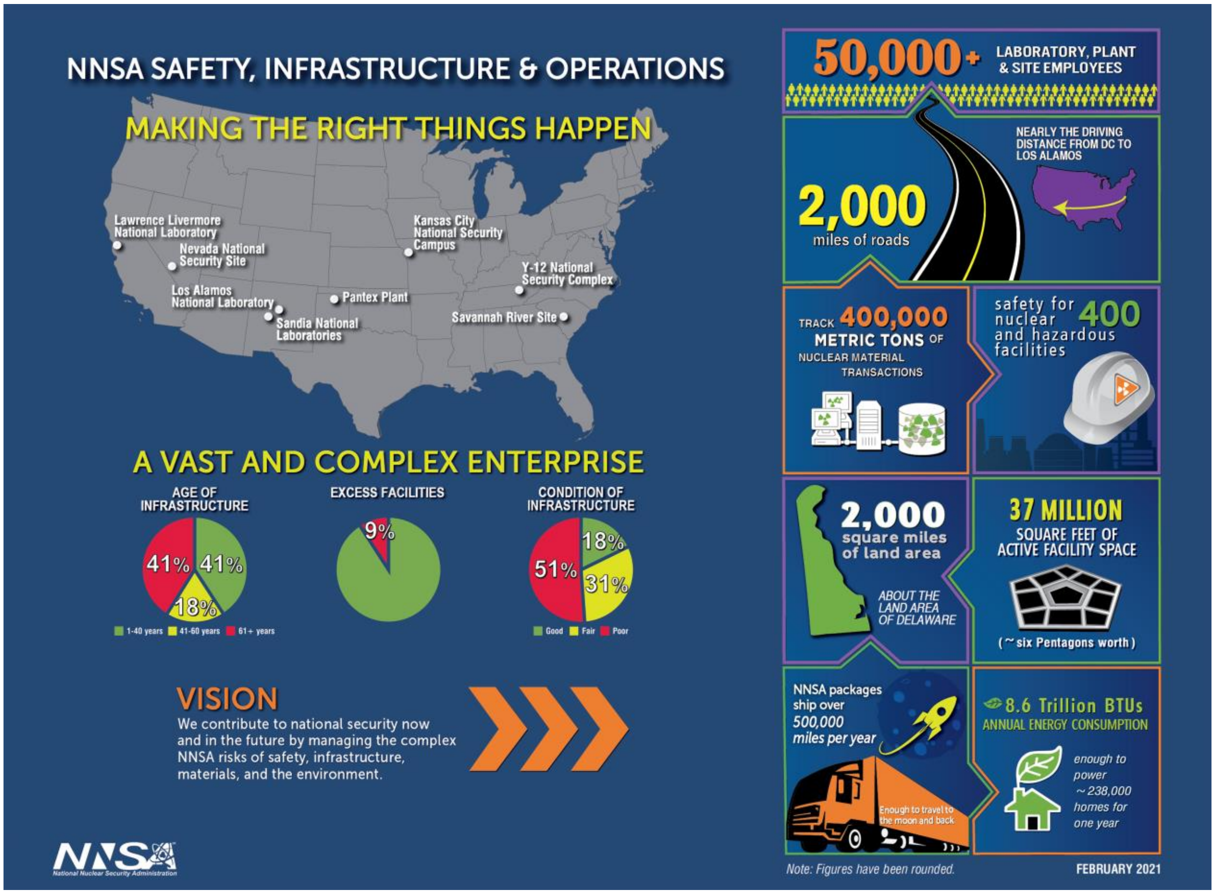


Figure 6–1. DOE/NNSA infrastructure size and scope

Section 6.7, rounding out the discussion of the Weapons Activities capability element that consists of facilities, infrastructure, and equipment.[1] Section 6.8 provides a discussion of how the DOE/NNSA programs outside the direct nuclear weapons mission areas benefit from Weapons Activities investments for their own national security mission needs. Section 6.9 concludes the chapter with a discussion on management and performance.

Within Sections 6.2 through 6.6, the various funding strategies and acquisition approaches provide the organizing framework for discussion. The wide range of programs, processes and funding types discussed are testament to the complexity of the task of aligning investment needs to funding sources. Facility acquisition occurs through line item projects, minor construction, purchase, or leasing. Operating, maintaining, and revitalizing existing facilities are funded through minor construction, Recapitalization, Maintenance, and other programs. The funding strategy to support any given type of project can vary greatly due to the budget structure, the scale of the project, and other factors.

In addition to modernizing DOE/NNSA's physical infrastructure, continuous investments are required to sustain and modernize critical physical security and cybersecurity elements across the nuclear security enterprise. Specific construction and recapitalization activities related to security are included in Sections 6.3 and 6.4. Additional physical security and information technology/cybersecurity activities are described in Chapter 5, Security.

[1] The Weapons Activities capability elements were introduced in Chapter 3, Section 3.1, in the *Fiscal Year 2021 Stockpile Stewardship and Management Plan* (FY 2021 SSMP).

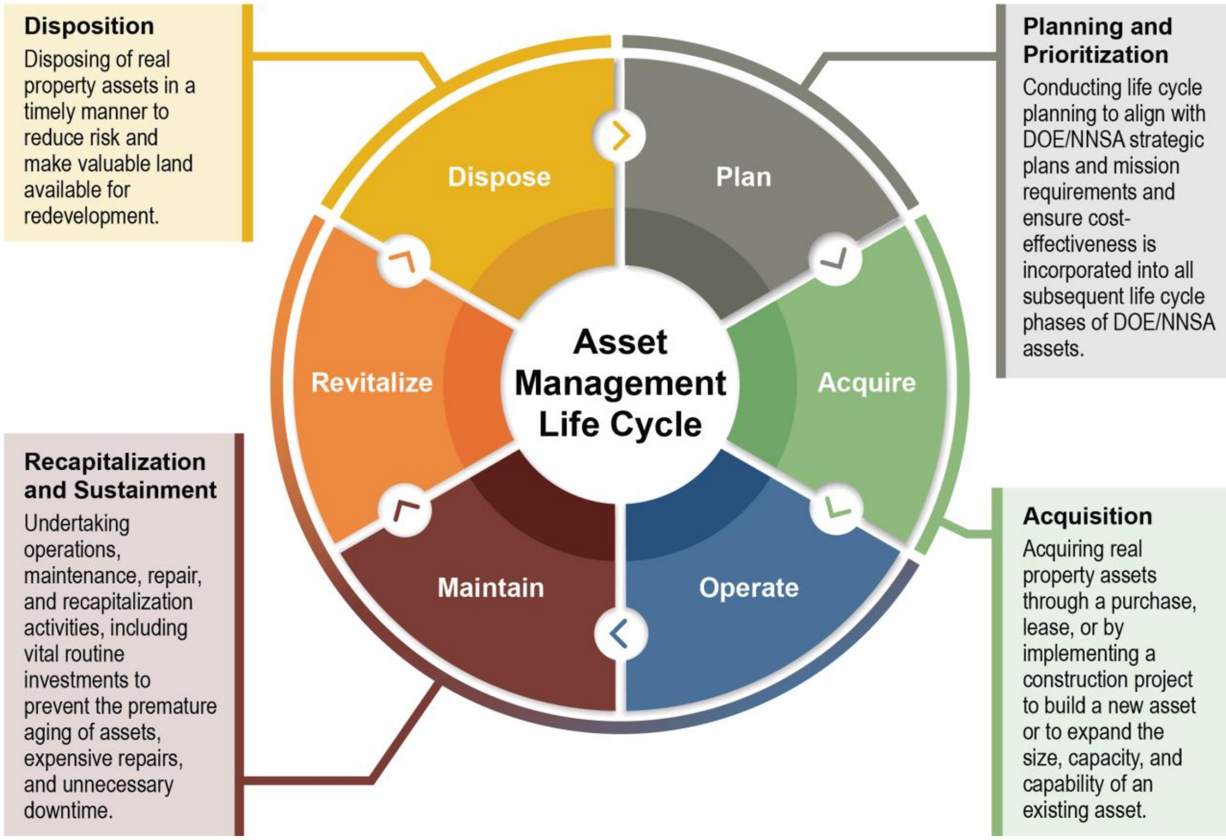


Figure 6–2. Asset management life cycle

6.1.1 Challenges and Strategies

In order to enable the nuclear deterrent mission, DOE/NNSA develops and implements infrastructure modernization strategies to meet significant challenges:

- The need to address the poor condition of DOE/NNSA facilities
- Continue improvement of comprehensive, enterprise-wide life cycle asset management
- The need for a more responsive, resilient enterprise
- The need for more efficient, effective execution

More than half of DOE/NNSA facilities are in insufficient condition to serve mission needs (e.g., poor or very poor condition). Nearly one-third are in fair condition and must be vigilantly maintained to avoid degradation. Only one-fifth of facilities are in good or very good condition (see **Figure 6–3**). Nearly 60 percent of facilities are more than 40 years old. Nearly 30 percent of facilities were constructed during the early Cold War era, and 9 percent are deemed excess to mission needs. The success of DOE/NNSA's unique national security mission depends on safe, reliable, and modern infrastructure. However, the current state of DOE/NNSA's infrastructure poses risk to the availability, capacity, and reliability of Weapons Activities capabilities.

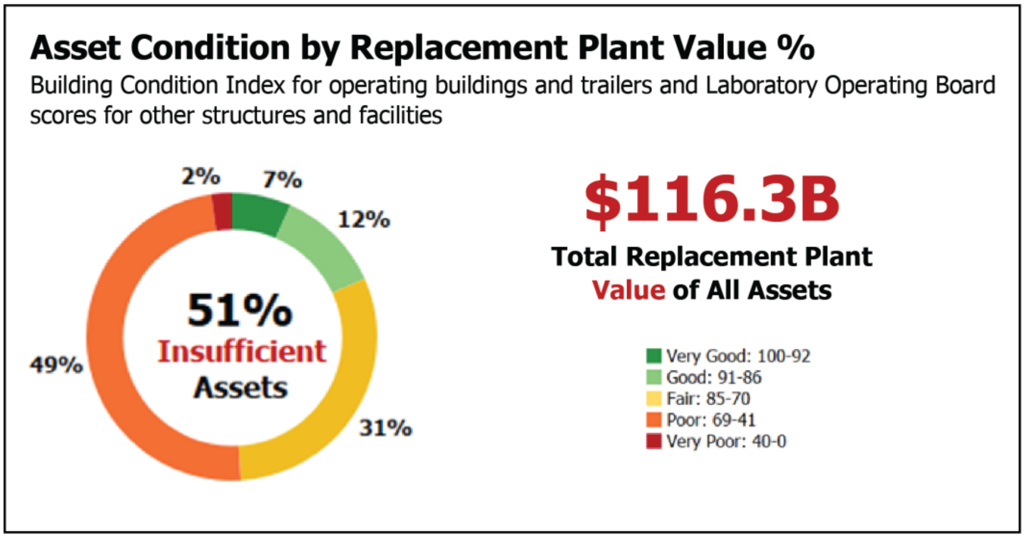


Figure 6–3. Asset condition by replacement plant value percentage

The Need for Enterprise-Wide Life Cycle Asset Management

Though the Uranium Processing Facility and other major production investments have received strong support, DOE/NNSA must appropriately prioritize sustainment of all capabilities that enable Weapons Activities programs throughout the life cycle of those capabilities. Going forward, DOE/NNSA must balance execution of a handful of high-visibility megaprojects needed to produce strategic materials and recapitalization of the many smaller facilities necessary for the design, production, and qualification of U.S. nuclear weapons components.

DOE/NNSA's assets include over 5,000 facilities, including major programmatic, office and laboratory buildings, electrical distribution systems, and security infrastructure that average over 40 years old. Upgrading or replacing aging infrastructure will require significant and sustained investment. By addressing infrastructure needs, DOE/NNSA can improve the overall condition of the physical infrastructure, increase efficiency of operations, and improve worker morale the ability to attract and retain the next-generation workforce.

A More Responsive, Resilient Enterprise

Supporting multiple concurrent warhead modernization programs requires a more responsive and resilient infrastructure. The modern nuclear security enterprise lacks resiliency, and aging facilities and equipment present a risk to mission execution. Further, the enterprise is not sufficiently responsive for the missions anticipated in the future; the existing infrastructure lacks the capacity in some areas to meet emerging mission requirements.

To meet expected future demands, DOE/NNSA's challenge is to transform the infrastructure so it is responsive and resilient enough to enable development and deployment of new weapon designs and refurbishments more rapidly and at lower risk than is currently possible. In addition to infrastructure planning, DOE/NNSA and its management and operating (M&O) partners are implementing a Stockpile Responsiveness Program to improve responsiveness via the full life cycle spectrum of nuclear weapon conceptualization, development, design, manufacture, and retirement to face technological surprise and potential geopolitical shifts in the future. See Appendix D for more information on the Stockpile Responsiveness Program.

More Efficient, Effective Execution

DOE/NNSA is taking steps to arrest the declining state of infrastructure through enhanced and optimized resources, including employment of innovative management tools to facilitate a data-driven, risk-informed planning process to guide investment decisions. Sites are also making investments to recapitalize facilities and equipment in support of multiple capabilities. The nuclear security enterprise demands best-in-class safety and physical security practices, emergency preparedness and response, and enhanced cybersecurity to counter the unexpected. Additional investments in these areas ensure that those demands are met.

The remainder of the chapter describes how DOE/NNSA is resolving these challenges through continuing improvements in data-driven long-term planning and project execution.

6.2 Infrastructure Planning and Asset Management

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

DOE/NNSA has undertaken considerable action over the last 5 years to better understand the long-term strategic investment needs of the nuclear security enterprise. Previous capital investment planning efforts were limited to the 5-year budget view represented by the Future Years Nuclear Security Program (FYNSP). This provided a realistic picture from an affordability perspective, but gave insufficient consideration to the long-term needs for infrastructure in both sustainment/renewal of existing assets and future needs tied to emerging capabilities and anticipated future workloads. DOE/NNSA's most recent integrated strategic planning efforts have yielded a much more realistic and time-critical picture of out-year infrastructure needs to support the mission and long-term sustainment of capabilities for the future. The processes for identifying and planning for these long-term needs is now greatly improved and expanded.

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

Direct mission needs have been better integrated with routine infrastructure sustainment and renewal processes to create a clearer, more comprehensive plan for long-term investments. An example of these integrated planning efforts is shown in **Figure 6–4**. Bottom-up planning across the nuclear security enterprise has been improved through area planning, described below, and deep dive reviews. The implementation of asset management software has provided accessible data for earlier planning of maintenance and sustainment needs. Because of this expanded, more integrated planning, DOE/NNSA has a more comprehensive understanding of the state of its physical assets and the actions needed to acquire, sustain, recapitalize and dispose of its assets, aligned much more closely with industry standards.

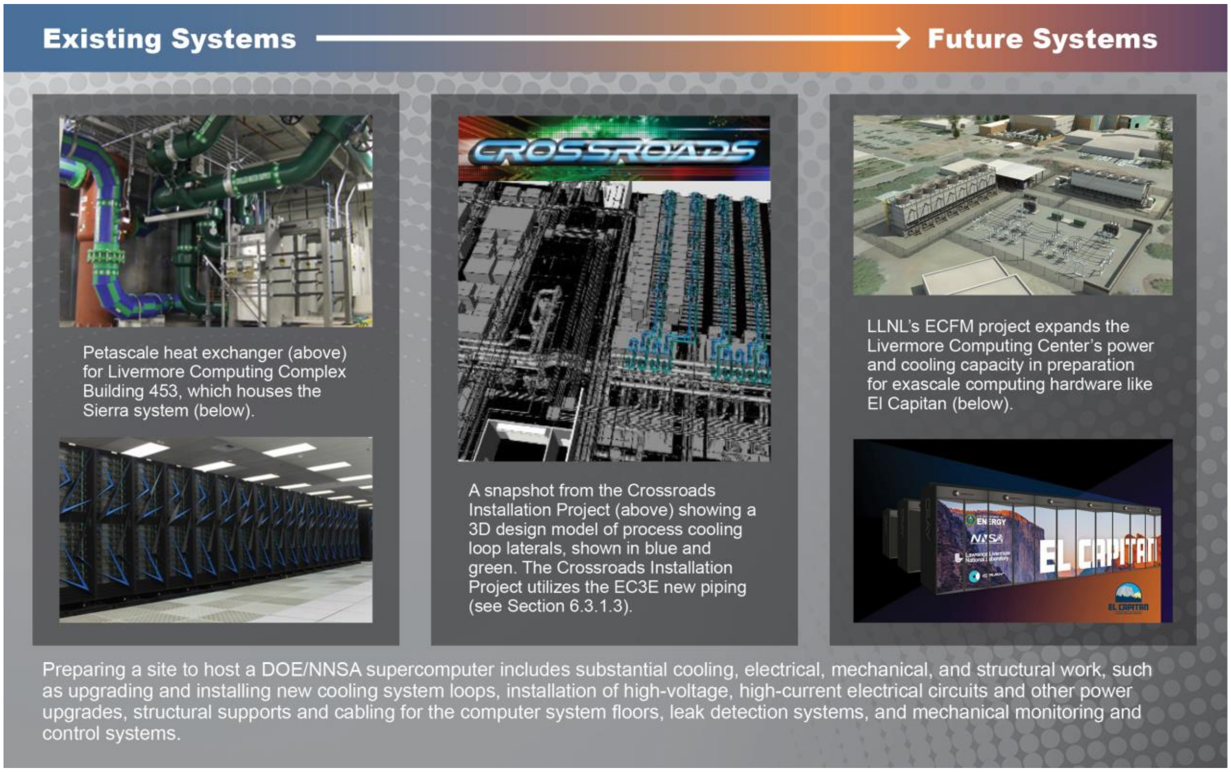


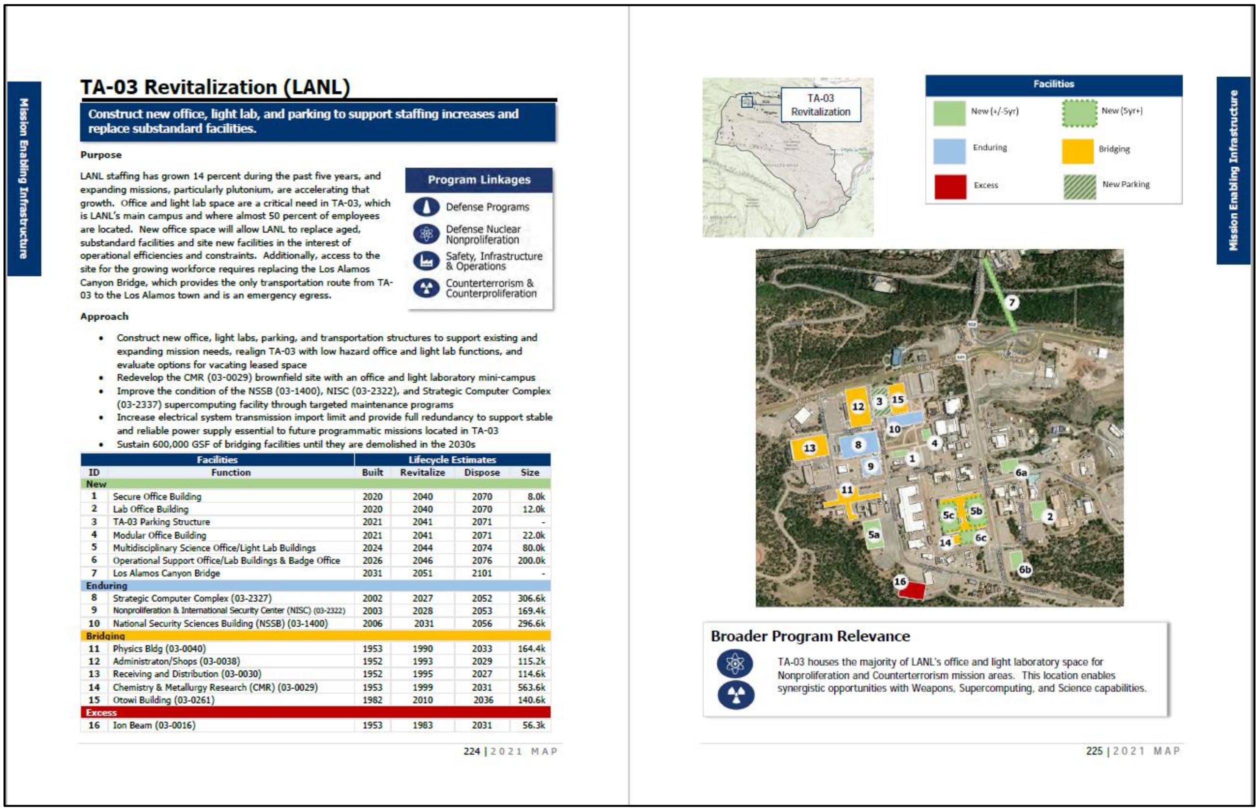
Figure 6–4. Integrated mission and infrastructure planning is crucial to the success of DOE/NNSA missions, as illustrated by this example from Weapons Simulation and Computing

The biennial infrastructure planning "deep-dive" reviews are held at each site to improve long-term planning and integrate mature project proposals into the overall plan prior to receiving funding. The deep dive meetings have been conducted virtually due to COVID-19 travel restrictions, with successful meetings held with the Kansas City National Security Campus (KCNSC), Y-12 National Security Complex (Y-12), Pantex Plant (Pantex), and Savannah River Site (SRS) in FY 2020. The deep dives and other planning efforts emphasize facility life cycle management, resulting in better investment decisions based on understanding the overall condition, capabilities, capacity, readiness, and reliability of DOE/NNSA's infrastructure.

The asset management life cycle, shown in Figure 6–2, is the basis for all investment planning within DOE/NNSA. It can be applied to a single facility or, as applied to numerous facilities, it can be used to organize the way the infrastructure program operates. The elements of the cycle must work together in balance to keep the nuclear security enterprise assets healthy. While the model appears straightforward, the processes employed to achieve that balance across multiple facilities for the purpose of meeting multiple competing priorities are not. In the DOE/NNSA environment, decision-making is complicated by the multiple funding mechanisms, guidance, and requirements. In order to understand these intricacies, the next several sections include some definitions of terms and background to aid in understanding the broad extent of investment planning and execution in the nuclear security enterprise.

6.2.1 Area Planning

Area plans are the newest element of DOE/NNSA's planning process, connecting plans to projects for achieving DOE/NNSA's strategic vision for the future nuclear security enterprise. They provide detailed information on the life cycle management strategies of a portfolio of co-located or functionally similar facilities, buildings, and other structures. See **Figure 6–5** for an example area plan.



Mission Enabling Infrastructure

TA-03 Revitalization (LANL)

Construct new office, light lab, and parking to support staffing increases and replace substandard facilities.

Purpose

LANL staffing has grown 14 percent during the past five years, and expanding missions, particularly plutonium, are accelerating that growth. Office and light lab space are a critical need in TA-03, which is LANL's main campus and where almost 50 percent of employees are located. New office space will allow LANL to replace aged, substandard facilities and site new facilities in the interest of operational efficiencies and constraints. Additionally, access to the site for the growing workforce requires replacing the Los Alamos Canyon Bridge, which provides the only transportation route from TA-03 to the Los Alamos town and is an emergency egress.

Program Linkages

Defense Programs
Defense Nuclear Nonproliferation
Safety, Infrastructure & Operations
Counterterrorism & Counterproliferation

Approach

- Construct new office, light labs, parking, and transportation structures to support existing and expanding mission needs, realign TA-03 with low hazard office and light lab functions, and evaluate options for vacating leased space
- Redevelop the CMR (03-0029) brownfield site with an office and light laboratory mini-campus
- Improve the condition of the NSSB (03-1400), NISC (03-2322), and Strategic Computer Complex (03-2337) supercomputing facility through targeted maintenance programs
- Increase electrical system transmission import limit and provide full redundancy to support stable and reliable power supply essential to future programmatic missions located in TA-03
- Sustain 600,000 GSF of bridging facilities until they are demolished in the 2030s

Facilities		Lifecycle Estimates			
ID	Function	Built	Revitalize	Dispose	Size
New					
1	Secure Office Building	2020	2040	2070	8.0k
2	Lab Office Building	2020	2040	2070	12.0k
3	TA-03 Parking Structure	2021	2041	2071	-
4	Modular Office Building	2021	2041	2071	22.0k
5	Multidisciplinary Science Office/Light Lab Buildings	2024	2044	2074	80.0k
6	Operational Support Office/Lab Buildings & Badge Office	2026	2046	2076	200.0k
7	Los Alamos Canyon Bridge	2031	2051	2101	-
Enduring					
8	Strategic Computer Complex (03-2327)	2002	2027	2052	306.6k
9	Nonproliferation & International Security Center (NISC) (03-2322)	2003	2028	2053	169.4k
10	National Security Sciences Building (NSSB) (03-1400)	2006	2031	2056	296.6k
Bridging					
11	Physics Bldg (03-0040)	1953	1990	2033	164.4k
12	Administraton/Shops (03-0038)	1952	1993	2029	115.2k
13	Receiving and Distribution (03-0030)	1952	1995	2027	114.6k
14	Chemistry & Metallurgy Research (CMR) (03-0029)	1953	1999	2031	563.6k
15	Otowi Building (03-0261)	1982	2010	2036	140.6k
Excess					
16	Ion Beam (03-0016)	1953	1983	2031	56.3k

224 | 2021 MAP

Broader Program Relevance

TA-03 houses the majority of LANL's office and light laboratory space for Nonproliferation and Counterterrorism mission areas. This location enables synergistic opportunities with Weapons, Supercomputing, and Science capabilities.

225 | 2021 MAP

Figure 6–5. Area plan example

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

DOE/NNSA and its M&O partners have developed 66 area plans during FY 2021, representing assets and associated capabilities across the nuclear security enterprise. These area plans showcase important elements of each capability's long-term infrastructure plans and span both direct mission and mission-enabling capabilities (see Section 6.2.2 for additional details). They cover a myriad of topical areas, from flagship experimental facilities and weapon components to utilities and emergency services. When viewed collectively, area plans provide a roadmap for modernizing DOE/NNSA infrastructure to deliver on the mission.

6.2.2 Weapons Activities Line Item Planning Integration

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

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

> ***DOE/NNSA Capital Construction Levels***
>
> *Line item – a capital project >$20 million, so called because it has its own line in the Federal budget*
>
> *Minor Construction – a construction project <$20 million*
>
> *Institutional General Plant Project – a minor construction project that addresses an institutional, multi-program, general site need rather than a specific program need, using funding derived from indirect cost pools*

The consolidation of line item investment proposals combines multiple current data collection processes and ensures a consistent, repeatable planning process for all line item construction projects. The comprehensive review of project proposals by program offices ensures that all current and proposed line item construction projects (detailed in Sections 6.3.1 – 6.3.3), represent investments that support the program of record. The cost estimation process for proposals within capital acquisition is described in Chapter 8, Section 8.10.1.

6.2.3 Critical Decision Acquisition Milestone Process

A basic understanding of DOE's Critical Decision (CD) acquisition milestone process is integral to understanding the next several sections that discuss current and planned line item construction projects. DOE Order 413.3B, Chg 6, outlines a series of staged approvals for line item projects, each of which is referred to as a CD. Each CD stage requires specific deliverables prior to and during the process in order to progress to the next stage, which may be tailored based on the size or risk posed by the project. **Figure 6–6** shows the four phases of the CD process (Initiation, Definition, Execution, and Closeout), along with their corresponding CD stages.

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

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

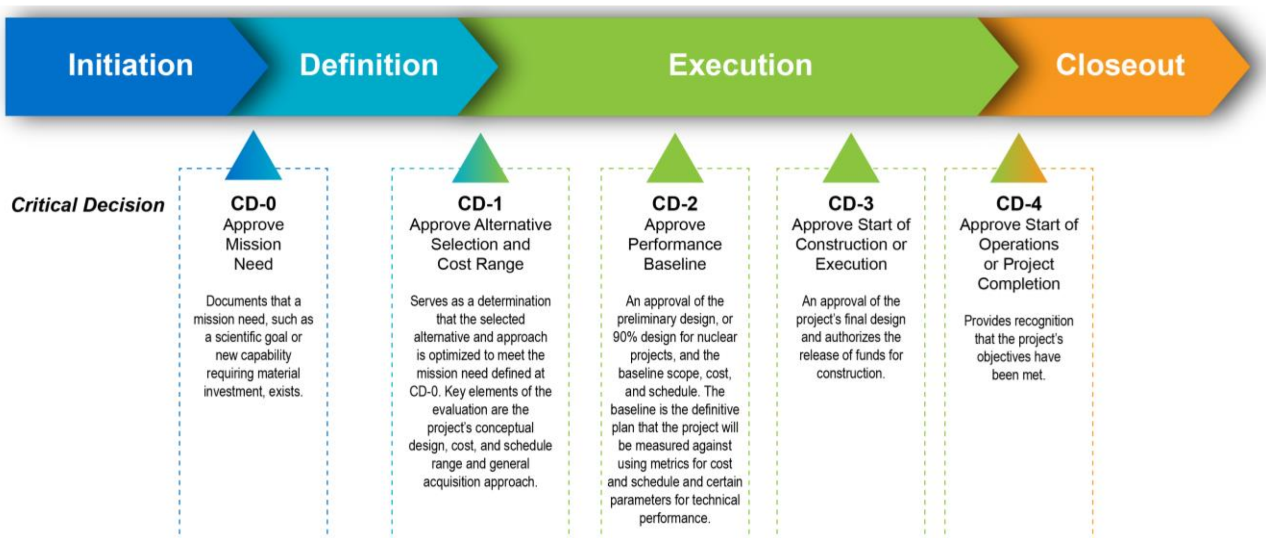
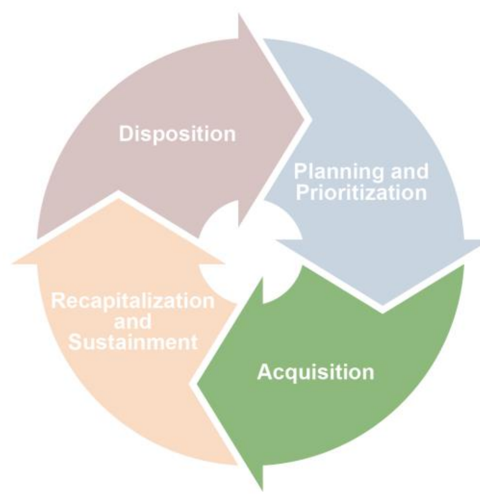


Figure 6–6. Critical Decision process

6.3 Acquisition Through Line Item Construction



In 2020, DOE/NNSA assets included over 5,000 facilities with an average age of over 40 years. Many of the largest and most complex of those facilities will require line item construction projects to accomplish modernization or replacement. Since aging facilities represent increasing risk to mission execution and line item projects often require significant coordination and funding over multiple years, DOE/NNSA continues to evaluate line item construction project proposals as a part of the overall 25-year plan for Weapons Activities.

DOE/NNSA's line item construction portfolio requires consistent, stable, and timely funding. In addition, the sizes and complexities of these projects present several program and project management challenges, as outlined in Section 6.1.1. In spite of these challenges, DOE/NNSA has demonstrated success: DOE/NNSA is no longer on the Government Accountability Office High-Risk List for the management of line item projects under $750 million. However, the complexity of the DOE/NNSA acquisition processes still presents a challenge to meeting enterprise needs in a responsive and timely manner.

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

6.3.1 Programmatic Construction

Since aging facilities represent increasing risk to mission execution, DOE/NNSA is implementing a line item portfolio solution to ensure infrastructure is in place to meet program requirements, while improving DOE/NNSA's facility condition and reducing the average facility age to a sustainable level. **Figure 6–7** demonstrates the historical average age growth of DOE/NNSA's major programmatic facilities and the planned reduction in average age after completing the projects identified through the Weapons Activities line item planning integration process.

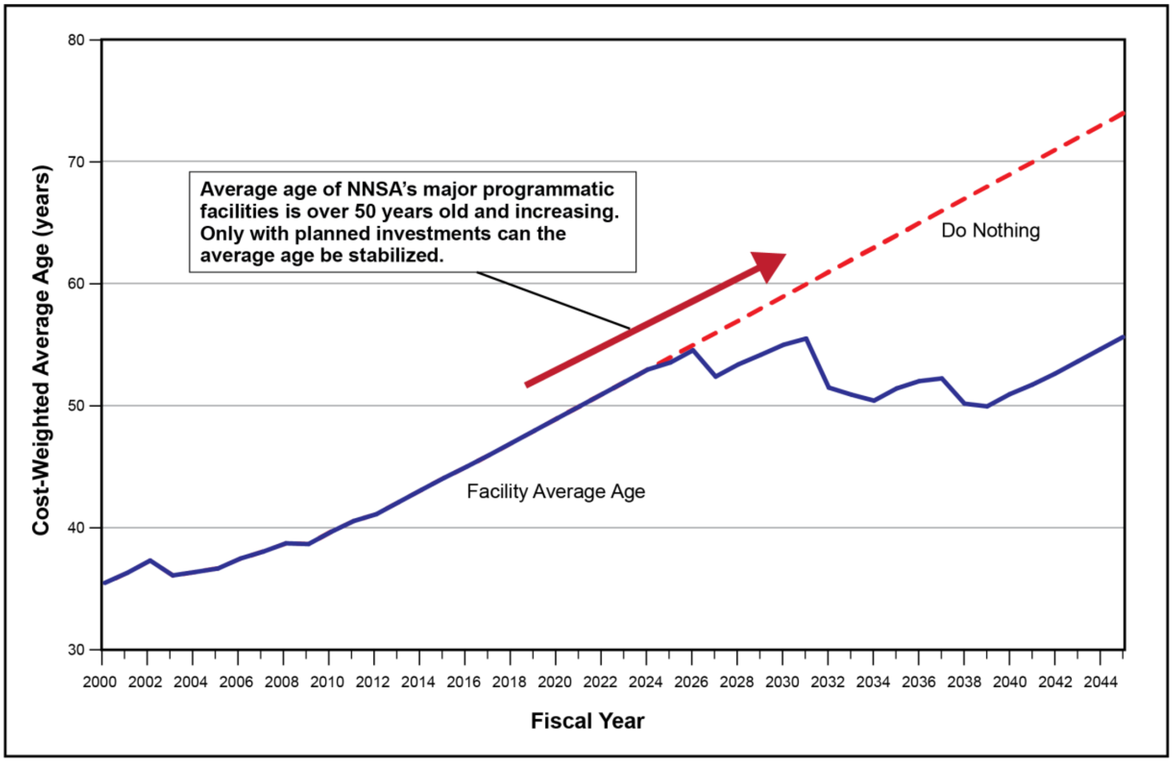


Figure 6–7. Historical and projected average age of major DOE/NNSA programmatic facilities

Programmatic construction projects are categorized according to the Weapons Activities capability portfolios introduced in the FY 2021 SSMP. Sections 6.3.1.1 – 6.3.1.7 describe current and proposed line item projects within each capability portfolio, including their projected schedules and cost ranges. Project proposals (Pre-CD-0) represent identified mission gaps as known and emerging requirements across the nuclear security enterprise, but require additional vetting before the gap is considered for satisfaction by a line item, another materiel solution, or deemed redundant if mission need is met through a different project. The projected schedules and cost ranges shown represent one potential planning scenario and may change in future SSMPs as stockpile and enterprise requirements are refined.

6.3.1.1 Weapon Material Processing and Manufacturing

Line item projects in the Weapon Material Processing and Manufacturing portfolio are related to 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. Current planning estimates and schedule dates for projects in this portfolio are listed in **Figure 6–8**.

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

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

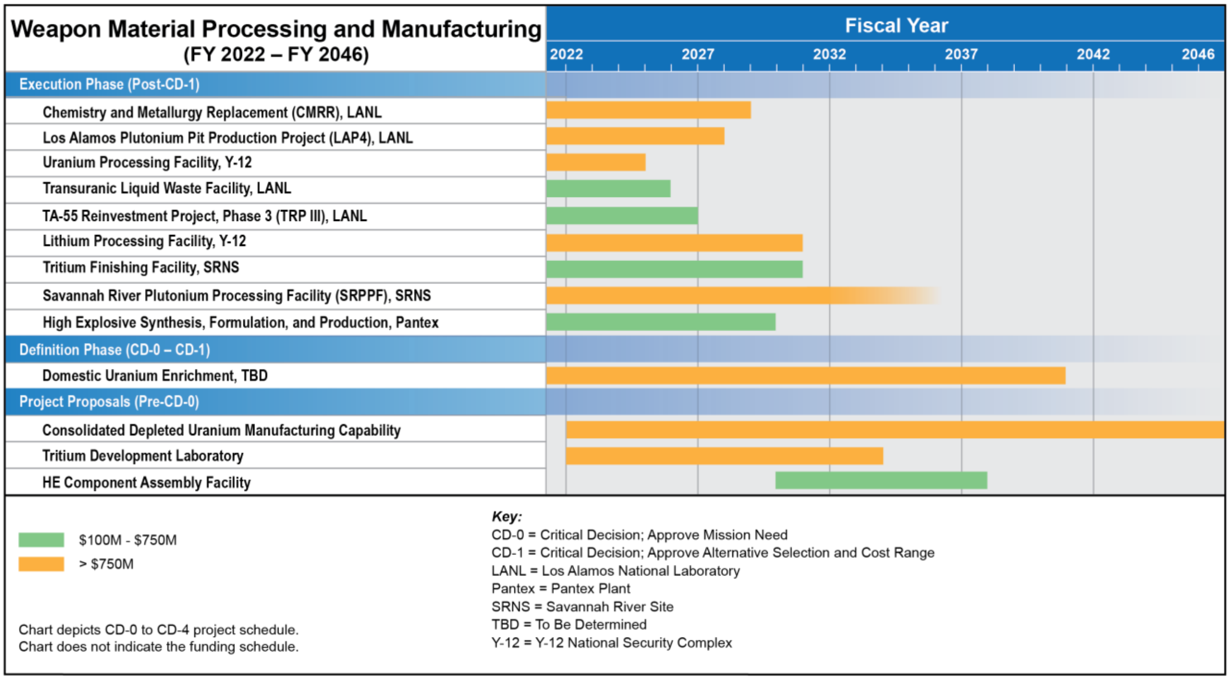


Figure 6–8. 25-year programmatic line item schedule for ongoing and proposed projects related to Weapon Material Processing and Manufacturing

- The **Los Alamos Plutonium Pit Production Project (LAP4)** will support plutonium pit production at LANL. The LAP4 project replaces aging/outdated equipment with pit manufacturing equipment in PF-4 to increase the throughput from 1 pit per year to 30 pits per year in 2026. LAP4 achieved CD-1 in FY 2021.
- The **Uranium Processing Facility** project will ensure the long-term viability, safety, and security of DOE/NNSA's enriched uranium capability. It will provide a modernized capability to manufacture weapon subassemblies containing enriched uranium components and convert excess enriched uranium into forms suitable for safe, long-term storage and reuse. The new facility will support the majority of Y-12's enriched uranium processing operations, which are currently housed in numerous aging, inefficient buildings in poor condition that pose multiple risks to meeting the mission. The oldest building supporting this capability, 9212, does not currently meet codes and standards, is costly to operate, and has many operating issues. This project will complete the first phase of the Uranium Mission Strategy.
- The **Transuranic Liquid Waste Facility** will support the treatment of transuranic liquid waste, which is a key support capability for DOE/NNSA operations at PF-4. The current facility that treats liquid waste is past its useful life and does not meet current codes requirements. The Transuranic Liquid Waste Facility is designed to receive up to 29,000 liters of liquid waste annually from PF-4 operations, which produces pits for the Nation's enduring stockpile.
- The **TA-55 Reinvestments Project (Phase 3)** will support design and construction of new fire alarm systems in PF-4 at LANL and removal of the old system. The main fire alarm panel and supporting devices represent a single-point failure risk.

Manhattan-era building 9212 at Y-12 (left) and construction on its replacement, the Uranium Processing Facility (right)

- The **Lithium Processing Facility** will construct a new facility to replace Y-12 Building 9204-2. At 75 years old, the current lithium facility is one of the oldest operating facilities in the nuclear security enterprise. Until the new Lithium Processing Facility is operational and qualified, much of the risk to lithium sustainment is associated with the age and degradation of the existing facility.
- The **Tritium Finishing Facility** project will construct two new processing buildings and relocate the vulnerable reservoir-related capabilities from the current facility to the newer, centralized facilities. This alternative will significantly reduce operational risk and increase facility reliability, compared to continuing operation in the current facility for an additional 20 years.
- The **Savannah River Plutonium Processing Facility (SRPPF)** will support plutonium pit production by repurposing the former Mixed Oxide Fuel Facility (MFFF) into a safe, secure, compliant, and efficient pit production facility. The former MFFF is a Security Category I/Hazard Category II[3] structure that provides an opportunity to achieve pit production in a facility designed to meet stringent security and safety requirements for plutonium operations. The SRPPF will provide a sustained production capacity of no fewer than 50 War Reserve pits per year at SRS. The project achieved CD-1 in FY 2021.
- The **High Explosives Synthesis, Formulation, and Production Facility** project will establish high explosives (HE) production capability within the nuclear security enterprise to address the inability of current domestic HE supply to meet DOE/NNSA production requirements. This project will consolidate limited legacy facilities that are inadequate for the mission need and will ensure the required capability and capacity is available to meet the future HE workload and mission requirements. Areas to be addressed include explosive and mock formulation operations to support multiple weapon programs, technology development for future programs, and support for strategic partners.

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

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

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

In addition to projects in the Definition and Execution Phases, DOE/NNSA is considering a number of programmatic line item proposals in the Weapon Material Processing and Manufacturing portfolio (Pre-CD-0). These project proposals are in the planning process but should not be considered a part of the program of record until they achieve appropriate approvals:

- The **Consolidated Depleted Uranium Manufacturing Capability** project will consolidate several processes required to meet customer needs. These processes include special materials, depleted uranium, and general manufacturing. Updating the processing methods and right-sizing the facility for current and foreseeable production needs will mean a significant reduction in the footprint defined by the existing facilities. This project will assure continued mission availability and reduce annual operating costs.
- The **Tritium Development Laboratory** project will reestablish the radiological research and development (R&D) capability required for maturation and de-risking of new tritium and gas transfer system (GTS) processing technologies to meet mission requirements, address obsolescence, increase efficiency, and maintain core competencies.
- The **High Explosive Component Assembly Facility** project will support weapons assembly, disassembly, and stockpile surveillance. The facility is required to fabricate parts for current weapon rebuilt units, future nuclear weapon assembly and rebuilds, and Joint Test Assemblies. These existing component assembly facilities support all current weapons systems subassembly, weapons surveillance subassembly, and main charge dismantlement activities under the current production, surveillance, and dismantlement Production Control Document schedule. Facility capacity must equal the assembly and disassembly rates required for future workloads.

6.3.1.2 Weapon Component Production

Line item projects in the Weapon Component Production portfolio support the research, design, development, qualification, surveillance, manufacturing and production for all non-nuclear components and systems for weaponization of the nuclear explosive package. Current planning estimates and schedule dates for projects in this portfolio are listed in **Figure 6–9**.

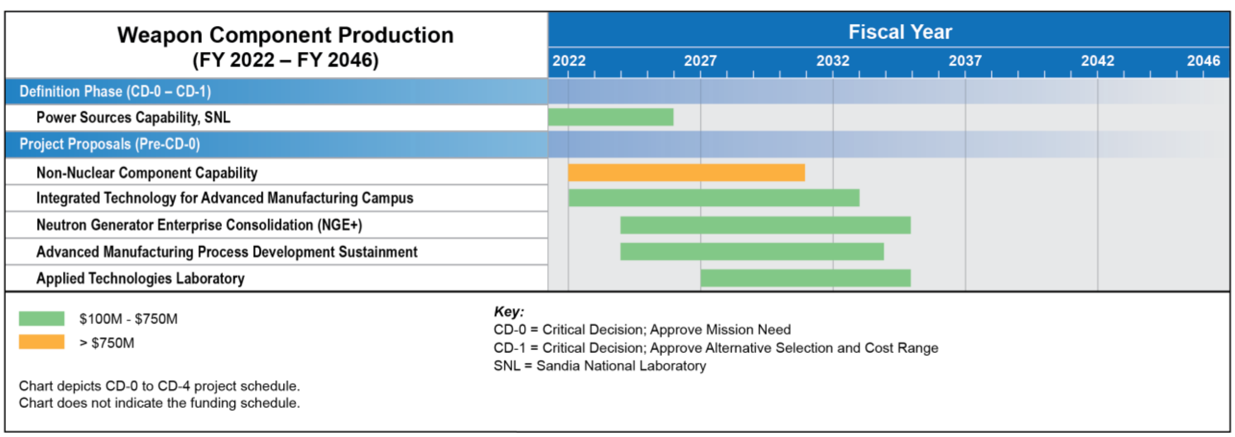


Figure 6–9. 25-year programmatic line item schedule for ongoing and proposed projects related to Weapon Component Production

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

- The **Power Sources Capability** project will support all current and planned nuclear weapon systems that require power source research, development, design, qualification, production, and surveillance activities. Requirements for these power sources are unique to nuclear weapons, and commercial suppliers are not viable for this work. The current facility cannot meet anticipated mission requirements due to both increasing workload and poor facility condition, which poses increasing risks to meeting weapon program deliverables. DOE/NNSA also supplies advanced power sources for other national security mission needs that cannot be commercially sourced. This project will mitigate risk by exploring options for a robust, agile, and reconfigurable facility that is adaptable to changing needs; enables engagement with supply chain partners; supports technology development; and fosters innovation. Scope options under consideration include dedicated dry room, battery testing, and chemistry/wet laboratories, as well as specialized spaces for rapid product realization, destructive testing, X-ray analysis laboratories, and hazardous storage.

In addition to the project in the Definition Phase, DOE/NNSA is considering a number of programmatic line item proposals in the Weapon Component Production portfolio (Pre-CD-0). These project proposals are in the planning process but should not be considered part of the program of record until they achieve appropriate approvals:

- The **Non-Nuclear Component Capability** project will support weapon modernization in several production programs during the mid-2030s. The Non-Nuclear Component Capability project approach may leverage current facilities, utilize new manufacturing and testing technologies, coordinate with existing commercial manufacturing facilities, and plan for new-build facilities on existing DOE/NNSA land to meet increasing demand.
- The **Integrated Technology for Advanced Manufacturing Campus (ITAMC)** project will create modern infrastructure with capabilities for development of advanced assembly system technologies (robotics and automation, welding, inspection, etc.) to accelerate deployment. ITAMC will collocate a number of capabilities, including manufacturing, assembly, computing, characterization, and inspection expertise, in an open, collaborative space with the ability to elevate to secure, when needed.
- The **Neutron Generator Enterprise Consolidation (NGE+)** project will optimize manufacturing by consolidating existing facilities for neutron generator operations that are currently conducted in several buildings across multiple sites. Additionally, modernizing aging infrastructure and providing flexible-use space is needed to accommodate agile responses to advancing requirements and technology, develop material and personnel flows, improve efficiency, consolidate processes, and reduce redundancies, waste, and risks to mission work.
- The **Advanced Manufacturing Process Development Sustainment** project will provide high-bay laboratory space to accommodate advanced additive manufacturing research and production-capable manufacturing tools while also addressing electrical and fabrication laboratories in a reconfigurable space that facilitates agile and rapid product realization. Improving these facilities also ensures continued support to the DOE/NNSA initiative to reduce weapon development cycle times and addresses anticipated obsolescence of manufacturing technologies and materials used today in the nuclear weapons program.
- The new **Applied Technologies Laboratory** will replace the aging development facilities with a smaller, modernized facility designed for technological advancement. These improvements are

critical to flexibility in accommodating DOE/NNSA design agency requirements, improving productivity, reducing operating costs, and protecting workers and the public.

6.3.1.3 Weapon Simulation and Computing

Line item projects in the Weapon Simulation and Computing portfolio enable high performance computing (HPC) and development of the weapons codes, models, and data analytics used to design and assess the behavior of nuclear weapons systems and components. Current planning estimates and schedule dates for projects in this portfolio are listed in **Figure 6–10**.

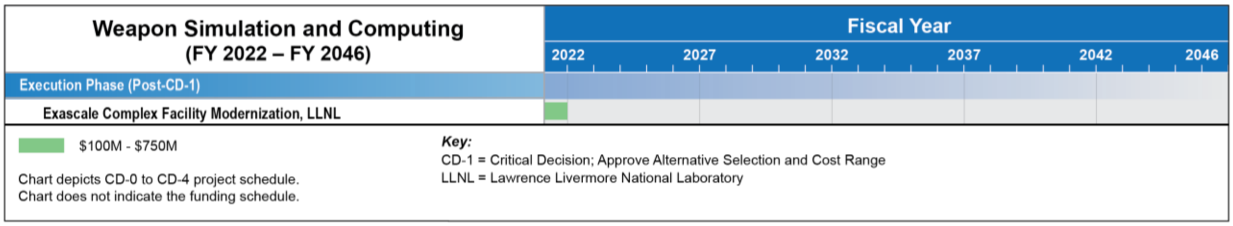


Figure 6–10. 25-year programmatic line item schedule for ongoing and proposed projects related to Weapon Simulation and Computing

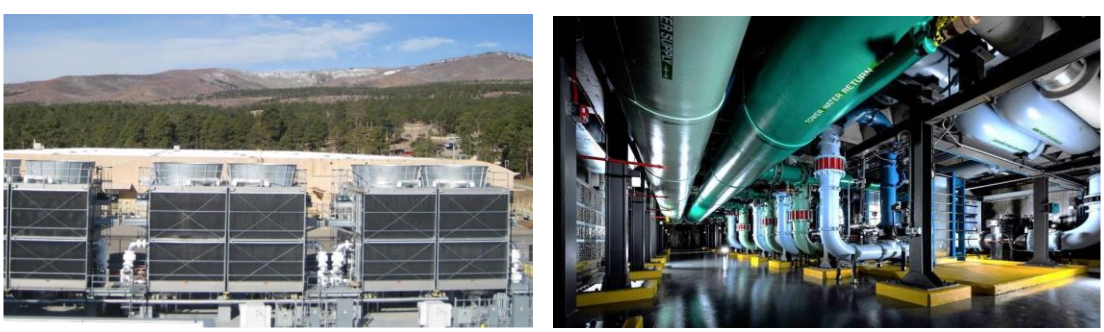
DOE/NNSA recently completed one project in the Weapon Simulation and Computing portfolio:

- The **Exascale Class Computer Cooling Equipment (EC3E)** project nearly doubles the highly efficient, warm-water cooling capability in the LANL Strategic Computing Complex and enables the facility operational support for current and upcoming supercomputers. The project provides warm-water cooling for LANL's next advanced-architecture supercomputer, Crossroads, which is scheduled for delivery in FY 2022. In May 2020, the project reached CD-4, 10 months ahead of schedule and $20 million under budget.

DOE/NNSA is currently executing one programmatic line item project in the Weapon Simulation and Computing portfolio that is past CD-1. Cost and schedule estimates for these projects vary from conceptual design-based estimates to baselined project estimates.

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

There are no current programmatic line item proposals in the Weapon Simulation and Computing portfolio (Pre-CD-0).



Cooling Towers and Tower Piping installed during the EC3E project at LANL

6.3.1.4 Weapon Design and Integration

Line item projects in the Weapon Design and Integration portfolio support the capabilities needed to research, design, test, analyze, qualify, and integrate components and subsystems into weapon systems that will meet all military requirements and endure all predicted environments. Current planning estimates and schedule dates for projects in this portfolio are listed in **Figure 6–11**.

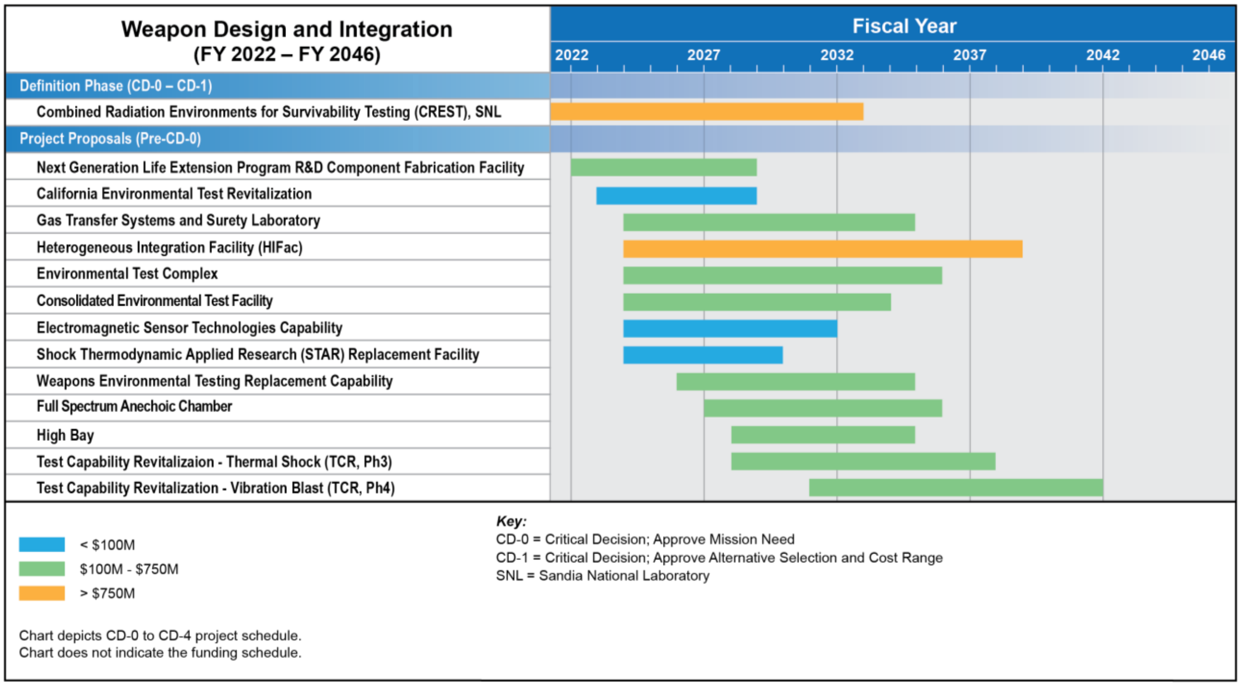


Figure 6–11. 25-year programmatic line item schedule for ongoing and proposed projects related to Weapon Design and Integration

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

- The **Combined Radiation Environments for Survivability Testing (CREST) Complex** project will provide an advanced radiation environmental test capability to fill a mission gap for R&D, qualification, and certification data in combined survivability/threat environments. The Annular Core Research Reactor's (ACRR) current capability provides high-fidelity neutron and gamma-ray environments that emulate nuclear weapon environments in support of weapons development and certification. The existing ACRR facility is aging and nearly 60 years old, was not designed to house a nuclear reactor, and does not meet modern codes or standards. The age and condition of the facility have resulted in inefficiencies that have reduced test operations to only 3 or 4 days per week. Nearly every weapon component in the stockpile undergoes testing at the ACRR, and demand is increasing. The proposed CREST project will explore options to provide a replacement facility into which the existing reactor fuel could be relocated. One option under consideration is to combine the current ACRR capabilities with an independent gamma-ray irradiation capability in a safe, purpose-built facility. Other scope options include new or improved nuclear material storage, handling, and processing space and associated laboratories, offices, and other infrastructure.

In addition to projects in the Definition and Execution Phases, DOE/NNSA is considering a number of programmatic line item proposals in the Weapon Design and Integration portfolio (Pre-CD-0). These project proposals are in the planning process, but should not be considered part of the program of record until they achieve appropriate approvals:

- The **Next-Generation Life Extension Program Research and Development Component Fabrication Facility (NextGen Fabrication Facility)** is a joint design agency-production agency-owned collaborative space and testbed that can assess, develop, tailor, and transition new manufacturing technologies and designs that will enable DOE/NNSA to accelerate the development and production of non-nuclear components for future modernization programs.
- The **California Environmental Test Revitalization** project is intended to improve the efficiency, effectiveness, agility, and responsiveness of the California environmental test capabilities through structural upgrades to aging facilities to meet modern security standards and current energy codes.
- The **Gas Transfer Systems and Surety Laboratory** project is needed to meet GTS and Surety mission requirements in the future. The future GTS and Surety project will provide a modern, lower-maintenance structure capable of meeting the expanded, future demands of the program. Work areas and equipment will be upgraded with an efficient layout and current, state-of-the-art technology to meet current and specific testing requirement needs.
- The **Heterogeneous Integration Facility (HIFac)** project is intended to provide additional modern, cleanroom space to ensure the delivery of critical strategic radiation-hardened microsystems meet system safety, security, and reliability requirements to reduce currently unacceptably high levels of risk.
- The **Environmental Test Complex** project consolidates multiple aged environmental testing operations to a single location closer to future assembly and radiography capabilities. The objective of this project is to provide an integrated environmental testing capability to support nuclear weapons-related testing for the Nation's current and future nuclear weapons stockpile.
- The **Consolidated Environmental Test Facility** project aims to upgrade, modernize, and consolidate environmental testing capabilities in support of stockpile modernization programs and limited life components associated with enduring the stockpile.
- The **Electromagnetic Sensor Technologies Capability** proposed project is a replacement of the current facility to accommodate new programmatic equipment. Supporting infrastructure is to be constructed near the current location to facilitate integration with related engineering and design activities and provide a low electromagnetic interference environment.
- The **Shock Thermodynamic Applied Research (STAR) Replacement Facility** project involves replacing the previous, over 50-years-old STAR Facility to both maintain current capabilities and expand ability and performance of scientific and science-based engineering research.
- The **Weapons Environmental Testing Replacement Capability** project aims to relocate and construct new facilities to consolidate and modify current environmental testing activities. These facilities will need to meet current and future requirements, such as being rated for explosives operations, cooling systems to handle testing, and ducting to accommodate external thermal condition units.
- The **Full Spectrum Anechoic Chamber** facility would provide improved experimental capabilities that would address design and qualification gaps. The facility would provide data to enable electromagnetic radiation application-code model validation and would provide better understanding of design margins.

- The **High Bay** project aims to replace aging infrastructure to meet advancing requirements, including seismic stabilizing needs.
- The **Test Capability Revitalization – Thermal Shock (TCR, Phase 3)** and **TCR – Vibration Blast (TCR, Phase 4)** projects focus on large subsystem- and system-level test facilities in thermal, fire, acceleration, impact, shock, and other environments. TCR, Phases 3 and 4, will renovate or replace existing capabilities and/or develop new capabilities at current facilities.

6.3.1.5 Weapon Science and Engineering

Line item projects in the Weapon Science and Engineering portfolio encompass the suite of physical sciences and engineering disciplines that comprise the theoretical and experimental capabilities necessary to assess the current nuclear stockpile and design and certify future stockpile weapons. Current planning estimates and schedule dates for projects in this portfolio are listed in **Figure 6–12**.

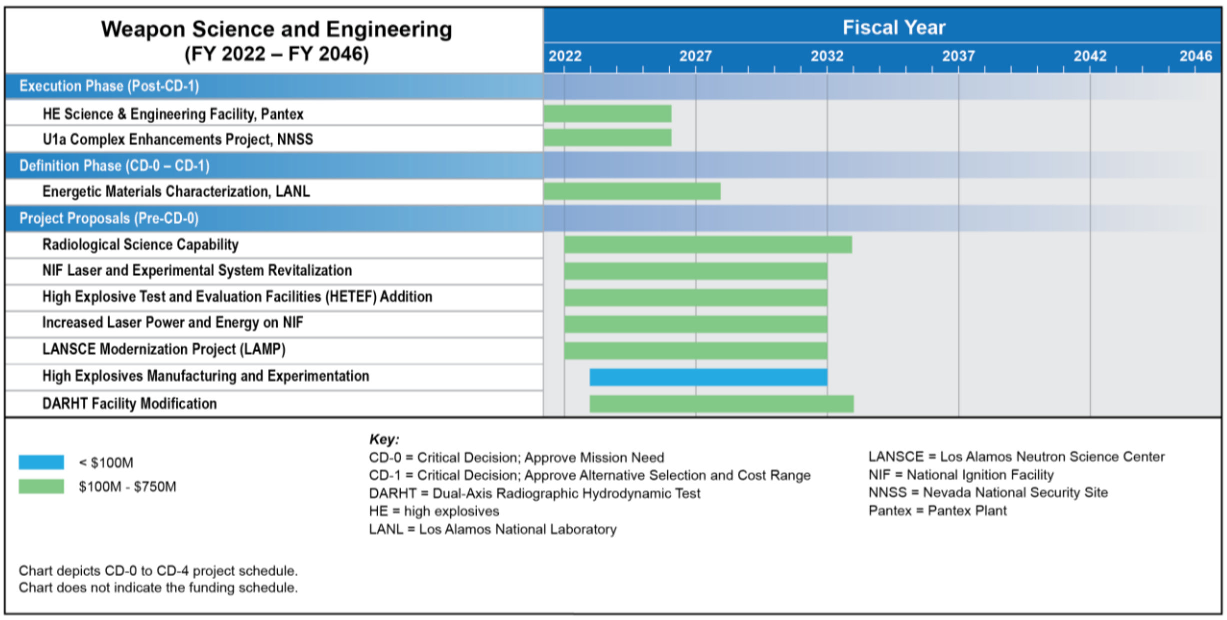


Figure 6–12. 25-year programmatic line item schedule for ongoing and proposed projects related to Weapon Science and Engineering

DOE/NNSA is currently executing one major item of equipment (MIE)[4] project, Advanced Sources and Detectors (ASD), in the Weapon Science and Engineering portfolio that is past CD-1.

- The **Advanced Sources and Detectors** project will fill the pulsed x-radiography capability gap through development of a four-pulse linear induction electron accelerator. The scope includes design, fabrication, testing, installation, commissioning, and execution of readiness at the U1a Complex.

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

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

- The **High Explosive Science and Engineering (HESE) Facility** will construct three new buildings to provide technology development laboratory and office space for technical staff. HESE will replace 15 current Manhattan-era facilities at Pantex, support the HE Center of Excellence for Manufacturing mission for DOE/NNSA, and help sustain high-quality scientific staff. The average age of the facilities to be replaced is 68 years old. The HESE facility will be approximately 73,000 square feet. Project design is complete, and the project received CD-3A approval in FY 2020. Site preparation and long-lead procurement activities started at the beginning of FY 2021.
- The **U1a Complex Enhancements Project (UCEP)** will provide infrastructure modifications to the U1a Complex at the Nevada National Security Site (NNSS) to house and field multi-pulse radiography. This includes structures, systems, and components necessary for deployment of the Enhanced Capabilities for Subcritical Experiment ASD Project's pulsed X-ray radiography equipment and potential future neutron-diagnosed subcritical experiments technology, which will produce valuable data on the phenomena associated with the final stages of a weapon implosion.

U1a dual-headed mining breakthrough: Two mining crews working over 960 feet underground finish tunneling toward each other to meet in the middle.

The following programmatic line item project in the Weapon Science and Engineering portfolio is in the Definition Phase of the CD process (CD-0 to CD-1):[5]

- The **Energetic Materials Characterization** project will support R&D to advance predictive capabilities for safety and performance assessments and qualification and surveillance; evaluate material responses to all phases of the stockpile-to-target sequence; resolve significant finding investigations (SFIs); provide technical data on which to base annual weapon assessments; and develop new/replacement materials in support of evolving HE technical requirements. The project will consolidate 18 structures into a single modern facility to reduce operating costs. Current structures are prone to sudden, unexpected failures and do not meet current design or safety standards.

In addition to projects in the Definition and Execution Phases, DOE/NNSA is considering seven programmatic line item proposals in the Weapon Science and Engineering portfolio (Pre-CD-0). These project proposals are a part of the planning process but should not be considered as a part of the program of record until they achieve appropriate approvals:

- The **Radiological Science Capability** project will consolidate and relocate the aging radiological facilities that support LANL weapons and global security mission requirements. The planned replacement facility will support critical missions including weapons programs, nuclear forensics, and nonproliferation programs, as well as broad science capabilities (e.g., actinide separation and synthetic chemistry).

[5] The previously reported Dynamic Mesoscale Materials Science Capability project has been canceled.

- The **National Ignition Facility (NIF) Laser and Experimental System Revitalization** project will update NIF, which was constructed in the 2000's and remains the Nation's premier high energy density (HED) facility and the world's largest laser. With over 10 years in operation and over 25 years since design and construction, many of NIF's systems are obsolete and are becoming unreliable and difficult to maintain. Many components are no longer available in industry and, in some cases, new technologies can replace obsolete systems to improve reliability and performance. This project would complete the required maintenance, refurbishment, and recapitalization work to keep NIF delivering for stockpile stewardship through the 2030s.
- The **High Explosives Test and Evaluation Facilities (HETEF) Addition** project integrates the synthesis, formulation, and explosives testing in one facility. Major stockpile modernization programs will require additional HE research capacity and capabilities to ensure the safety, security, and certification of warhead systems. The project includes construction for scientific and laboratory space utilized for explosives experimentation. The proposal approach is to leverage an existing large investment by DOE/NNSA by adding the HETEF to the High Explosives Application Facility (HEAF) to capitalize on the existing structure, equipment, and workforce.
- The **Increased Laser Power and Energy on NIF** project would close gaps in understanding boost, materials properties in extreme conditions, and nuclear weapon's vulnerabilities and hardness. The project has the potential to enable higher-yield experiments that further increase the fidelity of weapons physics experiments and enable the continued progress in support of ignition. This project includes modifications to the NIF and its support facilities to provide a 20-30 percent increase in power and energy to support the stockpile stewardship objectives described above. It is part of a broader effort to sustain and improve NIF as a vital HED physics tool for stockpile stewardship.
- The **Los Alamos Neutron Science Center (LANSCE) Modernization Project** would replace the entire front-end accelerating structures of the LANSCE accelerator and thereby extend the longevity of LANSCE. The LANSCE accelerator was commissioned in 1972 and is in danger of suffering a catastrophic failure. The front-end systems are large and difficult to maintain primarily due to the unavailability of obsolete components.
- The **High Explosives Manufacturing and Experimentation** project aims to modernize capabilities, including modernizing or refurbishing infrastructure, to manufacture legacy and new HE materials at pilot scale for weapons design and prototyping efforts.
- The **Dual-Axis Radiographic Hydrodynamics Test (DARHT) Facility Modernization** project will modernize the DARHT accelerators, control systems, and building safety systems, and will be phased to follow and leverage experience with the Scorpius hydrodynamic capability being built at NNSS. The Weapons Program needs high-quality, reliable, reproducible DARHT data at the rate of 10 to 15 full-scale hydro tests per year. Currently, aging accelerator, control, and safety systems must be brought up to modern standards to support design community requirements and assure uninterrupted delivery of data to support concepts of a flexible and responsive stockpile.

6.3.1.6 Weapon Assembly, Storage, Testing, and Disposition

Line item projects in the Weapon Assembly, Storage, Testing, and Disposition portfolio support the safe and secure assembly, storage, testing, and disposition of weapon components and warheads. Current planning estimates and schedule dates for ongoing and proposed projects in this portfolio are listed in **Figure 6–13**.

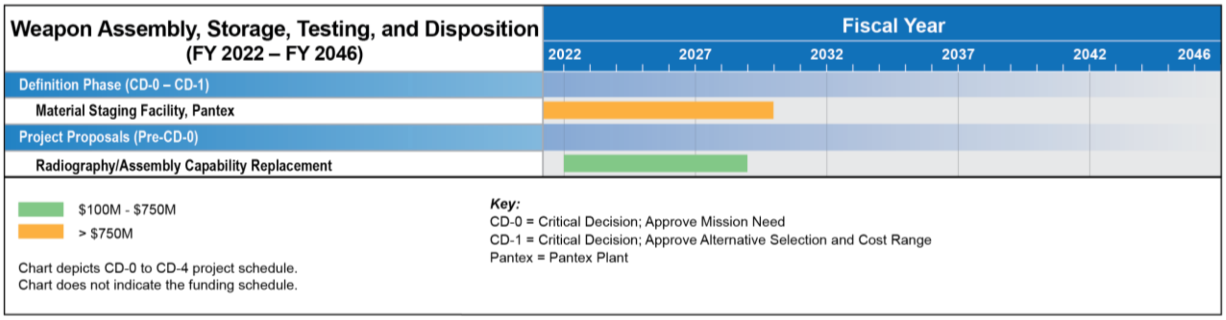


Figure 6–13. 25-year programmatic line item schedule for ongoing and proposed projects related to Weapon Assembly, Storage, Testing, and Disposition

DOE/NNSA is not currently executing any programmatic line item projects in the Weapon Assembly, Storage, Testing, and Disposition portfolio. The following programmatic line item project in this portfolio is in the Definition Phase of the CD process (CD-0 to CD-1):

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

In addition to the project in the Definition Phase, DOE/NNSA is considering one programmatic line item proposal in the Weapon Assembly, Storage, Testing, and Disposition portfolio (Pre-CD-0). This project proposal is in the planning process but should not be considered as part of the program of record until it achieves appropriate approvals:

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

6.3.1.7 Transportation and Security

Line item projects in the Transportation and Security portfolio support the protection of all aspects that are critical to the function of the nuclear security enterprise. The Secure Transportation capability within this portfolio has no current or proposed line item projects. The projects listed below support the Physical Security capability, which protects all nuclear materials, infrastructure assets, and the workforce at DOE/NNSA sites that are involved in Weapons Activities programs and operations.[6] Current planning estimates and schedule dates for projects in this portfolio are listed in **Figure 6–14**.

[6] The Physical Security line item construction projects are funded under Defense Nuclear Security, not Infrastructure and Operations. They are included here to provide a complete overview of Weapons Activities line item projects. See Chapter 5, Security, for complete description of Defense Nuclear Security activities.

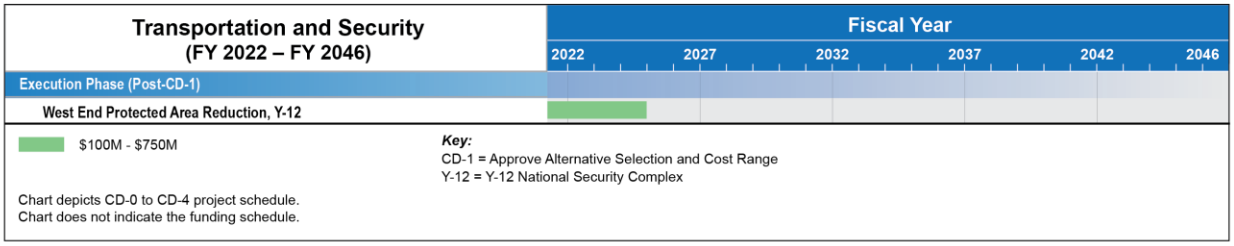


Figure 6–14. 25-year programmatic line item schedule for ongoing and proposed projects related to Transportation and Security

DOE/NNSA recently completed one project in the Transportation and Security portfolio:

- The **Device Assembly Facility (DAF)** Argus Project at NNSS supported installation of new security system elements in the DAF Building and around the perimeter.

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

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

6.3.2 Mission Enabling Construction

DOE/NNSA also funds mission-enabling infrastructure line items that provide site-wide utilities, office and laboratory space, and other services that support the nuclear deterrence mission (see **Figure 6–15**). These projects are required to meet day-to-day operational needs across the nuclear security enterprise.

The mission enabling projects listed below are currently in the Execution Phase of the CD process. This includes four pilot projects (Y-12 Fire Station and the three Emergency Operations Centers at Y-12, LLNL, and SNL). The pilot projects present an opportunity to acquire commercial-like facilities using an approach that is novel for DOE/NNSA, but is common in commercial construction. The pilot plan will use existing, successful minor construction program management processes, certified Federal Project Directors, and widely-used commercial construction practices to appropriately streamline the delivery of these small, lower risk projects. The intent is to challenge the current norms to the greatest extent possible in order to create a new, streamlined process for this class of commercial-like, low-risk, low-cost construction.

- The **Technical Area 3 (TA-3) Substation Replacement** at LANL will provide increased distribution capacity, improved reliability, reduced maintenance, support for greater operational flexibility, and increased worker safety. It will provide separate power feeds to both LANL and Los Alamos County.

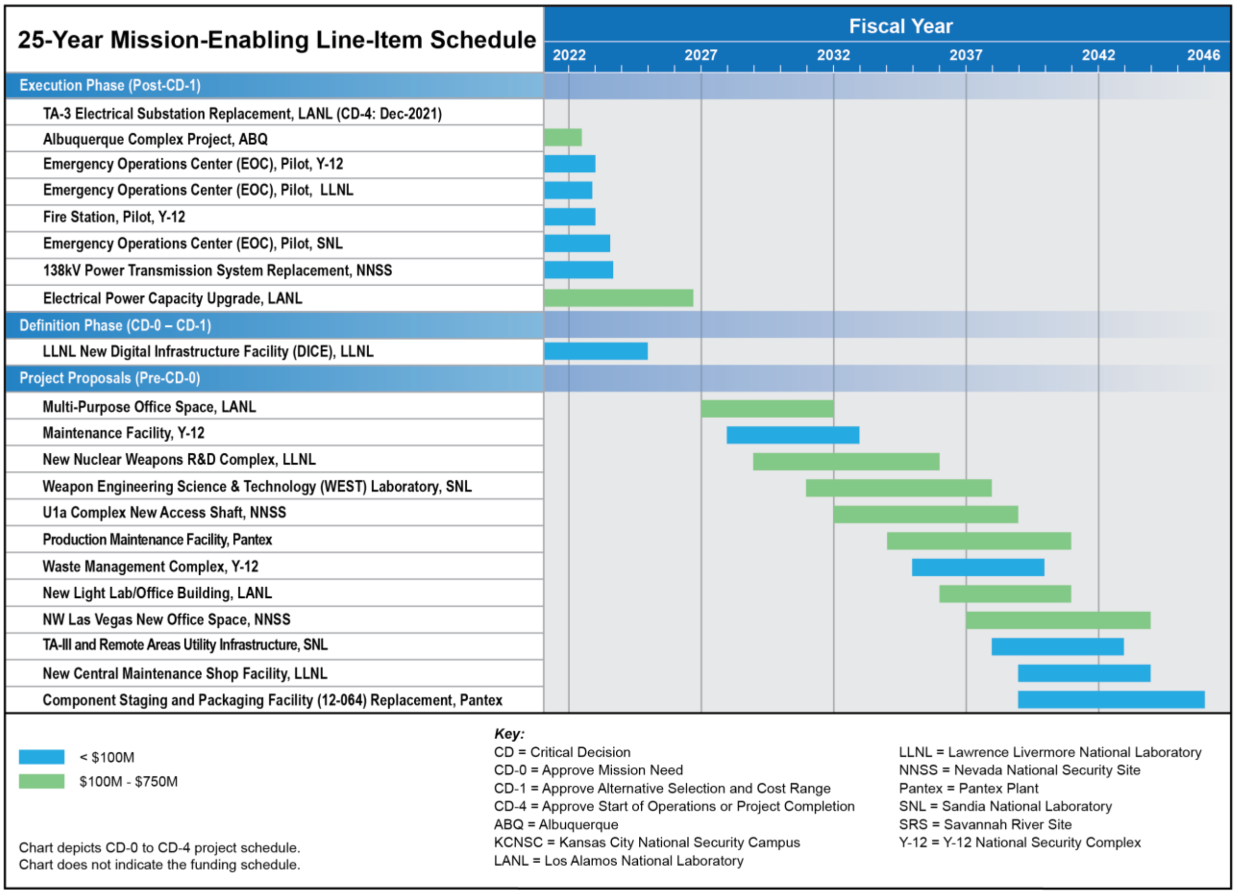


Figure 6–15. 25-year mission-enabling line item schedule

- The **Albuquerque Complex Project** is under construction on DOE property in Albuquerque, New Mexico, adjacent to Kirtland Air Force Base. The current DOE/NNSA Albuquerque Office Complex is beyond its design life and does not meet DOE/NNSA's mission needs. Construction was completed in FY 2021 on a 333,000-square-foot building to house approximately 1,200 employees. The new building is designed to Leadership in Energy and Environmental Design Gold Standards.
- The **Emergency Operations Center** at Y-12 will provide a centralized, comprehensive emergency management capability for the development, coordination, control, and direction of emergency planning, preparedness, readiness assurance, response, and recovery actions. The current facility is not compliant with DOE Order 151.1C, *Comprehensive Emergency Management System*. This project has been delegated to the Alternative Construction Pilot Program for acquisition and construction. Construction began in FY 2021 and is planned for completion in FY 2022.
- The **Emergency Operations Center** at LLNL provides a new permanent Emergency Operations Center with comprehensive emergency management capabilities for the development, coordination, control, and direction of emergency planning, preparedness, readiness, assurance, response, and recovery actions. The 20,000-gross-square-foot building will allow an occupancy rate needed during an emergency event that the current Emergency Operations Center cannot accommodate; provide additional parking; and contain or interface with approximately 60 systems, including closed-circuit television, metrology, site fire and life safety alarms, radio communication, emergency services disaster dispatching, etc.

- The **Fire Station** project at Y-12 provides a single-story building (approximately 35,000 square feet) to meet all emergency response requirements including firefighting, emergency medical treatment and transport, hazardous materials spill mitigation, and technical rescue responses for all events within the site emergency response boundary at the Y-12 site. The new facility will be built to meet all safety standards and building codes to support 24-hour, 7-days-a-week operations under all environmental conditions. The facility will accommodate a workforce and a fleet of large fire apparatus vehicles, ambulances, emergency response vehicles, and other support vehicles. This project has been delegated to the Alternative Construction Pilot Program for acquisition and construction. Construction began in FY 2021 and is planned for completion in FY 2022.
- The **Emergency Operations Center** at SNL will provide a facility that meets DOE/NNSA and SNL standards and requirements, to include personnel parking, computing, communications, building systems, and fuel and water storage sufficient to mitigate all potential emergency operations/management response capabilities.
- The **138kV Power Transmission System Replacement** project will replace a 55-year-old 138-kilovolt (kV) power transmission system in the NNSS Mission Corridor in Mercury, Nevada, to provide the site with reliable power and communications to mission-critical facilities. The project will design and construct a new 138-kV power transmission system to replace and upgrade 23 miles of the degraded existing power transmission system. It will also upgrade the collocated fiber optic lines to meet vital national security mission requirements.
- The **Electrical Power Capacity Upgrade** at LANL will address projected increases in the capacity and distribution of the electrical transmission and distribution system at LANL to reliably support demand for multiple program activities being performed at the site. By 2024, power demand for all programs is expected to exceed the capacity and performance requirements of LANL's existing transmission and distribution system. This electrical upgrade will support critical Weapons Activities requirements for stockpile modernization programs, SFIs, ongoing stockpile stewardship programs, and other work.

The following mission enabling project is in the Definition Phase of the CD process:

- The **Digital Infrastructure Capability Expansion** project at LLNL will provide safe, secure, resilient, reliable, flexible, and sustainable infrastructure for LLNL's networking and telecommunications digital infrastructure needs. The project will expand capabilities to meet growth projections for the next 40 years.

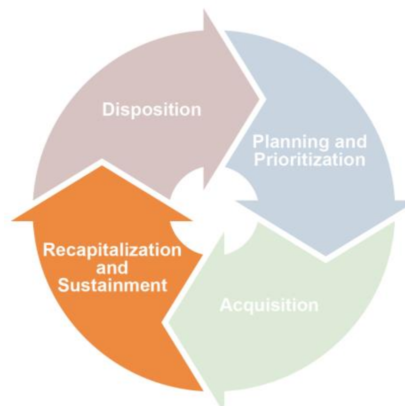
There are multiple proposals for new mission enabling projects that are planned over the next 10 to 25 years, some of which include:

- The **Multi-Purpose Office Space** at LANL will provide secure, safe, sustainable office/light laboratory facilities to conduct increasing operations at LANL.
- The **Maintenance Facility** at Y-12 will replace the antiquated maintenance facilities that supports all Y-12 production missions and support preventive, predictive, and corrective maintenance across the site. The new facility will consolidate maintenance processes and eliminate square footage of aging facilities in a more optimized, efficient location.
- The **New Nuclear Weapons R&D Complex** at LLNL will collocate dispersed, end-of-life Weapons Program office buildings into a more centralized location and will enable optimization of space utilization. This project will also permit the backfilling and collocation of employees relocated from other poor quality offices.

- The **Weapon Engineering Science and Technology Laboratory** at SNL/California will integrate the Materials Science and Engineering capabilities across materials development and engineering design. The primary existing facility is in poor condition, is functionally unfit for advanced materials science R&D, and lacks sufficient capacity to meet the current and projected demand. The modernized infrastructure will ensure that world-class instruments operate at the highest level of performance and lead to the development of breakthrough materials to solve enduring and emerging national-security challenges.
- The **Northwest Las Vegas New Office Space** at NNSS would provide sustainable infrastructure that supports the health, safety, and welfare of NNSS employees, the public, and the environment. As NNSS moves toward a smaller, safer, more secure, and less expensive enterprise, consolidation of functions into newer and fewer facilities at the site is necessary to align with DOE and DOE/NNSA Strategic Plans.

6.4 Modernization Through Minor Construction and Recapitalization

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



Modernization of the nuclear security enterprise is accomplished through formal recapitalization programs planned and funded at the DOE/NNSA level, as well as through site-directed investments and Institutional General Plant Projects. This section describes planned and current projects for modernization through all of these vehicles.

6.4.1 Recapitalization Program

The Recapitalization program executes prioritized minor construction and recapitalization investments to improve the condition, reliability, efficiency, and capability of infrastructure to meet mission requirements. The program plans and executes replacement, installation, upgrades, and minor construction projects to revitalize existing facilities or construct new facilities and additions below the $20 million minor construction threshold. Examples of such projects are the completed New Polymers and Engineering Facility at LLNL, SM-39 Classified Machine Shop Upgrade at LANL, and the 50-Year Sprinkler Head Replacements Portfolio at Y-12. This investment method is used in conjunction with line item construction to provide timely, appropriately sized, and integrated infrastructure solutions.

In addition to supporting the enterprise through strategic minor construction investments, the Recapitalization program sustains and modernizes DOE/NNSA infrastructure by improving the state of obsolete support and safety systems. The program provides funding to revitalize assets that are beyond the end of their design life and improve the safety, reliability, and capability of infrastructure to meet mission requirements. Recapitalization investments also achieve operational efficiencies; reduce risks to safety, security, environment, and programs; and improve the quality of the workplace.

Recapitalization program investments are evaluated and prioritized using an enterprise-wide, risk-based assessment of program and safety effects, sustainability, return on investment, and deferred maintenance reduction to obtain optimal benefits within the available budget. DOE/NNSA has also incorporated enhanced project management practices that have increased transparency, reporting accuracy, project definition and readiness, and overall program performance.

In FY 2020, DOE/NNSA completed 63 recapitalization projects. This performance reflects the effect of advanced planning based on detailed data and the use of the improved reporting tools and processes.

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

- Building 3 Area Modification for Production Security Verification at KCNSC
- CMR Wing 2 and 3-Hot and Cold Labs Disassembly and Contamination Hazard Reduction at LANL
- Superblock Electrical Building System Upgradeat LLNL
- Applied Materials and Engineering Capabilities Modernization Facility at LLNL
- U1a New Air Supply Borehole at NNSS
- Building 12-31 heating, ventilation, and air conditioning (HVAC) replacement at Pantex
- 20th and G Intersection Relocation at SNL
- New Z pulsed power facility (Z) and TA-4 Missions Support Facility at SNL
- 234-7H Air Handling Units Replacement at SRS
- Building 9204-2E 815 Switchgear Replacement at Y-12

Completed DARHT Weather Enclosure at LANL

6.4.1.1 Current Recapitalization Projects

DOE/NNSA currently has over 190 active recapitalization projects. The majority of these projects are below $10 million. There are more than a dozen projects ranging between $10–20 million. Projects are placed into portfolios, which are used to highlight significant multi-year investment in a common attribute or area at a particular site. Below are some examples of DOE/NNSA's ongoing Recapitalization portfolios and projects.

$10-20 Million Project Examples

- PF-4 Power and Communications Systems Upgrade at LANL
- New Nondestructive Evaluation Building at LLNL
- New Mercury Building 23-461 at NNSS
- New Advanced Fabrication Facility at Pantex
- New Explosives Manufacturing Science and Technology Facility at SNL

Project Portfolio Examples

- Building 2 Mechanical Component Manufacturing Revitalization at KCNSC
- CMR Initial Projects to Prepare for Closure Portfolio at LANL

- High-Level Radiochemistry Gloveboxes Laboratory Revitalizations at LLNL
- U1a Complex New Refuge Chamber Drift Installation at NNSS
- Bay and Cell Safety System Upgrades Portfolio at Pantex
- Obsolete Glovebox Oxygen Monitors Replacement Portfolio at SRS
- Diesel Generator Replacement at SRS
- Nuclear Facility Electrical Modernization Portfolio at Y-12

6.4.1.2 Recapitalization Program Planning Improvements

DOE/NNSA is improving understanding of long-term programmatic capability and associated capacity throughput requirements to better evaluate infrastructure options. Additionally, more front-end planning studies are being initiated to ensure that DOE/NNSA can integrate multiple Federal and M&O site organizations while designing multi-project plans to address complex infrastructure challenges. These efforts strengthen DOE/NNSA's modernization plans by ensuring that projects are fully scoped, well-integrated, and executed on time and within budget.

6.4.2 Site-Directed[7] Minor Construction Investments

DOE/NNSA's contracts with various consortia for management and operation of its sites contain requirements for M&O partners to plan for and manage DOE/NNSA assets for current and future missions. Sites fulfill these responsibilities in part by making minor investments in facilities and infrastructure from funds controlled at each site. The sources for these investments can be direct programs (as discussed in the previous sections) or indirect funding pools, depending on the nature of the asset and whether the site has a multi-mission program portfolio.

Many DOE/NNSA M&O partners use indirect funding to address high-priority needs at each site. On multi-mission program sites, indirect funding pools may be created through institutional assessments or other similar mechanisms. These pools are used to fund maintenance, utilities, and operations; some funding is set aside for site-wide investments. In all cases, expenditure of these funds aligns with accounting standards for demonstrating a causal-beneficial relationship, i.e., indirect funds are used for multi-mission program functions and purchases that deliver benefits across programs. M&O partners are also responsible for maintaining Weapons Activities capabilities to meet mission needs and often use portions of their budgets to fund minor investments in facilities, infrastructure, and equipment to meet those responsibilities.

Examples of indirect expenditures include Institutional General Plant Projects (IGPPs) at multi-mission program sites, especially the laboratories. These IGPPs are often limited refurbishments of legacy facilities or new, moderately sized buildings to accommodate growth at the site and enable prudent space management for the institution to maintain facilities in good condition and replace worn-out assets. IGPPs can also provide upgrades/replacements for institutional services such as parking structures, cafeterias, or medical facilities.

Site-directed investments over $1 million are reported through the DOE/NNSA Program Management Information System, Generation 2 (G2). Providing this information to one centralized system increases transparency and coordination for all infrastructure investments (both direct and indirect). Capturing the details of these projects in G2 ensures that indirect infrastructure investments align with DOE/NNSA's strategic priorities; enhances integration between direct- and indirect-funded infrastructure investments;

[7] Another term for "site-directed" investments is "indirect-funded" investments.

improves reporting to understand total infrastructure recapitalization costs across the enterprise; and ensures the capability to prioritize and plan for DOE/NNSA's long-term stewardship responsibilities.

6.4.3 Defense Nuclear Security Recapitalization and Minor Construction

The Security Infrastructure Revitalization Program (SIRP) was created by DOE/NNSA's Office of Defense Nuclear Security (DNS) to assure the strength of the physical security infrastructure supporting the DOE/NNSA mission at the eight sites now and into the future. DNS developed and submitted to Congress the *10-Year Physical Security Systems Refresh Plan* to outline and guide the scope of the SIRP effort. This plan contains a comprehensive condition assessment of the security infrastructure at each site and a nuclear security enterprise-wide prioritized listing of the required upgrades.

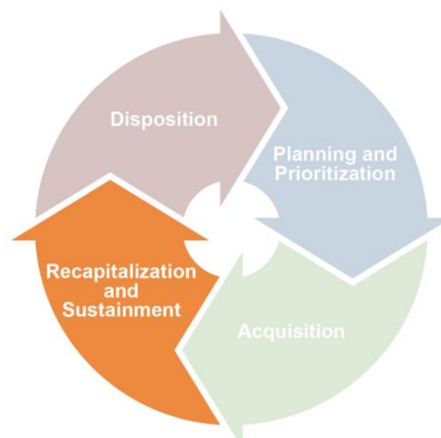
The *10-Year Physical Security Systems Refresh Plan* identifies and prioritizes security infrastructure investments critical to revitalization efforts throughout the nuclear security enterprise.

DNS minor construction project status for FY 2021:

- TA-72 Outdoor Range Upgrades Project, LANL (completed FY 2021)
- Range Classroom Facility Replacement, LLNL (funded FY 2019, construction completed FY 2021)
- Vehicle Barrier, Y-12 (funded FY 2020, estimated completion FY 2024)

6.5 Sustainment

This section describes how DOE/NNSA maintains and operates existing infrastructure in support of the nuclear security mission. DOE/NNSA, in partnership with the M&O partners, sustains its assets to enable mission success and readiness; ensure operational safety and security; safeguard the workforce, public and environment; and, meet mission needs more efficiently and cost- effectively.



6.5.1 Infrastructure Operations and Sustainment

The Operations of Facilities under Infrastructure and Operations program is responsible for operating DOE/NNSA facilities in a safe and secure manner and includes essential support such as water and electrical utilities, safety systems, lease agreements, and activities associated with Federal, state, and local regulations associated with the environment and worker safety and health.

The Maintenance and Repair of Facilities program provides direct-funded maintenance activities across the nuclear security enterprise for the recurring day-to-day work required to sustain and preserve DOE/NNSA facilities and equipment in a condition suitable for their designated purpose. These sustainment activities are executed through a combination of innovative tools that provide data for risk analyses that inform infrastructure management decisions. These decisions dedicate critical resources to maintaining facilities already in good condition and repairing the highest risks in DOE/NNSA assets. One of these tools is BUILDER, a web-based software tool that enables decisions concerning when, where, and how to best maintain, repair, and recapitalize infrastructure. DOE/NNSA's goal is to collect all condition assessment data in BUILDER and use it as an auditable, consistent sole source of information on the condition of DOE/NNSA's physical infrastructure. DOE/NNSA's deployment of BUILDER is an ongoing multi-year effort. Upon full implementation, DOE/NNSA will continue working to integrate each site's computerized maintenance management system with BUILDER to capture data for long-term sustainment. Integration of BUILDER with DOE/NNSA's Infrastructure Management programs, including the Recapitalization Program, will enhance the decision-making process by making use of risk-informed data.

Maintenance and repair activities sustain an acceptable condition of real property assets to perform their designated purpose or to mitigate risks posed by excess assets until their disposition. These efforts support the recurring day-to-day work needed to sustain plant, property, assets, systems, roads, and equipment in a condition suitable for its designated purpose. Efforts include required maintenance through surveillance and predictive, preventive, and corrective maintenance activities to maintain facilities, property, assets, systems, roads, equipment, and vital safety systems. Maintenance funding can be used for sustainment efforts or to respond to unexpected/urgent issues that require immediate correction to ensure safe, compliant, and reliable operations. In most cases, the funding does not have discrete cost, scope, and schedule milestones attached.

Deferred maintenance is defined as any maintenance activities that were not performed when they should have been or were scheduled. As a result, they are rolled over as a continued expected expense to subsequent fiscal years until the maintenance can be completed. Repair needs are the repairs required to ensure that a constructed asset is restored to a condition that is substantially equivalent to the most recently configured designed capacity, efficiency, or capability. In FY 2019, DOE/NNSA began its transition to BUILDER data to determine total deferred maintenance and repair needs. Importantly, this transition to a standardized, structure-based approach provides DOE/NNSA with increased transparency and deferred maintenance data accuracy across the enterprise. In FY 2020, DOE/NNSA conducted an in-depth analysis of FY 2019 calculations and implemented a few minor enhancements to ensure a more accurate reflection of the true condition of DOE/NNSA's infrastructure.

As a result, DOE/NNSA's deferred maintenance backlog increased from $4.78 billion in FY 2019 to $5.84 billion in FY 2020. This increase does not fundamentally change the physical condition of DOE/NNSA's infrastructure, but more accurately represents DOE/NNSA's deferred maintenance backlog. In fact, a vast majority of our facilities are in the same condition as they were in FY 2019. High deferred maintenance is a sign of infrastructure in poor condition and in need of modernization. Revitalizing DOE/NNSA infrastructure requires grappling with a $116 billion enterprise in which more than half of DOE/NNSA facilities are in insufficient condition to serve mission needs (e.g., poor or very poor condition). Addressing this legacy while building for the future requires significant, sustained, and timely funding; robust planning and execution; and close collaboration across all stakeholders. DOE/NNSA remains committed to continuous improvement of our management practices and transparency in stewarding taxpayer resources as we work to modernize our nation's nuclear infrastructure.

The Asset Management Program repairs and replaces major building systems that are common across the DOE/NNSA enterprise (e.g., roofs; HVAC systems; etc.).

DOE/NNSA's Roof Asset Management Program (RAMP) uses supply chain management strategies and economies of scale to increase purchasing power and improve the timeliness of procurements. RAMP prioritizes the highest-risk roofs across the enterprise and has repaired or replaced more than 6 million gross square feet of roofs since its inception in FY 2004. The Cooling and Heating Asset Management Program (CHAMP) uses systems engineering and supply chain management strategies to quickly and economically address HVAC issues, achieve economies of scale, and increase purchasing power. CHAMP provides reliable HVAC systems that are vital for maintaining precise temperature, humidity, and ventilation requirements for the production of mission-critical components.

6.5.2 Programmatic Facility Sustainment

In some instances, the nature of core mission areas leads to direct programmatic sustainment funding for certain operations. For example, the Stockpile Research, Technology, and Engineering (SRT&E) program is responsible for the HPC capabilities needed for stockpile stewardship in modeling, simulation, and experiments conducted at various facilities and experimental capabilities such as inertial confinement fusion. Within SRT&E, operational costs at facilities are directly supported and budgeted within the Inertial Confinement Fusion (ICF) and Advanced Simulation and Computing (ASC) Programs. The ICF Facility Operations and Target Production subprogram supports efficient operations at NIF, Omega Laser Facility (Omega), Z, and the Trident and NIKE facilities (see Chapter 4, Section 4.3.3, for more information on NIF, Z, and Omega). Similarly, the ASC Facility Operations and User Support subprogram provides the facilities and services required to execute nuclear weapon simulations. Facility Operations include physical space, power, and other utility infrastructure; local area/wide area networking for local and remote access; and system administration, cybersecurity, and operations services for ongoing support.

Programmatic operations must be responsive to the safety and health of workers and the protection of the environment, regardless of the funding source. As part of DOE/NNSA's efforts for a more sustainable enterprise, Z was awarded an environmental management award of excellence for significantly reducing emissions of the powerful greenhouse gas, sulfur hexafluoride.

Sulfur hexafluoride reclaiming system being used on SNL's Z

ASC is the primary user and chief programmatic advocate for the facilities and services required to run nuclear weapons simulations and operate Commodity Technology and Advanced Technology systems. Each laboratory's computing capability comprises not only HPC systems, but also ancillary physical components such as space, power, storage, file systems, local area/wide area networking for local and remote access, and a host of system administration, cybersecurity, and operations services for ongoing support of HPC system and support equipment. There are also specific user services associated with items such as a computer center hotline and help-desk services, account management, web-based system documentation, system status information tools, user training, trouble-ticketing systems, common computing environment, and application analyst support that are included in the fiduciary responsibilities of the program. As such, each center's footprint can physically span multiple buildings.

ASC manages the costs associated with each laboratory's current computing centers and considers multi-year budget planning to deliver future systems based on programmatic need. The funding necessary to operate and modify the computing centers comes from a combination of direct programmatic funding from the ASC and other DOE/NNSA programs, which may use the same buildings, or indirect overhead charges brought in by the laboratories directly. Within Weapons Activities, the Infrastructure and Operations Program provides capabilities and SNM infrastructure for the nuclear security enterprise, but is not responsible for maintenance and operations of the ASC computing centers themselves.

6.5.3 Site-Directed Sustainment Investments

At multi-program sites, indirect pools may be created to pay for maintenance and operations. These funds are then used to pay utility bills; provide preventive, predictive, and corrective maintenance to facilities and equipment; and replace equipment associated with facilities and infrastructure. These funds may also cover various site-wide services. Site-directed investments are reported through G2. Providing this information to one centralized system increases transparency and coordination for all infrastructure investments (both direct and indirect). Capturing the details of these investments in G2 ensures that indirect infrastructure investments align with DOE/NNSA's strategic priorities; enhances integration between direct- and indirect-funded infrastructure investments; improves reporting to understand total infrastructure recapitalization costs across the enterprise; and ensures the capability to prioritize and plan for DOE/NNSA's long-term stewardship responsibilities.

6.5.4 Real Estate and Leased Facilities

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

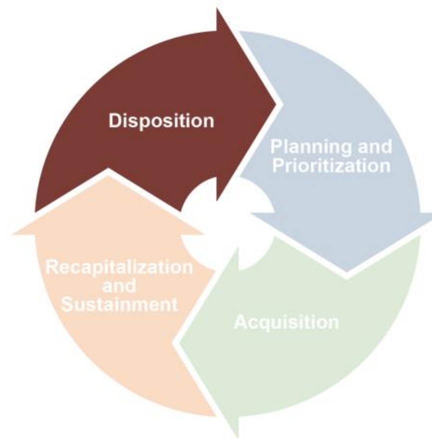
DOE/NNSA is implementing a range of innovative tools and processes related to our leasing strategies. DOE/NNSA executed its first "option purchase" acquisition in June 2020 and is preparing to pursue the purchase of other leased facilities across the enterprise. The inaugural purchase of 103 Palladium, a 73,000-square-foot facility on a 21-acre campus in Tennessee, will set the stage for future purchases. All will use existing *Atomic Energy Act of 1954* authorities to acquire facilities that are under $20 million. Additionally, the lease scoring system rolled out in early 2019 is driving better decision-making by offering an objective metric for evaluating a lease's risk and comparing it within DOE/NNSA's broader leasing portfolio. This system helped improve the terms and conditions in leases, minimize tenant improvements, and ensure that exit strategies are in place for new leases. Scoring is also normalizing soliciting for space to encourage better rates and conducting site visits to improve usage and ensure lessor is delivering per the lease.

Kansas City Short Term Expansion Project

Since the consolidation of operations in 2014 from the original Bannister Road facilities to the leased facility on Botts Road, KCNSC has seen a significant increase in workload in support of the nuclear stockpile modernization. The activities supporting the growth in workload have consumed all KCNSC's factory space at the Botts Road facility and have driven KCNSC to address this shortfall by executing a bridge lease on a nearby facility, KCNSC East. The Kansas City Short Term Expansion Project (KCSTEP) is a series of multi-year projects that will provide for KCNSC East infrastructure upgrades, relocation of specific manufacturing capabilities to KCNSC East, and expansion and rearrangement of other manufacturing capabilities remaining at the Botts Road main campus. While efforts continue to assess a long-term facility expansion strategy, KCSTEP will provide increased factory capacity to support the B61-12 life extension program and W88 Alt 370, as well as partially filling needs for the W80-4 and W87-1 programs.

KCNSC Botts Road Main Campus

6.6 Disposition of Excess Facilities



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

Approximately 10 percent of assets located on DOE/NNSA's sites are designated as excess. DOE/NNSA's highest disposition priorities are to stabilize degraded facilities, characterize hazards and conditions, remove hazardous and flammable materials, and place facilities in the lowest acceptable risk condition possible until they can be dispositioned. If facilities are process-contaminated then the responsibility to disposition resides with DOE's Office of Environmental Management. The DOE/NNSA Disposition Strategic Plan outlines the details of how DOE/NNSA plans to address these excess facilities.

DOE/NNSA's FY 2019 budget included more than $50 million to continue reducing the risks posed by excess facilities and to decontaminate and demolish buildings.

From 2016 through 2020, DOE/NNSA demolished a total of 374 assets representing over 5 million gross square feet, which included 14 assets identified as high-risk excess facilities. Although most of the high-risk facilities will remain until DOE Environmental Management demolishes them, DOE/NNSA has made progress in reducing its overall footprint.

6.7 Modernization of Programmatic Equipment

Facilities and infrastructure are just one of the three aspects of sustainment that must be managed in support of the mission; equipment and people are also critical to mission performance. The workforce aspects are discussed in Chapter 7. This section focuses on the equipment aspects of sustainment.

DOE/NNSA manages and funds equipment procurement across the nuclear security enterprise through multiple programs such as stockpile modernization programs or the Engineering Program. These programs selectively fund mission-related equipment procurement to meet their schedule or new requirements. In addition to these, a number of other programs maintain nuclear security enterprise capabilities through equipment refurbishment and replacement. Those programs include Capabilities-Based Investments (CBI), Production Operations, Non-Nuclear Component Modernization, Operations of Facilities, and Maintenance and Repair of Facilities. Furthermore, the organization that initially funds procurement of a piece of equipment will most likely not be the only organization benefiting from the acquisition in the future, which adds complexity to the task maintaining and replacing equipment. Part of the responsiveness of DOE/NNSA's infrastructure is defined by the ability to maintain and find new or improved uses for existing equipment.

While each program focuses on its own respective responsibilities and requirements, the integrated nature of nuclear weapons work creates natural mission overlap across programs. In these cases the Programmatic Recapitalization Working Group works with the M&O sites to capture the current inventory of capital equipment items as well as future needs across the FYNSP to allow DOE/NNSA to better plan and program capital equipment needs amongst the appropriate funding program offices. This allows better alignment of planning and programming activities across relevant DOE/NNSA programs.

Equipment modernization, replacement, and refurbishment planning will enable DOE/NNSA to recapitalize the nuclear security enterprise's infrastructure and provide an effective, responsive, and resilient nuclear weapons infrastructure. It is also crucial to the maintenance of the nuclear security enterprise's current capability. The investment strategies described in the following sections presents a variety of programs focused on investing in programmatic equipment, as well as certain equipment-related sustainment activities funded by Infrastructure and Operations. Together, they provide the baseline activities essential to maintaining a functional and efficient nuclear security enterprise.

6.7.1 Programmatic Equipment Investments

Equipment investments by mission-specific programs are dictated by programmatic need.

For the weapons programs (Stockpile Major Modernization and Stockpile Sustainment), equipment purchased might include radiography machines, shaker tables, blast tubes, centrifuges for qualification, certification, and surveillance activities that are specific to a weapon system. A weapon program might also require specific capabilities in production equipment, such as specialized mills and lathes, to produce component designs and would cover these costs, as the requirements for that equipment would be tied directly to their program. For example, the W80-4 Life Extension Program (LEP) has funded programmatic equipment such as the digitizers needed for hydro shot diagnostics, a computer numerical controlled mill and lathe for both HE and radiological materials to meet integrated weapon experiment deliverables, and inspection equipment to validate that machines' experimental components meet weapon engineer-specified requirements.

Weapon programs also invest in equipment and infrastructure necessary to maintain their schedule. Often these investments are split among weapon programs that could benefit from such procurements in the future. For instance, the W88 Alt 370 benefited from investments made by the W76 and B61-12 LEPs. Where multiple stockpile modernization programs can benefit, CBI (described in Section 6.7.2) is also a major source of funding.

SRT&E investments cover a range of highly specialized and common equipment that is essential to the high-tech work of stockpile stewardship. SRT&E equipment might provide or facilitate environments for testing and experimentation, produce data from those experiments, or help synthesize the data from the experiments to inform research, design, production, qualification, and surveillance activities across multiple different weapon systems and programs. Examples include next generation computing platforms, diagnostic equipment tied to subcritical and hydrodynamic experiments, and accelerators associated with advanced radiography. Given the specialized nature of these types of equipment, investments can be quite costly. New equipment is procured by SRT&E programs as mission needs arise, equipment becomes technologically obsolete, emerging technologies demand investment in new capabilities, or new facilities or capabilities come on line. In addition, as urgent needs arise, CBI and Non-Nuclear Component Modernization makes investments in equipment for SRT&E missions that are tied to LEP schedules.

The Additive Manufacturing and Component Manufacturing Development programs make equipment investments aimed at validating production and qualification processes that are vital to the future stockpile, with a long-term goal of reducing required production floor space and attendant infrastructure. While these programs may purchase one to two pieces of equipment with advanced capabilities, the weapon programs, CBI, or appropriate modernization offices would be expected to purchase the remaining equipment needed to realize the Additive Manufacturing and Component Manufacturing Development-provided capability at full production scale. In some cases, the initial investment by these programs could fulfill production requirements, and the responsibility for the operations and maintenance of that equipment would transfer to the appropriate program, such as Production Operations. Examples of equipment procured through these programs include a variety of additive manufacturing machines, advanced testers, and other supporting equipment.

6.7.2 Capabilities- Based Investments

The CBI program focuses on modernization via capital investment in equipment, tools, supporting facilities and infrastructure directly related to enduring, multi-program weapon activity capabilities, mission deliverables, and management of programmatic risk across the nuclear security enterprise.

> ***CBI Accomplishments***
>
> - *Replaced PF-4 trolley control cabinets, LANL*
> - *Established metal additive manufacturing capability, Y-12*
> - *Established Laser Powder Bed Fusion Capability, KCNSC*
> - *Supported new Design Agency/Production Agency integrated Polymer Enclave, LLNL*
> - *Re-constituted DARHT confinement vessel production capability, LANL*
> - *Completed design for new Weapons Evaluation Test Laboratory High-G centrifuge, SNL*

Over the years, DOE/NNSA's manufacturing capabilities have been lost or degraded due to aging, damaged, or outdated equipment and supporting systems. The investments supporting core programmatic requirements address needs beyond any single facility, campaign, or weapon system that are essential to achieving program mission objectives.

Additional warhead programs, new organizational structures, and changes to other programs' funding strategies have all contributed to changes and evolutions in CBI activities in FY 2021 and beyond. The increase in the number of active warhead programs will add to the overall workload of the nuclear security enterprise, which will challenge existing capacities and accelerate existing issues related to aging and condition. Under the new budget structure introduced with the FY 2021 request, some scope has shifted out of CBI into other programs (e.g., High Explosives and Energetics and Non-Nuclear Component Modernization), which affords some opportunities to focus on mission needs that may have been underserved in previous years. CBI is participating in the Programmatic Recapitalization Working Group to better identify, analyze, and coordinate equipment repair, replacement, and recapitalization needs. In coordination with changes in how other programs approach their funding priorities, CBI will make adjustments to address resulting gaps in programmatic equipment investments as needed.

Table 6–1 provides a high-level summary of CBI challenges and strategies.

Table 6–1. Summary of Capabilities-Based Investments challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Environmental testing equipment is aging more rapidly than sustainment and recap efforts can manage.	Investigate preprioritization of equipment recap needs to ensure environmental testing equipment is available and operational as needed.	Continue monitoring status of testing capabilities and coordinate prioritized needs with the Office of Research, Development, Test, and Evaluation and the Office of Stockpile Management.
Programmatic equipment investments and recapitalization are not keeping up with the increasing amount of equipment required to support the various modernization efforts.	The Non-Nuclear Components program within Defense Programs was established beginning in FY 2021, with responsibility to allocate resources for this issue in coordination with the Office of Stockpile Management and the Office	Incorporate enterprise modeling and Programmatic Recapitalization Working Group data to inform programmatic equipment resource allocation and coordinate resourcing across program offices.

Challenges	Strategies	
	Current Strategy Being Implemented	**Future Strategies Needed**
	of Safety, Infrastructure, and Operations.	
The increase in weapon modernization efforts is putting increased strain on existing equipment throughout the nuclear security enterprise.	Non-Nuclear Components, CBI, Office of Safety, Infrastructure, and Operations, and the Office of Stockpile Management are jointly working with the sites to understand the highest priorities to allocate limited resources.	Prioritize recapitalization based on Programmatic Recapitalization Working Group data analysis and program of record requirements to sustain and modernize the stockpile.

6.7.3 Production Operations Equipment Investments

Production Operations provides site-specific base capabilities to enable assembly, disassembly, and production activities funded by Stockpile Major Modernization, Stockpile Sustainment, or Weapons Dismantlement and Disposition (refer to Chapter 2, Section 2.4, for additional information on Production Operations). The Production Operations program also maintains specific multi-weapon base production capabilities for critical nuclear weapon components, such as neutron generators at SNL and detonators at LANL.

The program addresses a range of base capability replacements or repairs with a focus on multi-weapon system support and the nuclear security enterprise's production agencies. Equipment procurement and installation within Production Operations has traditionally addressed items ranging from greater than $5 million MIEs to equipment below $100,000. With the reorganization of Defense Programs, Production Operations' equipment scope is more focused on sustainment through refurbishment, maintenance, and in some cases, replacement of existing equipment. Within this revised mission space, Production Operations must increase its ability to respond to unplanned failures of key equipment.

Typical investments funded by Production Operations include:

- Multi-weapons system base capability sustainment in component manufacturing, assembly, and disassembly, including gloveboxes, mills, and lathes
- Sustainment through refurbishment, maintenance, and in some cases, replacement of existing equipment for moving product
- Sustainment through refurbishment, maintenance, and in some cases, replacement of existing equipment for the production of multi-weapon system tooling and the qualification of materials to be used in production
- Multi-weapon system capabilities for the qualification and surveillance of weapon components and materials
- Simulation capabilities, including HPC equipment and qualified analysts, to support improved manufacturing process reliability (thus decreasing waste and costs), and accelerate timeline for production activities, including the use of advanced manufacturing techniques

6.7.4 Infrastructure Operations, and Maintenance Equipment Investments

The Operations of Facilities program funds some existing scientific and/or process equipment that provides the nuclear security enterprise with the capabilities needed to accomplish programmatic milestones and activities:

- Costs associated with staffing to manage and support the equipment/capability
- Activities required to run the equipment/capability in a safe, secure, reliable, and "ready for operations" manner (calibration, surveillance)
- Equipment/capability utilization analysis, modification and upgrade analysis, and the technical operations and staffing necessary for the equipment/capability to function effectively
- Training required to operate the equipment/capability in a safe, secure, and effective manner

The Maintenance program funds activities to sustain and preserve equipment in a condition suitable to perform its purpose.

6.7.5 Site-Directed Equipment Investments

As with facilities and infrastructure, sites may make investments in equipment for activities that support weapons and other site missions (multi-program), and these investments may either be made using direct funds or include indirect cost pools. The cost of programmatic equipment that supports multiple programs should be allocated to those programs in accordance with the benefits received.

6.8 Leveraging Weapons Activities Investments Across DOE/NNSA

Several other DOE/NNSA programs (e.g., Defense Nuclear Nonproliferation, Counterterrorism and Counterproliferation, and Emergency Management Programs) rely on infrastructure funded by Weapons Activities and other DOE program offices. These programs are described in DOE/NNSA's *Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats (FY 2022 – FY 2026)*.

6.8.1 Support of Nonproliferation Efforts

Defense Nuclear Nonproliferation's Global Material Security Program relies on infrastructure maintained by other DOE/NNSA offices, as summarized below.

- TA-5 at SNL conducts nuclear security training for the International Atomic Energy Agency and bilateral partners.
- The DOE/NNSA National Training Center in Albuquerque, New Mexico, will, on a limited basis, provide bilateral partners with Protective Force training.
- The Y-12 Alarm Response Training facility conducts radiological security training for domestic and international security forces, health and safety personnel, and local law enforcement to effectively respond to the theft of radioactive sources.
- SNL and LANL provide technical expertise, testing equipment, and SNM sources that are critical in the evaluation and characterization of commercial detection equipment.

Defense Nuclear Nonproliferation's R&D program relies on supportive capabilities at a number of laboratories, plants, and sites that enable mission-relevant R&D activities, as summarized below.

- NNSS hosts several experimental and applied test beds to demonstrate next-generation nonproliferation technologies for detecting foreign nuclear weapons development activities, which will result in new capabilities at the national security laboratories.
- The DAF hosts and facilitates detection experiments for university and laboratory projects.
- SNL, LANL, LLNL, and NNSS provide critical expertise and infrastructure to support a number of weapons-related experimental campaigns, to include U1a and Big Explosives Experimental Facility.
- The Microsystems Engineering, Sciences, and Applications Complex at SNL provides resources to develop beyond leading-edge trusted microsystems technologies that enable space-based detonation detection capabilities.
- SNM irradiation experiments are conducted at the National Criticality Experiments Research Center at NNSS, where criticality assembly machines provide the capability for research to improve precision measurements of nuclear fission product yields and other nuclear data parameters.
- HPC is used for a broad range of modeling and simulation research across multiple research areas at SNL, LANL, and LLNL.

Defense Nuclear Nonproliferation's Material Management and Minimization (M3) Program relies heavily on the infrastructure maintained by other DOE/NNSA offices. Effects of the aging infrastructure on the implementation of key nonproliferation programs are summarized below.

- **Conversion Program**
  - Y-12's uranium facilities perform downblending and casting activities that produce low-enriched uranium-molybdenum (LEU-Mo) material that will allow conversion of the U.S. high-performance research reactors from highly enriched uranium (HEU) to LEU. Aging casting furnaces at Y-12 are a programmatic risk to production of future LEU-Mo material. To address the aging facility issues, Y-12 is working to construct a new facility that will use new technologies. In the future, M3 will shift to using BWX Technologies, Inc., for its alloy casting capability instead of Y-12. M3 will still rely on Y-12 for production of LEU metal feedstock. This shift is planned to begin in FY 2025 and fully transition by FY 2028.
  - The Sigma facility at LANL develops and optimizes LEU-Mo fuel fabrication processes.
- **Material Disposition Program**
  - PF-4 at LANL disassembles nuclear weapon pits and converts the resulting plutonium metal into an oxide form using the Advanced Recovery and Integrated Extraction System. While this is a Defense Nuclear Nonproliferation program, this equipment set is also used to support pit surveillance and other Defense Programs activities.
  - The K Area Complex at SRS stores surplus plutonium that will be dispositioned. The K Area Complex is a DOE Environmental Management facility; however, DOE/NNSA plans to install equipment for the Surplus Plutonium Disposition Program under the Dilute and Dispose strategy, and completed construction of a transuranic waste storage pad and loading capability for shipping diluted plutonium oxide to the Waste Isolation Pilot Plant (WIPP).

  - Under the proposed Dilute and Dispose strategy, WIPP is the permanent disposal site for diluted plutonium oxide, along with waste generated by Defense Programs and other nonproliferation activities.
  - The Material Disposition program relies on resources, facilities, and support from Pantex and KCNSC to support the Dilute and Dispose strategy.
  - DOE/NNSA's Secure Transportation Asset Program will provide resources to ship Security Category I quantities of SNM within the nuclear security enterprise in support of the Surplus Plutonium Disposition Program under the Dilute and Dispose strategy.
  - The H-Canyon at SRS will be used to disposition portions of the plutonium inventory returned to the United States through the Nuclear Material Removal Program. The Savannah River National Laboratory provides R&D and implements technical solutions for a variety of material disposition activities.
  - Enriched uranium operations at Y-12 allow analysis, processing, and packaging of materials to be downblended or properly disposed. The Material Disposition program also provides inventories of HEU for research reactor and other uses. The Material Disposition program recognizes the same risks listed by the Conversion Program above. Additionally, completion of Material Disposition work at Y-12 is heavily leveraged in the low-equity discards work, which relies on the waste management infrastructure managed by Defense Programs at Y-12, as well as disposal sites.

- **Nuclear Material Removal Program**
  - DOE/NNSA's Secure Transportation Asset Program provides resources for multiple material removal campaigns. The DOE/NNSA Office of Secure Transportation facilitates these projects by providing safe and secure transport of nuclear material within the territory of the United States.
  - The L-Reactor basin at SRS, a DOE Environmental Management facility, receives enriched uranium from the Removal Program and stores the material pending disposition.
  - The K Area Material Storage facility receives enriched uranium and plutonium from the Removal Program and stores the material pending disposition.
  - Savannah River National Laboratory operates the Mobile Plutonium Facility in support of international removal activities and provides other critical support to the Removal Program.
  - Oak Ridge National Laboratory (supported by the Y-12 National Security Complex) operates the Mobile Uranium Facility in support of international removal activities and provides other critical support to the Removal Program.

Defense Nuclear Nonproliferation's Nonproliferation and Arms Control (NPAC) Program also relies on the infrastructure maintained by other DOE/NNSA offices, as summarized below.

- NPAC relies on the availability of Category I, II, and III SNM standards and sealed sources for detector and system development, as well as facilities for testing prototype radiation detection monitoring and safeguards equipment and for training U.S. personnel in equipment use and foreign partner personnel in the fundamentals of safeguards and material measurement. While the health of the facility and SNM infrastructure remains sufficient at this time, downsizing over the last decade has required programs to use less Category I and II materials and more Category III and IV materials for detector development and training. As DOE/NNSA recapitalizes facilities that are critical to the NPAC mission, Defense Nuclear Nonproliferation offices will work with the appropriate program managers to ensure NPAC goals are incorporated as resources allow.

- NPAC uses NNSS as a training ground to develop a U.S. capability to perform field verification activities for suspected nuclear explosions. Focused training and exercise events for the Test Site Verification Team will coordinate with other programs' activities as appropriate and are expected to begin at NNSS in FY 2022 – FY 2023, with the goal of an integrated field exercise, potentially at NNSS, in FY 2022 – FY 2023 to assess the readiness of the team, equipment, and procedures in a realistic field setting. Out-year efforts will focus on regular team training and targeted development to improve the capability, depending on needs and priorities.
- NPAC relies on facilities and operational expertise at Pantex and Y-12 to test warhead monitoring and verification capabilities, and to assess the feasibility of equipment deployment at weapons facilities. Demonstrations and evaluations at operational nuclear weapons facilities are essential for developing potential long-term solutions to the technical challenges of verifying nuclear weapon reductions. They support the U.S. ability to engage technically with partner countries under initiatives such as the International Partnership for Nuclear Disarmament Verification.
- NPAC relies on access to nuclear weapons design information and access to weapons activities subject matter experts to help evaluate potential nuclear warhead monitoring and verification capabilities and ensure U.S. weapons design information will be protected as part of any future monitoring initiative.
- NPAC and various U.S. agencies work with DOE/NNSA Defense Programs to support transparency initiatives in fulfilling the Nation's Article VI commitments under the Nuclear Non-Proliferation Treaty.
- NPAC uses KCNSC, LANL, LLNL, SNL, and NNSS to conduct seminars on proliferation-sensitive commodities and technologies, particularly those subject to export controls and related to nuclear weapons and associated delivery systems. These seminars and workshops provide the U.S. agencies with knowledge of these commodities that is available nowhere else. Participants can apply what they learn in their jobs in nonproliferation policy, export licensing, export enforcement, and other functions related to preventing weapons of mass destruction proliferation.

6.8.2 Support of Counterterrorism and Counterproliferation and Emergency Operations Efforts

The Office of Counterterrorism and Counterproliferation (CTCP) heavily leverages infrastructure primarily used for stockpile stewardship. These invaluable assets ensure that CTCP is able to execute its missions to counter nuclear threats, respond to nuclear incidents and accidents, and deliver an emergency response and consequence management capability for the U.S. Government. CTCP is further able to harness these resources to inform U.S. Government policies and deliver nuclear and radiological emergency preparedness training for the U.S. Government and its foreign partners.

- **Nuclear Counterterrorism (NCT) Assessment Program**
  - LANL, LLNL, and SNL support the NCT Assessment program by maintaining and advancing the U.S. Government's ability to assess potential nuclear threat devices, including improvised nuclear devices or foreign nuclear devices out of state control. To do so, CTCP leverages DOE/NNSA infrastructure originally developed for stockpile stewardship to enable computational assessment of nuclear threat devices through expansion of the HPC code

capabilities. This understanding of nuclear threat devices is used to inform broader U.S. Government material security, nuclear incident response, and international nuclear threat reduction efforts.

- CTCP conducts focused and integrated experiments at all DOE/NNSA national security laboratories and several DOE Office of Science and Engineering laboratories for the refinement and validation of predictive models.
- In order to understand materials not traditionally studied by the U.S. stockpile, LLNL, LANL, and SNL execute foundational science programs to characterize nuclear materials and explosives on similar platforms. For example, CTCP uses diamond anvil cell facilities, gas guns, and other high-pressure facilities to evaluate nuclear materials. Specific unique facilities supporting stockpile stewardship are also used to improve NCT Assessment activities, including TA-55 and proton radiography at LANL, Joint Actinide Shock Physics Experiment Research gas gun (JASPER) and HEAF at LLNL, Z at SNL, etc. These activities are informed by foundational science that yields a broad understanding of nuclear material behavior in various pressure regimes and explosive performance, mechanical, and thermal response and reaction violence. Data from these nuclear materials or explosives experiments are used to improve material models then used in computational codes used across DOE/NNSA programs.
- LANL, LLNL, and SNL support the development and validation of predictive modeling in support of nuclear incident response, as well as training to the interagency weapons of mass destruction defeat community. Facilities such as DARHT at LANL, the Site 300 Global Security Campus Facility (Building 850), Contained Firing Facility at LLNL, as well as multiple explosives testing sites across LANL, LLNL, and SNL, support CTCP experimental validation efforts.
- In cooperation with LANL, LLNL, and SNL, NNSS provides unique facilities and infrastructure to support NCT Assessment integrated experimental validation efforts. Capabilities at NNSS allow experimental efforts on hazardous materials or at threat-representative scale.

- **Nuclear Forensics Program**
  - Technical nuclear forensics performance depends on the core capabilities developed during the U.S. nuclear weapons development and testing program. Weapons design expertise and the simulation tools, manufacturing base, and experimental capabilities required for Weapons Activities provide a strong foundation for the technical nuclear forensics mission. Weapons Activities supports much of the expertise, facilities, nuclear material handling infrastructure, and historic knowledge necessary to perform technical nuclear forensics, including the National Nuclear Material Archive. DOE/NNSA’s Secure Transportation Asset provides safe and secure transportation of nuclear material in the United States and supports the CTCP response teams, including technical nuclear forensics. The technical nuclear forensics mission also relies on DOE’s broader ST&E capabilities, including laboratories maintained by DOE’s Offices of Science and Nuclear Energy.
- **Nuclear Incident Response Program**
  - CTCP provides operational support, training, and equipment for major public events and emergencies, both foreign and domestic. CTCP is able to draw upon these activities to aid in the development of effective public policies, medical procedures, and tabletop and field exercises that guarantee a robust multilateral incident preparedness and response for countering nuclear and radiological incidents, accidents, and terror threats.

  - To support the Nuclear Emergency Support Team (NEST) Technical Reachback and training to build international capacity, as well as the U.S. Government's effective response to a nuclear or radiological incident or emergency, CTCP relies on a diverse base of rapidly deployable assets, including specialized facilities, vehicles, and equipment. These assets include the Radiological Assistance Program, based at 11 DOE locations around the Nation; the Aerial Measuring System stationed at the Radiation Sensing Laboratories at Joint Base Andrews (Washington, DC) and Nellis Air Force Base (Las Vegas, Nevada); the National Atmospheric Release Advisory Center at LLNL; the Nuclear Response Group Readiness Operations Center located on Kirtland Air Force Base; and the Radiation Emergency Assistance Center/Training Site at the Oak Ridge Institute for Science and Education in Oak Ridge, Tennessee. The NEST Technical Reachback Home Teams are a virtually connected capability that has static nodes located at and operated by LANL, LLNL, SNL, Pantex, and both Remote Sensing Laboratory locations (NNSS and Nellis Air Force Base). When activated, Home Teams provide the necessary remote technical assistance to the deployed NEST assets of the Joint Technical Operations Team; the Accident Response Group; regional Stabilization Teams; Render Safe Unit of the Federal Bureau of Investigation; Department of Defense (DoD) National Mission Force; DoD custodial organizations; NNSA OST; and specific international partners; as well as the Nuclear Incident Team at DOE Headquarters Forrestal building and its alternate location at the DOE facility in Germantown, Maryland. These infrastructure elements help ensure that the U.S. Government has dedicated resources that are capable of quickly responding to nuclear or radiological incidents worldwide and the emergency management infrastructure required to coordinate the response effort.

DOE/NNSA's Office of Emergency Operations is DOE/NNSA's primary office of interest in Continuity of Operations Planning and relies on the infrastructure maintained by other DOE/NNSA offices, as summarized below.

- "Alternate Operating Facilities" is a term used to refer to alternate sites where essential functions are continued or resumed and where organizational command and control of essential functions occurs during a catastrophic emergency. An Alternate Operating Facility is sufficiently distanced, but within the same region from the primary facility used to conduct continuity operations, and is staffed by deployed Emergency Relocation Group members. The Primary Alternate Operating Facility for DOE/NNSA is the DOE Germantown Facility, located in Germantown, Maryland.
- Devolution planning supports continuity planning and addresses continuity events, catastrophes, and "notice" and "no notice" events. These events could render DOE/NNSA leadership and staff unavailable or incapable of providing control and direction to organizations performing essential functions. Devolution should be used when the Primary Operating Facility and Alternate Operating Facility are not viable or available. The primary DOE/NNSA Headquarters devolution of operations site is the DOE/NNSA Albuquerque Complex in Albuquerque, New Mexico.

6.9 Management and Performance

Since 2011, DOE/NNSA has delivered approximately $2 billion in projects, a significant portion of DOE/NNSA's total project portfolio, under budget. DOE/NNSA is committed to encouraging competition and increasing the universe of qualified contractors by streamlining major acquisition processes. DOE/NNSA will continue to focus on delivering timely, best-value acquisition solutions for all programs and projects, by using a tailored approach to contract structures and incentives that are appropriate for the special missions and risks at each site. DOE/NNSA continues to:

- lead improvements in contract and project management practices;
- provide clear lines of authority and accountability for program and project managers;
- improve cost and schedule performance; and
- ensure that Federal Project Directors and Contracting Officers possess the appropriate skill mix and professional certifications to manage DOE/NNSA's work.

Chapter 7
Workforce

7.1 Overview

The Department of Energy National Nuclear Security Administration's (DOE/NNSA's) workforce[1] is the nuclear security enterprise's most critical asset. DOE/NNSA's ability to meet its nuclear security missions requires a unique, diverse, and highly skilled workforce of nearly 50,000 people with expertise across a broad array of disciplines, including computer science, physics, materials science, chemical engineering, and mechanical engineering. The technical staff and managers working in these areas possess advanced science, technology, engineering, and math degrees, with years of experience working directly for DOE/NNSA or its management and operating (M&O) partners. The need to recruit, develop, and retain this workforce will continue to grow, given DOE/NNSA's major modernization programs and current workforce demographics.

> ***Workforce Snapshot (Enterprise-Wide)***
> ***(October 1, 2019–September 30, 2020)***
> - *Total Headcount: 49,059*
> - *Average Age: 46*
> - *Average Years of Service: 11*
> - *Average Retirement-Eligible Population: 25.6%*
> - *Hires (as of September 30, 2020): 5,158*
> - *Separations (as of September 30, 2020): 2,960*
> - *Net Change (as of September 30, 2020): 2,198*

DOE/NNSA and its M&O partners devote extensive effort to recruiting, training, sustaining, and revitalizing the workforce that supports the nuclear deterrent. Workforce-related activities are driven by current mission needs and designed to anticipate future developments that may require new skills to address emerging challenges.

President Biden signed an Executive Order on June 25, 2021, to advance diversity, equity, inclusion, and accessibility (DEIA) in the Federal workforce. In response, DOE/NNSA plans to release a DEIA Strategic Plan in March that is data-driven by a DEIA Climate Assessment that highlights strengths and identifies areas of improvement. DOE/NNSA's Senior Leadership is committed to this effort and will create actionable initiatives across the organization.

Despite the challenges posed by the COVID-19 pandemic, DOE/NNSA's workforce has adapted its operations, performed its national security missions with additional safety precautions, and met major milestones and deliverables, especially in maintaining confidence in the active stockpile, pushing forward on major modernization programs, and maintaining secure transportation. This is a testament to the workforce, its flexibility and responsiveness, and its commitment to U.S. national security.

This chapter provides an overview of the composition, status, and demographics of the workforce. It also covers challenges, strategies used to address those challenges, and accomplishments. Appendix E of this report, (Workforce and Site-Specific Information)," covers the missions, capabilities, and workforce data for each of the eight nuclear security enterprise laboratories, plants and sites.

[1] This workforce discussion is primarily speaking for the Weapons Activities account.

7.2 Workforce Composition

DOE/NNSA's workforce has three components: the Federal workforce, the eight M&O partner-operated sites,[2] and a wide variety of non-M&O entities that provide crucial support to DOE/NNSA's missions.

7.2.1 Federal Workforce

The Federal workforce is situated at DOE/NNSA Headquarters in Washington, DC; Germantown, Maryland; and Albuquerque, New Mexico, as well as field offices located across the nuclear security enterprise.

The Federal workforce is responsible for program and project management, as well as Federal contractor assurance and oversight of the national security missions across the enterprise. They are responsible for performing inherently governmental functions such as:[3] planning activities, fiduciary oversight, risk prioritization, product acceptance, supply chain management, legal, human resources, acquisition, and environmental, safety, and health oversight duties. This workforce comprises of highly educated and experienced civil servants from a variety of backgrounds. Included in the Federal workforce are the agents responsible for the secure transport of stockpile weapons as discussed in Chapter 5 and several active-duty military officers on rotational assignments. Recent legislation has increased the limit on full-time equivalent (FTE) personnel, providing DOE/NNSA more flexibility in handling its slate of warhead modernization activities.

An Integrated Workforce

DOE/NNSA's workforce consists of three essential integrated components, forming one team to accomplish DOE/NNSA's nuclear security missions.

- *The Federal workforce leads planning, programming, budget formulation (and execution), and evaluation activities for DOE/NNSA's national security programs, and provides other supporting roles. It provides a strategy to accomplish the mission that the sites implement.*
- *The M&O partners perform the full spectrum of technical activities in support of DOE/NNSA's nuclear security missions while the Federal workforce provides oversight. The M&O and Federal workforces partner to develop and implement strategic planning for the nuclear security enterprise.*
- *Non-M&O partners enable mission success by providing materials, components, and specialized services; access to supplemental experimental assets; and use of academia's R&D resources. In several areas, DOE/NNSA is becoming more reliant on the non-M&O workforce, including vendors, subcontractors, and other service providers, to meet the mission requirements.*
- *The effectiveness of this integrated workforce is enhanced by personnel exchange and embedding programs that foster deepening understanding of partner roles and mission critical contributions while strengthening communication lines within and between partner organizations.*

7.2.2 Management and Operating Workforce

The M&O workforce is situated at the eight government-owned or leased nuclear security enterprise laboratories, plants, and sites discussed in Chapter 1, Section 1.3 of this report. The laboratories partner closely with both the Federal workforce and the non-M&O workforce to address challenges across the science and engineering spectrum from basic science questions through weapons design and production. The production plants produce most of the designed weapon components and assemble warheads. Some laboratories, e.g., LANL and SNL, host production missions for a limited number of components in addition to their roles as design agencies and Federally Funded Research and Development Centers. The M&O workforce contains the bulk of the enterprise's scientists, engineers, operators, technicians, and crafts and labor personnel whose scientific, engineering, and technical

[2] M&O partners are consortia of industrial and academic contractors. More detail on these contractors may be found in Appendix E.

[3] As defined in Section 5 of the *Federal Activities Inventory Reform Act*, Public Law 105-270, these are functions that are so intimately related to the public interest that they require performance by Federal Government employees.

expertise supports the nuclear deterrence mission. The M&O workforce is integral to achieving DOE/NNSA's national security missions as it performs the surveillance, design, and production of the warheads and their components. This workforce is instrumental in defining the technical requirements for success in stockpile stewardship and management.

7.2.3 Non-Management and Operating Workforce

The non-M&O workforce consists of a variety of entities that assist DOE/NNSA in fulfilling its national security missions across the enterprise and are critical to success. This workforce includes, but is not limited to, support service contractors providing advisory and technical support and services to the Federal workforce; the supply chain entities providing specific materials and components necessary to fulfill key production and research and development (R&D) missions; and academic institutions that support DOE/NNSA through the academic alliances and partnerships integral in providing a pipeline of highly skilled and educated talent into the enterprise.

7.3 Status

DOE/NNSA must have a sufficient workforce with the right capabilities to ensure that it can execute warhead modernization activities and carry out the full scope of DOE/NNSA's missions. DOE/NNSA is currently balancing the B61-12 and W80-4 Life Extension Programs, the W87-1 Modification program, and the W88 Alt 370 Program, while planning for systems that will be needed in the 2030s and 2040s as detailed in Chapter 2. The workforce must also simultaneously manage surveillance, warhead maintenance, technology exploration and maturation, R&D, supply chain management, and acquisition, among other responsibilities. Given this workload, attracting and retaining the right talent is critical.

DOE/NNSA faces several challenges in keeping the nuclear security enterprise appropriately staffed, such as lengthy training periods for new hires and replacing retiring personnel who leave with specific technical knowledge. Over one-quarter of the workforce is retirement-eligible. New staff must be hired to replace separated employees in the early career demographic to meet future technological advances and challenges. In addition, the level and type of expertise required to fulfill DOE/NNSA's mission is often learned on the job over a significant period of time. DOE/NNSA and its M&O partners require a sufficient number of experienced personnel to transfer knowledge and skills with respect to stockpile technologies and processes to newly hired personnel who need time to develop these skills. All of these factors make maintaining a cleared, qualified, and technically trained workforce a complicated challenge. Recruitment and long-term retention of the workforce is therefore critical to the development, growth, and maintenance of scientific, engineering, and technical competencies.

7.3.1 Approaches and Programs

DOE/NNSA is addressing its workforce challenges and reinforcing its scientific, technical, engineering, and program management capabilities. NNSA's Administrator launched a Nuclear Security Enterprise Workforce Strategy Team in 2018 to devise effective methods to attract and retain the best and brightest from colleges, universities, trade schools, community colleges, and industry. The workforce strategy is informed by several factors necessary to attract and retain a high-caliber workforce. These factors include:

- Facilitating understanding of the mission and each individual/organization's role in accomplishing it, as detailed in DOE/NNSA's *Governance and Management Framework*
- Highlighting the ability to work with state-of-the-art experimental, computational, and manufacturing capabilities

- Employing modern and more efficient business and operating systems
- Working in modern workspaces with state-of-the-art equipment
- Providing ample career development opportunities

DOE/NNSA is pursuing an aggressive hiring strategy to add thousands of employees to the enterprise on an annual basis, most of whom are filling M&O personnel needs. To accomplish this strategy, the Workforce Strategy Team uses multiple approaches including coordinating job fairs and collaborating with M&O partners through "Nuclear Security Enterprise Days" at U.S. universities. These job fairs expedite applications, allow applicants to see each of the enterprise's locations, and provide opportunities for applicants to directly speak with hiring managers and HR personnel. DOE/NNSA, through its Enterprise Days has recruited motivated candidates at several education levels for Federal and contract positions at headquarters, field offices, and the M&O sites.

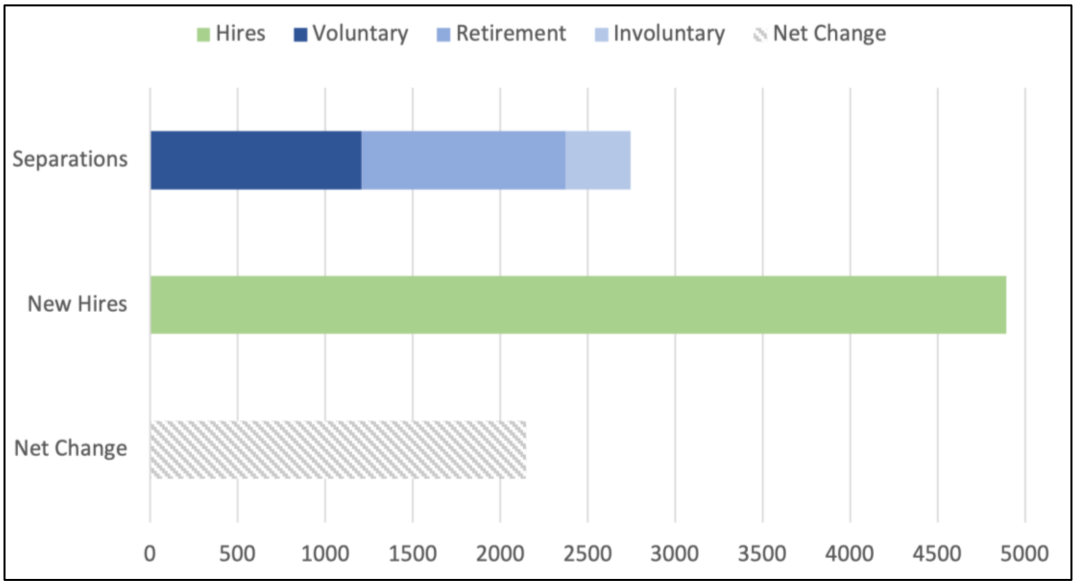


Figure 7–1. Management and operations net change during fiscal year 2020

DOE/NNSA is retaining and developing its workforce through succession planning, knowledge preservation, and training. Each M&O partner has several established programs aimed at improving retention. Since there are usually many employees with 0-5 years of experience or service, these retention programs are critical to maintaining workforce capabilities and managing risk to the mission. Examples of these programs include:

- Critical skill retention programs that provide pay incentives for hard-to-fill critical positions
- Employee leadership development programs
- Increased employee support and engagement through employee resource groups, 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

As detailed in Chapter 4, Section 4.3.6, several academic programs are essential to providing a pipeline of prospective employees in critically important scientific and engineering academic disciplines. These disciplines include, but are not limited to, radiochemistry, plasma physics, high performance computing, and advanced manufacturing. The academic programs include: the Stewardship Science Academic Alliance, Stewardship Science Graduate Fellowship, Computational Science Graduate Fellowships, the Predictive Science Academic Alliance Program, the Joint Program in High Energy Density Laboratory Plasmas, and the Minority-Serving Institution Partnership Program (MSIPP). For example, MSIPP, highlighted in Section 4.3.6, is designed to build a sustainable STEM pipeline that prepares diverse, top-tier talent through strategic partnerships between minority-serving educational institutions and the nuclear security enterprise. MSIPP aligns investments in university capability and workforce development with DOE/NNSA mission areas to cultivate a more diverse technical workforce and to enhance research and education capabilities at these minority-serving institutions through STEM grants, engagement, and internships. The Computational Science Graduate Fellowship program, through graduate fellowships, provides students the relevant experience for weapons code development through open science applications. These programs locate institutions and develop pathways to train a wide variety of students with the critical skills and disciplines required in the DOE/NNSA workforce and hire those familiar with the enterprise.

Laboratory Directed Research and Development, Plant Directed Research Development, and Site Directed Research and Development programs also have a significant role in the development of the workforce. These programs fund high-risk and potentially high-payoff research projects aimed at developing science and technology tools and capabilities to meet future national security challenges. This creates a vibrant R&D community that is attractive to high caliber personnel, including both new recruits and experienced researchers. Subsequently, DOE/NNSA benefits not only from the expertise of the individuals, but also the establishment of long-term relationships with future recruits and the academic institutions at which they study. These programs have developed postdoctoral paths that help transition in-demand researchers to full-time career employees and provide opportunities to introduce new hires to the nuclear security enterprise. In FY 2019 alone, the Laboratory Directed Research and Development program supported over 700 postdoctoral researchers, representing over 50 percent of all postdoctoral employees at the labs. These programs pave the way for early career scientists and engineers to find a lifelong professional home where their knowledge will be immediately utilized in impactful, mission-relevant research.

Finally, the NNSA Graduate Fellowship Program has been administered by Pacific Northwest National Laboratory for 25 years with a goal of identifying and developing the next generation of leaders to strengthen the nation through nuclear security work. The program routinely brings in top talent and provides several opportunities for fellows to work alongside experts, support major events, and engage in professional development opportunities. The fellows are assigned to work with a program office, field office, M&O partner, or other agency involving nuclear issues for a one-year term. The program has

steadily grown over the years and has over 500 alumni. About 85 percent of the NNSA Graduate Fellowship Program fellows continue to serve the Nation in a national security capacity.

7.3.2 Workforce Demographics

As of September 30, 2020, the nuclear security enterprise consisted of nearly 50,000 Federal and M&O employees.[4] The nuclear security enterprise added over 5,000 employees during FY 2020 and over 11,500 employees since the last detailed workforce data reported in the FY 2020 SSMP.[5] During FY 2020, the enterprise experienced just under 3,000 separations, slightly more than FY 2019 numbers reported in the FY 2021 SSMP.[6] Consistent with what has been reported in previous SSMPs, there is a continuing, significant voluntary separation rate for those classified as having five or fewer years of service. This will continue to require monitoring to maintain DOE/NNSA's scientific, engineering, and technical competencies.

Federal Workforce

As of September 30, 2020, DOE/NNSA's Federal workforce had a headcount of 2,297 employees. This number does not include support service contractors and Naval Reactors, but does contain several categories of personnel within the Office of Secure Transportation. **Figure 7–2** represents headcount rather than FTEs.[7] Of the 2,297 employees, approximately 1,200 are directly working on, or playing a supporting role in, the Weapons Activities programs discussed throughout this plan. The rest are involved in areas such as Defense Nuclear Nonproliferation and the budget, human resources, general counsel, external affairs, and field offices. The Federal workforce tends to skew heavily towards the general management labor category, although engineers and physicists are represented as well.

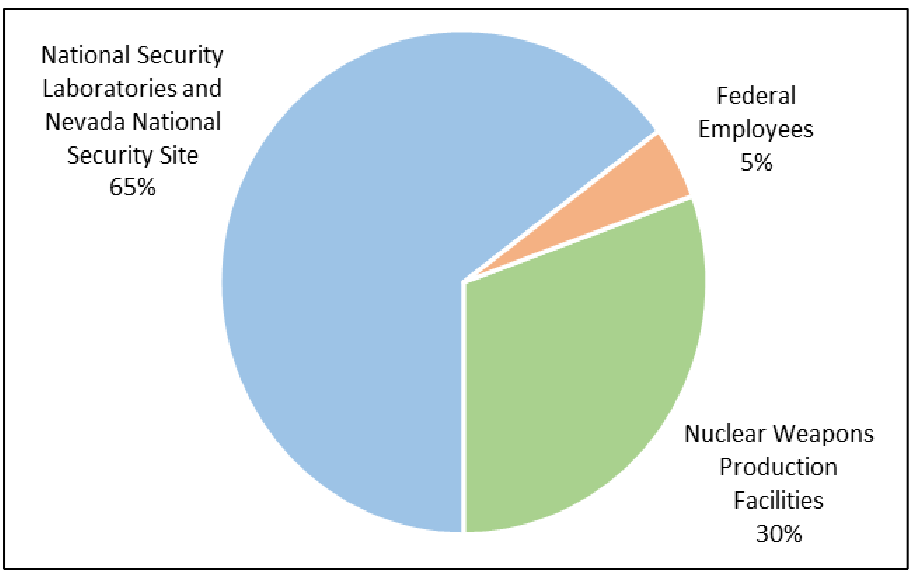


Figure 7–2. Management and operating and Federal share of total Weapons Activities workforce

[4] This number does not contain the Naval Reactors workforce, or Support Service Contractors.
[5] Data for the FY 2020 SSMP was collected as of September 30, 2018.
[6] The FY 2021 SSMP contains a focused summary of separations and retention data, different from the detailed information required in even-year documents.
[7] Headcount includes every individual employee counted as "1" body. Full-Time Equivalent counts focus on hours worked rather than individual employees, and can be calculated by dividing the number of regular hours worked by employees by the number of compensable hours in a year (usually 2,080). On a smaller scale, if there are two employees working part-time (for example, 20 hours per week), they add up to 1 FTE, while the headcount value would be 2.

The average age of the Federal workforce is 48 years old, with approximately 16 percent eligible for retirement. The average employee has roughly fifteen years of service. DOE/NNSA has focused on shifting age, years of service and retirement demographics by hiring more entry-level employees. Attrition has remained consistent at just under 9 percent. Projected needs over the next 5 years are stable, topping out at a headcount of 2,646.

M&O Workforce

DOE/NNSA's M&O partners reported 46,762 employees at the end of the fiscal year on September 30, 2020. The national security laboratories and the Nevada National Security Site reported 31,773 employees, while the production plants reported 14,989 employees. Similar to Federal headcount, not all employees are fully engaged in Weapons Activities work. Almost half of the M&O workforce has five or fewer years of service; retention of those personnel is vital to maintain DOE/NNSA's weapons expertise. Growth in many of the labor categories is expected across the FYNSP. However, these projections are based on current plans and are subject to change based on resource allocation and policy changes.

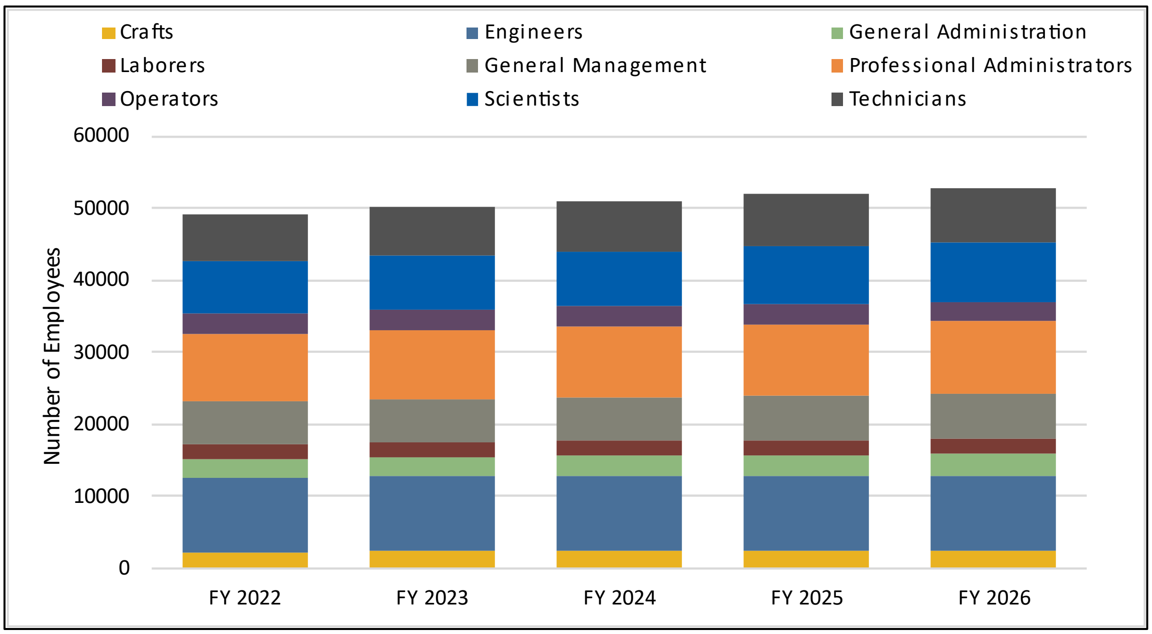


Figure 7–3. Management and operating partner workforce projections by Common Occupational Classification System (as of September 30, 2020)

Age, Years of Service, and Separations

The enterprise workforce, when viewed in total, has a fairly even distribution across age groups. A review of **Figure 7–4** displays a slightly more even age distribution for the production sites, especially in terms of younger personnel, while the national security laboratories have a slightly higher number of older employees. This is influenced by the population of both of those groups. There are no significant anomalies in the total age distribution shown in **Figure 7–5**, but more significant insights appear in the years of service and separation data.

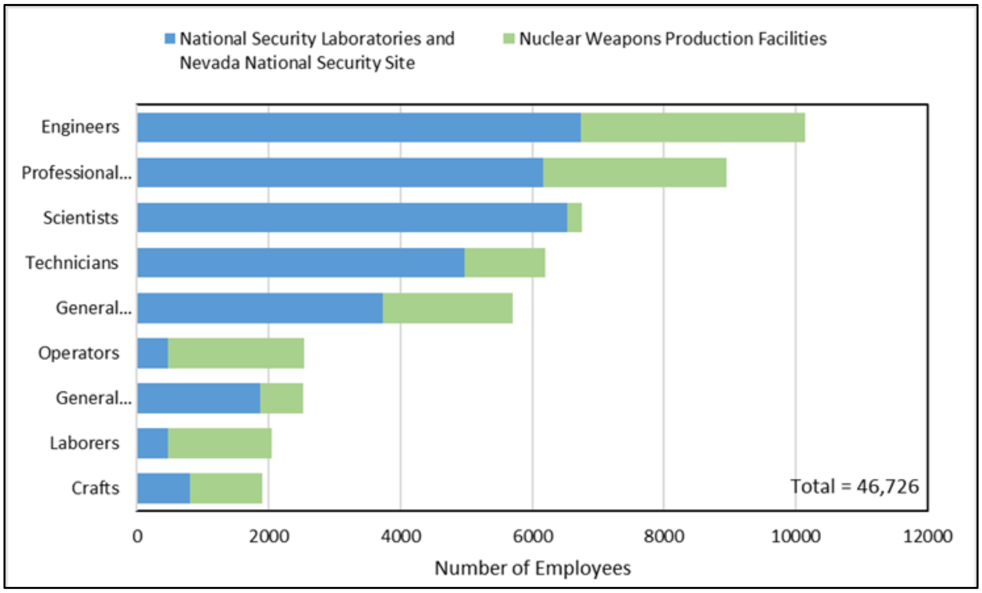


Figure 7–4. Workforce breakdown of national security laboratories,[8] the Nevada National Security Site, and weapons production facilities[9, 10] by Common Occupational Classification System[11] (as of September 30, 2020)

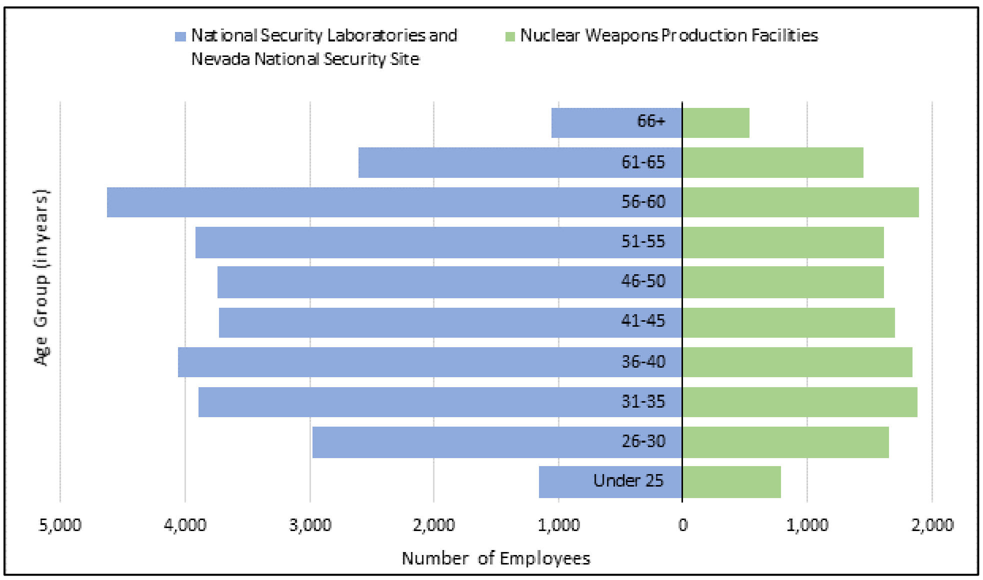


Figure 7–5. Workforce breakdown of national security laboratories, the Nevada National Security Site, and weapons production facilities by age group (as of September 30, 2020)

[8] The national security laboratories include LANL, LLNL, and SNL.
[9] The weapons production facilities include KCNSC, Pantex, SRS, and Y-12.
[10] This does not account for production functions at SNL and LANL. While these site sites have significant production missions, they are included with the National Security Laboratories for the purpose of consistent SSMP data reporting.
[11] From *Environmental Restoration/Waste Management Activities Common Occupational Classification System* (COCS), Revision 2, May 1996 by Pacific Northwest National Laboratory. Federal and M&O workforce data are reported in the standardized COCS categories to allow consistent comparison among the sites. These categories are not completely descriptive of the functions within each category. For example, the broad COCS category "General Management" also includes technical and scientific management functions, and the "Professional Administrators" category includes technical analysis and drafting design functions.

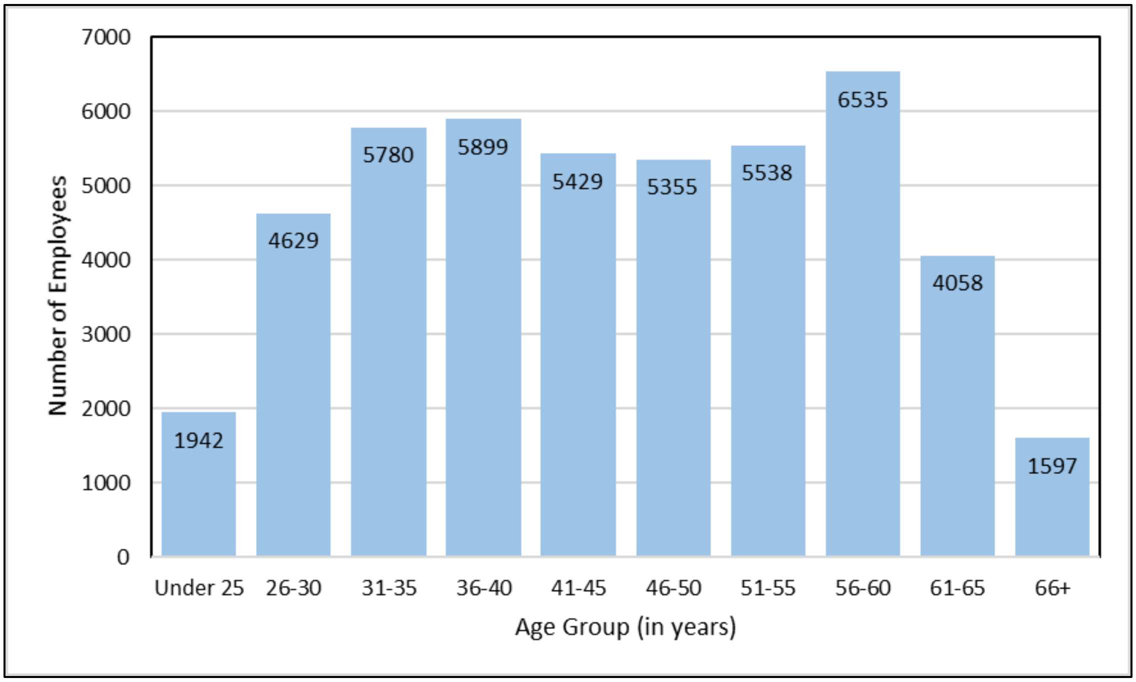


Figure 7–6. Total management and operating partner headcount distribution by age (as of September 30, 2020)

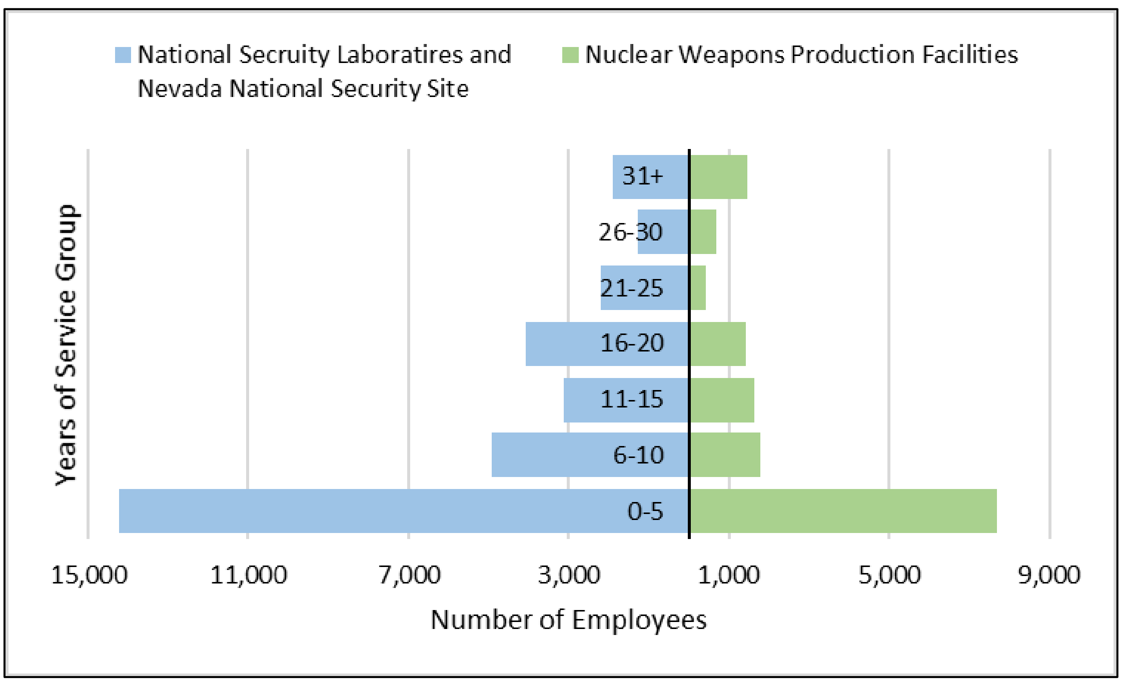


Figure 7–7. Workforce breakdown of national security laboratories, the Nevada National Security Site, and weapons production facilities by years of service (as of September 30, 2020)

The previously described hiring push, combined with retirement and separations trends, has resulted in significant changes in the years-of-service data. The plant and laboratory workforces are heavily concentrated in the 0-5 years-of-service category. 61 percent of the workforce has 10 or fewer years of service. This necessitates acceleration of knowledge transfer activities and training for younger and/or less experienced personnel before specialized knowledge is lost due to retirements and separations. Comparatively, the Federal workforce is a more even distribution, with many personnel having 11-15 years of service.[12] While trends are similar, the Federal Government has a clearer opportunity to manage risk while less experienced personnel develop in their careers. It should be noted that less experience does not necessarily equate to younger age groups and individuals considered "mid-career" may be new to the enterprise and applying expertise from a previous industry to specialized nuclear weapons work.

For separations, many of those in older age groups are retiring, as expected. As previously noted, most non-retirement, voluntary separations are in the 0-5 years of service category. These voluntary separations are spread out among several age groups, yet they are concentrated in the level of experience needed to offset retirements and maintain the enterprise's levels of technical expertise. This trend holds for both the Federal and M&O workforces. DOE/NNSA's workforce strategies, as discussed in Section 7.4, are addressing this issue.

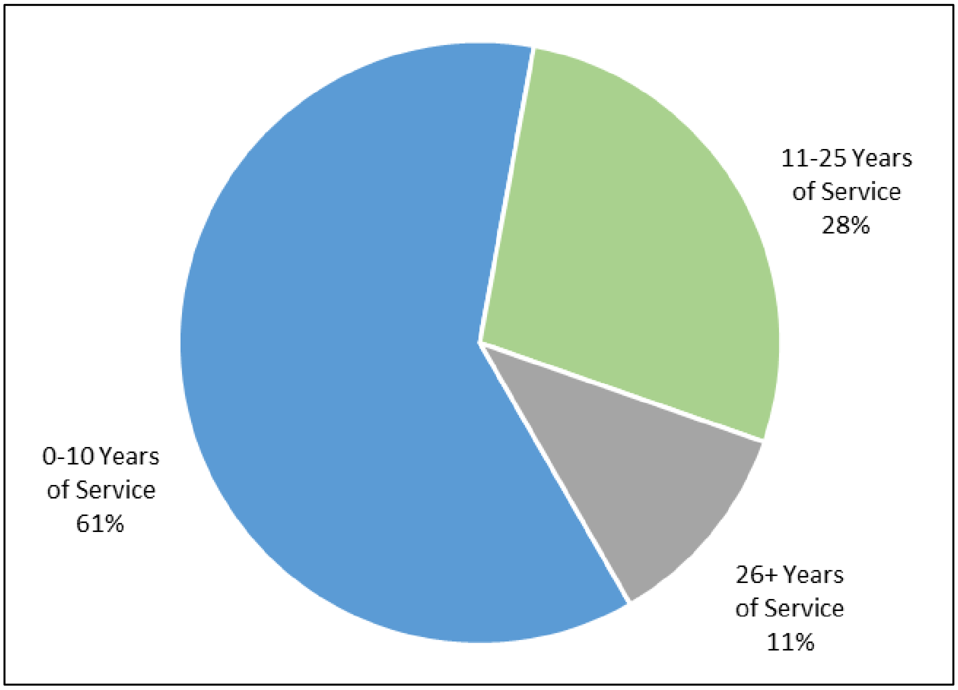


Figure 7–8. Management and operating partner workforce years of service at current site (as of September 30, 2020)[13]

[12] Federal workforce data can be found in Appendix D.

[13] Please note that this is years of service in the nuclear security enterprise. Although an employee may have fewer years in the enterprise, they may have several years of experience elsewhere before application to nuclear weapons work. Or, if in case of a lateral transfer, an enterprise veteran may have several years of service at a different site and be counted as having one year at their current site.

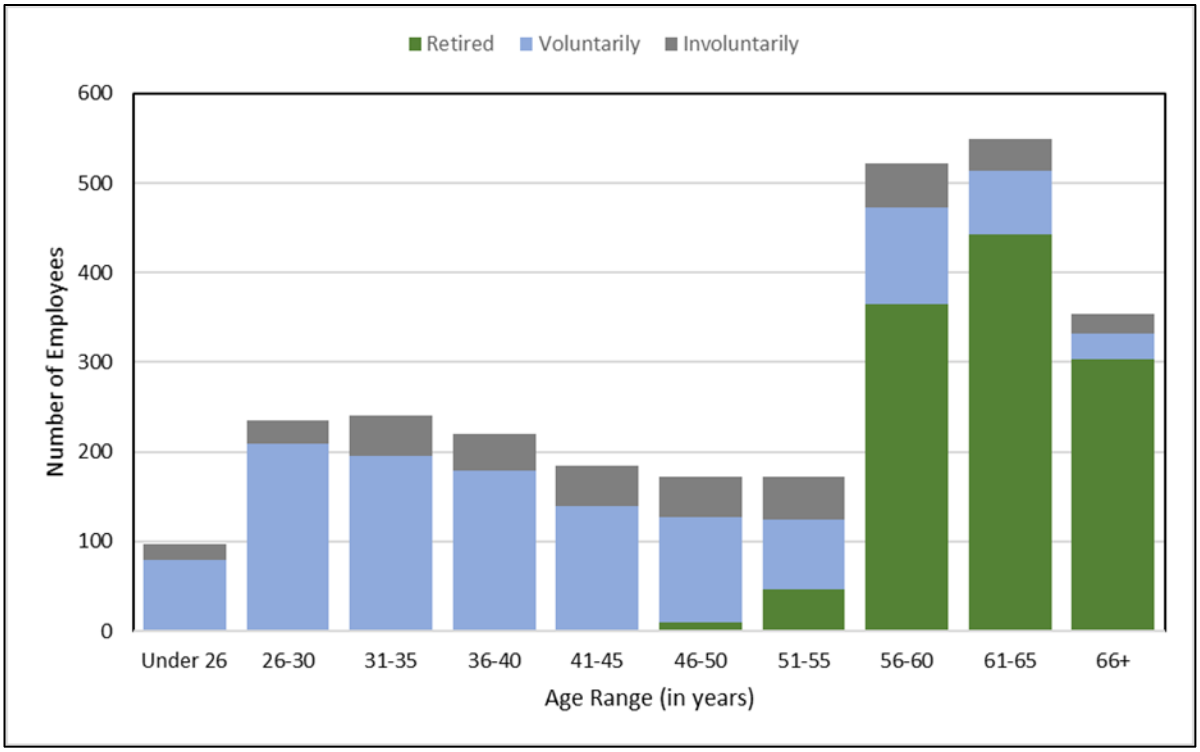


Figure 7–9. Total management and operating separations by age group (as of September 30, 2020)

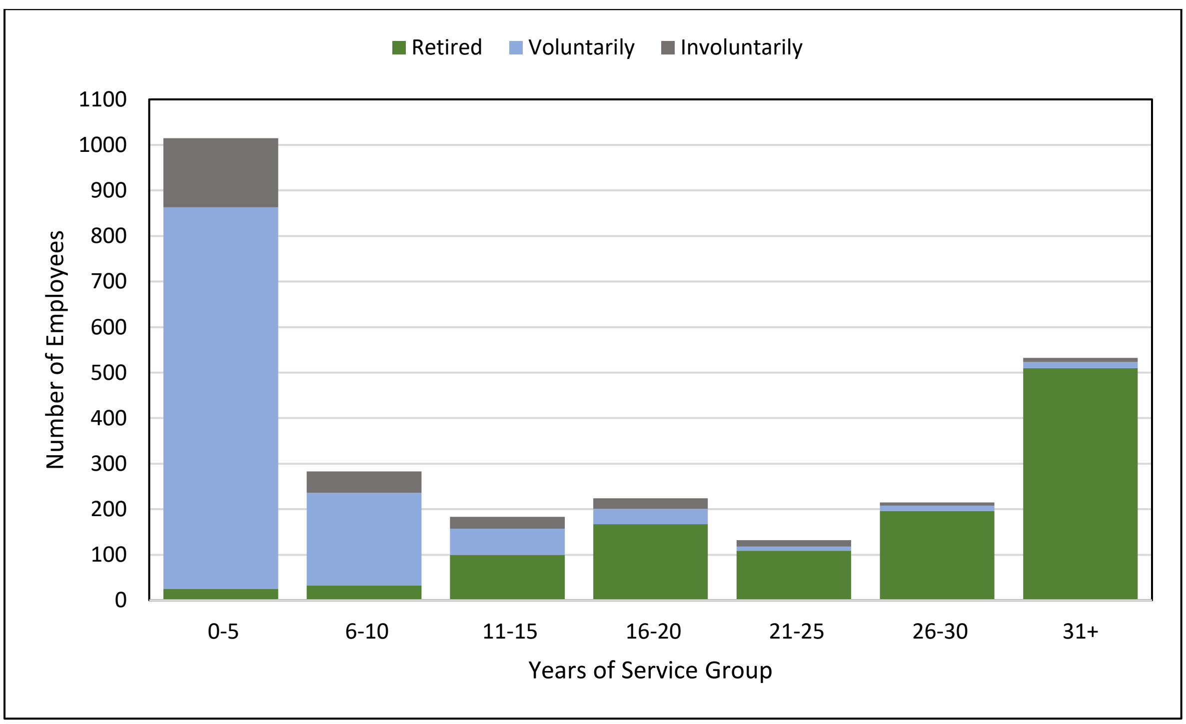


Figure 7–10. Total management and operating separations by years of service (as of September 30, 2020)

7.3.3 Unique Set of Skills for Nuclear Weapons Work

Successful execution of the nuclear weapons mission requires essential, specialized skillsets. DOE/NNSA and the M&O partners monitor and manage the workforce to ensure that a minimum skillset is maintained. However, much of the enterprise's essential expertise is developed through specialized applications of fundamental technical knowledge and understanding that is only obtained through weapons-specific work experience. In many areas, these skills cannot be learned in the classroom and are not directly transferable from other industries.

Areas in which specialized knowledge/experience is required include, but are not limited to, electrical engineering, systems engineering, toolmakers, nuclear criticality safety engineering, high explosives manufacturing and surveillance, weapons design, radiation effects sciences, radiological control technicians, quality control and assurance personnel, data scientists and high performance computing, cybersecurity professionals, welding, radar, and optics. This unique specialization of the enterprise workforce means that high retention rates, beyond what may be standard or desired in private industry, is essential for workforce and capability continuity.

7.4 Workforce Challenges and Strategies

Building and retaining a workforce capable of maintaining the current stockpile, while also planning for and responding to future requirements, is a complex task. Workforce planning efforts are focused on both the near- and long-term challenges of managing increased workload necessary to support weapons modernization. Bolstering the workforce's depth and breadth in required skill areas and transferring institutional knowledge is critical as a significant number of employees retire. The same is true for retaining individuals who possess those skill sets and cultivating career paths that enable development of enterprise specializations. These challenges are articulated for specific disciplines and areas of expertise in the challenges and strategy sections throughout this SSMP.

Through a variety of approaches and strategies, the Federal, M&O, and non-M&O partners ensure a sustained world-class workforce that will provide the knowledge, skills, and experience needed to maintain the current and future stockpile through a standard talent management approach.

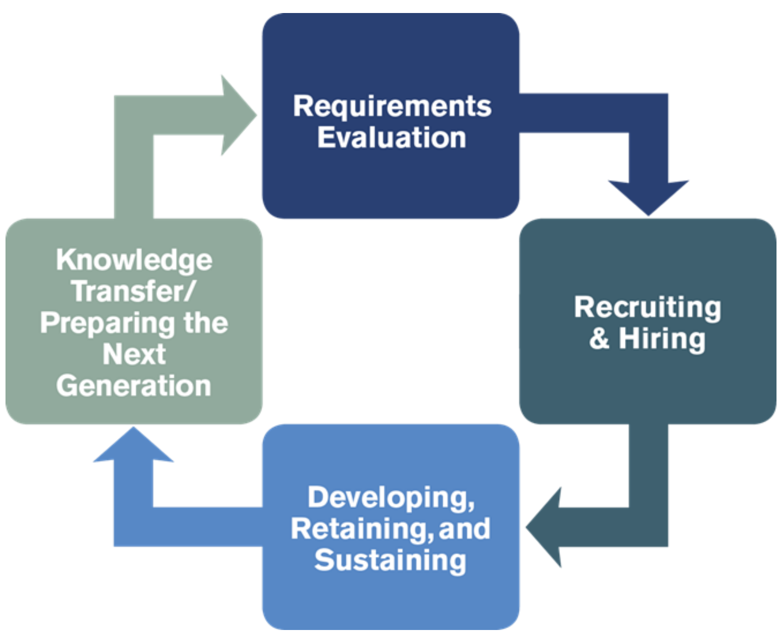


Figure 7–11. A simplified model of the talent management life cycle

7.4.1 Recruiting and Hiring

DOE/NNSA and its M&O partners continue to increase hiring to meet mission requirements set forth by the Nuclear Weapons Council. As stated above, DOE/NNSA is pursuing an aggressive hiring strategy to add thousands of new hires to the nuclear security enterprise each year. Each site employs strategies that address its unique recruiting and hiring challenges. **Table 7–1** provides a non-exhaustive summary of these approaches.

Table 7–1. Summary of Recruitment and Hiring challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Maintain the scientific, engineering, and technical capabilities of the enterprise workforce. Enterprise workforce needs are in high-demand STEM fields such as electrical engineering. US citizens earning degrees in these fields have many opportunities with which the enterprise must compete. Competition for skill sets that can integrate across multiple disciplines such as systems engineering, production science and engineering, and highly technical project management controls.	Pursue current hiring strategies to hire thousands into the enterprise each year. Promote access to unique, world-class R&D, science, technology, and engineering capabilities and facilities. Create developmental programs for highly skilled disciplines; work on adding non-exempt relocation benefits to allow national recruitment of high-demand/hard-to-find disciplines (e.g., toolmakers and technicians). Emphasize stable employment, even during economic downturns, with long-term financial stability and higher quality of life. Utilize university partnerships that leverage research contracts and relationships for top-tier talent. Negotiate offers and offer stronger benefits packages. Emphasize flexible work schedules, paid parental leave, and work-from-home options.	Develop postgraduate programs with opportunities to become career employees. Continue current university strategy and efforts to build brand educational institutions and events. Continue exploring telecommuting as a strategy for wider recruitment. Expand partnerships with educational and trade institutions and develop specialized pipeline programs for critical-skills positions. Encourage high school students to pursue STEM careers. Expand diversity & Inclusion initiatives.
Remote geographic location of some sites, resulting in difficulty recruiting nationally.	Target willing candidates via university partnerships. Increase emphasis on local hiring and training; focus greater emphasis on internships and apprenticeships to increase the local pool of workers. Coordinate with DOE on community outreach to encourage students at middle schools and high schools to develop local workforces with strong STEM interests and education."	Continue current efforts.[14]
Federal Positions are limited and must be balanced across a range of program offices.	Leverage lab opportunities and provide temporary detail opportunities.	Utilize excepted service authority.
Salary may not match up with private sector for in-demand skills.	Current salaries, pay for performance, performance-based incentives.	
COVID-19	Virtual interviews, career fairs, testing, onboarding, delayed relocations.	Increase virtual visibility with candidate sources. Continued flexibility from the Office of Personnel Management and relocation leniency.

[14] It is currently unknown how this may be affected by the COVID-19 pandemic, and potential long-term workplace changes that will be developed in response (e.g., work from home).

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
Competition between M&O sites for similar skills.	Joint M&O presence at job fairs with a focus on jobs within NNSA, as opposed to specific sites.	Strengthen engagement between M&Os in recruitment and hiring processes to simplify applications.

7.4.2 Developing, Retaining, and Sustaining the Workforce

Many aspects of nuclear weapons work require the enterprise to "grow its own" workforce, which places a premium on retaining workers when they have successfully acquired relevant experience. As noted, most non-retirement separations occur within the first five years of employment and represent a loss of the enterprise's investment in developing fully capable employees. Today's workforce leans toward being increasingly mobile and desires greater independence, more responsibility, and quicker advancement. These changes in expectations complicate approaches to keep new staff involved given lengthy security clearance wait times, multi-year training periods, and constantly-changing workloads and priorities. Retention will require continued focus on involvement, bench strength, succession planning, analytics, exit interview analyses, proactive planning, and an increased focus on career paths. These include areas such as enhanced individual development plans, learning and development to improve knowledge transfer, and increased diversity and inclusion strategies. **Table 7–2** displays a non-exhaustive summary of enterprise approaches.

Pantex and the National Science Bowl: Supporting Future STEM Leaders

Programs like the National Science Bowl, a highly competitive science education and academic event, encourage development of future STEM leaders. Teams of high school and middle school students compete in a fast-paced verbal forums to solve technical problems and answer questions in all branches of science and math. Pantex has sponsored the regional competitions for more than 25 years with a goal to provide STEM opportunities for students in the Panhandle and South Plains. STEM outreach activities stimulate interest in developing STEM skills for possible future employment, especially for some of the more remote sites in the nuclear security enterprise.

Table 7–2. Summary of Development, Retainment, and Sustainment challenges and strategies

Challenges	Strategies	
	Current Strategy Being Implemented	*Future Strategies Needed*
National Security missions require the ability to retain a resilient and responsive workforce.	Talent Development Initiatives for potential employees.	
COVID-19	On-line Development, Virtual coaching, briefings, and meetings. Strict adherence to health and safety protocols.	Continued On-line Development. Evaluate effectiveness of virtual development. Shift to wider video participation to increase engagement.
Salary	Varied offers correspond to different levels of skill and education.	
We must remain competitive in our ability to support employee work-life balance.	Current strategies include flexible work schedules, paid parental leave, and work from home.	Continue to explore flexible work arrangements and cost-effective benefits options that meet the needs of the workforce. (e.g., expanded work from home policies, vacation front-loading, transportation and childcare solutions, aligning benefits to demographics). Explore career path variations that support desired work-life balance.
Continued attrition, employee skillsets in high demand.	Exit interviews to assess reasons for departure.	Strategies from evaluation of exit interview data.

7.4.3 Training and Knowledge Transfer to the Next Generation

Implementing training and knowledge-transfer programs that are sufficient to mitigate the loss of expertise through the retirement of experienced personnel continues to be an area of emphasis for the enterprise. Heavy stockpile modernization workloads provide an opportunity for new employees to learn on the job. This must be in tandem with adequate mentoring and guidance to be an effective method of deep knowledge transfer. Many sites, especially the national security laboratories, have mentoring systems in place as part of an employee's career development. These systems provide new employees opportunities to learn from experienced professionals while enabling experienced employees and retirees to transfer their knowledge.

SRS Apprentice Opportunities: Growing the Workforce

Savannah River Site (SRS) along with the State of South Carolina and other community partners are participating in a regional task force committed to creating 300 new registered apprentice opportunities within the South Carolina Technical College System in the Central Savannah River Area. The focus is to prepare skilled individuals for careers at SRS and other organizations. Participants will be able to work part-time, go to classes and school part-time, and get on the job training for a new career, greater opportunities, and endless possibilities.

Aside from active mentorship, the knowledge and expertise of seasoned employees approaching retirement must be documented and preserved for future weapon designers. The enterprise recognizes that efforts to gather weapons knowledge prior to the retirement of late-career employees must continue to be improved by enhancing existing programs and developing additional programs. **Table 7–3** provides a non-exhaustive list of enterprise approaches.

Table 7–3. Summary of Training and Knowledge Transfer challenges and strategies

	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Significant increase in the number of employees with less than two years of experience across the business.	Created a workforce development program to accelerate time to proficiency. Developed resources to increase knowledge and help new employees understand our customer, our business and exceed program management requirements.	Evaluate, adjust, and continue current efforts.
COVID-19	Online Development. Strict adherence to health and safety protocols.	Continue Online Development and whenever possible, in-person development and learning opportunities.
The infrastructure needed to train a growing workforce are already near or at capacity, causing delays.	Institute smaller class size. Leverage off-site locations and room-to-room virtual presentation. Address inefficiencies in on-shift training, with special attention given to critical skills that require the longest duration for training/certification.	Acquire dedicated on-site training space for new hire and uncleared personnel. Integrate needs for both training and execution spaces in future infrastructure investments. Leverage online training capabilities to support increased demand.
Engagement during clearance process.	Expedite clearances and integrate classroom and hands-on learning to maintain interest while awaiting clearance.	Evaluate, adjust, and continue current efforts.
Adequate transfer of knowledge for new employees to replace tenured employees.	Use simulators, knowledge preservation management programs. Provide leadership opportunities to high potential younger workers. Hire through internship and apprenticeship programs.	Evaluate, adjust, and continue current efforts.

7.5 Workforce Accomplishments

The technical accomplishments of the nuclear security enterprise documented throughout this report are cutting-edge, far-ranging in scope and effect, and indicative of the uniquely talented, highly educated, and highly trained workforce. The talent and accomplishments of the workforce are also evident from the numbers of publications, awards, patents, and other recognitions that have been bestowed on members of this workforce.

Collectively, the sites have had more than 4,000 technical, peer-reviewed journal articles published over the last 2 years. At least 30 employees have been granted fellowship in several prestigious technical societies, such as the American Association for the Advancement of Science, The American Physical Society, and the Institute of Electrical and Electronic Engineers. Ten young researchers at the national laboratories were recipients of the Presidential Early Career Awards in Science and Engineering. Over a dozen employees received accolades from technical diversity societies and other national technical honors. Members of the nuclear security enterprise also participated in several projects that won R&D 100 awards, the Secretary of Energy's Achievement Award, and other program office excellence awards.

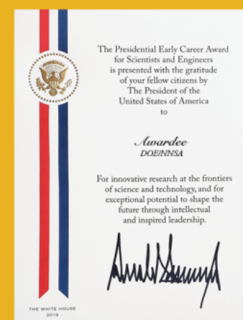
The innovation and intellectual capital of the enterprise is also apparent in the number of patents and invention disclosures attributable to the nuclear security enterprise. Together, the sites were granted more than 600 patents in the last 2 years and filed applications for many times that number. These patents and innovations benefit not only the nuclear weapons enterprise but the broader R&D community.

Workforce Accomplishments (from 2019-2020)

- *Journal Articles Published: approx. 4,000*
- *Patents Granted: approximately 600*
- *Technical Fellows: 30*
- *Presidential Early Career Awardees: 10*
- *Diversity Awards: 12*
- *John Dawson Award for Excellence in Plasma Physics Research*
- *Robert R. Wilson Prize in Particle Accelerators*

Presidential Early Career Award for Scientists and Engineers (PECASE)

The Presidential Early Career Award for Scientists and Engineers (PECASE) recognizes scientists and engineers who, while early in their research careers, show exceptional potential for leadership at the frontiers of scientific knowledge. The PECASE Award was established in 1996 and is the highest honor bestowed by the U.S. government on outstanding scientists and engineers beginning their independent research careers. The awards are conferred annually at the White House following recommendations from participating agencies.



In 2019, DOE/NNSA awarded this high honor to 11 scientists and engineers at several sites in the nuclear security enterprise, which encourages their continued contributions to national security.

4 Recipients

Lawrence Livermore National Laboratory

4 Recipients

Sandia National Laboratories

2 Recipients

Los Alamos National Laboratory EST. 1943

1 Recipient

Nevada National NNSS Security Site

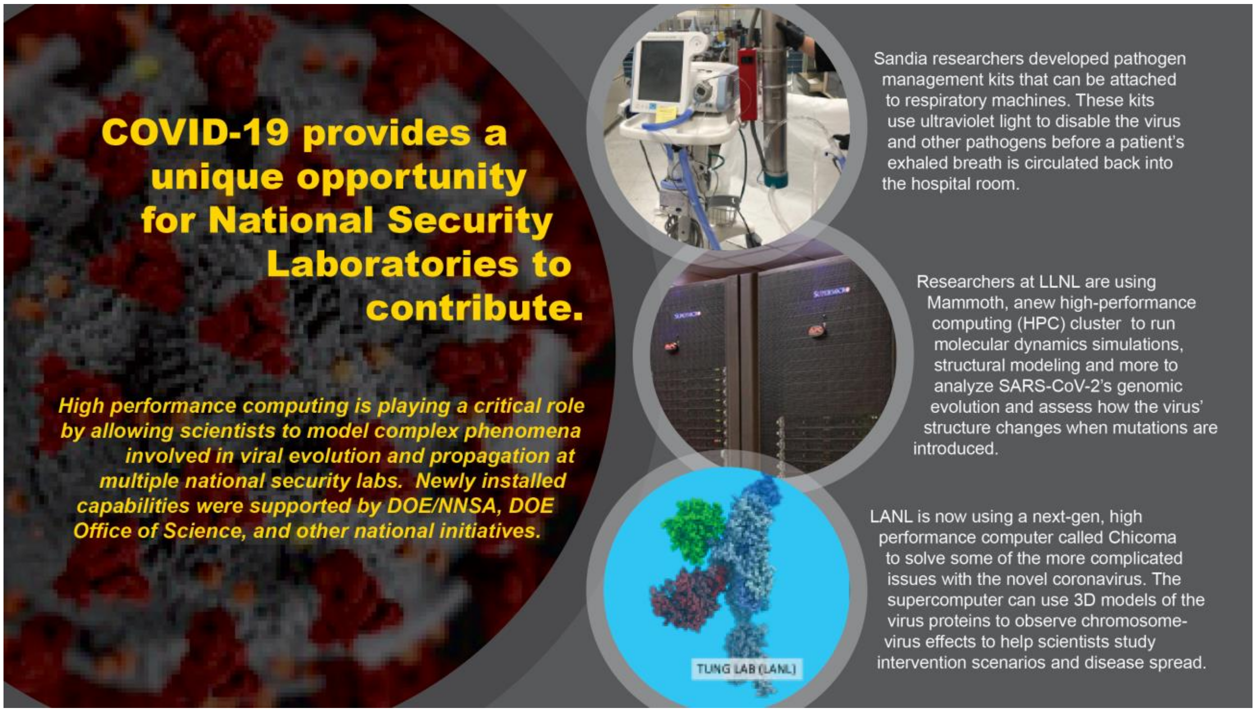


Figure 7–12. Workforce achievements: using computers to fight COVID-19

Chapter 8
Budget and Fiscal Estimates

The Fiscal Year (FY) 2022 President's Budget for Weapons Activities supports the nuclear stockpile and associated modernization programs. Consistent with the past two transition year budgets (FY 2018 and FY 2010), the FY 2022 President's Budget does not include program-based defense budget levels beyond the upcoming budget year. Instead, the defense estimates for FY 2023-2026 simply reflect inflated FY 2022 levels, not policy judgments. The Administration will include out-year defense program funding levels in the FY 2023 Budget, in accordance with strategy documents currently under development. The FY 2023 President's Budget will be accompanied by a Future Years Nuclear Security Program (FYNSP) that reflects this Administration's policy judgments.

The first part of this chapter displays budgetary information for the FY 2022 budget request based on the program of record described in this *Fiscal Year 2022 Stockpile Stewardship and Management Plan* (FY 2022 SSMP). Sections 8.4 through 8.8 compare the FY 2022 budget request to the FY 2021 enacted budget and present key milestones representing progress toward program goals. Key milestones beyond the next 5 years represent planned activities to meet DoD requirements and are contingent on future decisions.

The second part of the chapter describes cost projections for selected programs beyond FY 2022, including the basis of those cost projections used to estimate the potential long-term cost of the U.S. Department of Energy's National Nuclear Security Administration (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 plan and an analysis of the affordability of the Weapons Activities program.

8.1 Planning, Programming, Budgeting, and Evaluation

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

- The Planning phase of the PPBE process considers the full range of work in a manner that is fiscally informed, but not constrained, to ensure all requirements and mission needs are incorporated. This is attained by specifying strategic goals and objectives through Department-level and NNSA-level strategic planning documents that are issued during each new Administration. These internal strategic documents must align with and support the mission priorities in the Interim National Security Strategic Guidance and any forthcoming national strategy documents, as well as priorities reflected in program-level plans and input from managing and operating (M&O) contractor partners. Those priorities drive the development of a budget that allows timely execution of key mission priorities and enables DOE/NNSA to achieve its missions.

- The Programming phase is the decision-making process to align available program resources with priorities resulting in a balanced, integrated, executable FYNSP[1] to be proposed by DOE to the Office of Management and Budget (OMB) as the basis for that year's congressional budget request. This is primarily a Headquarters-driven process that allocates resources and integrates the funded activities to ensure accomplishment of the highest priority efforts.
- The Budgeting phase involves the production of a formal budget request and associated justifications to OMB. In coordination with program, field, and functional elements, DOE/NNSA develops OMB budget justification materials for the FYNSP2 that articulate work scopes and schedules commensurate with the funding request. The program elements approve these materials.
- Evaluation, which includes execution and performance, is the phase in which appropriated resources are distributed and controlled to achieve their approved purpose. The OMB apportionment process makes funds available to DOE for obligation and expenditure. Appropriation legislation and accompanying tables are the controlling documents for funds distribution and display the budgetary resources available. Performance is the assessment of progress made toward achieving identified performance measures at multiple levels within DOE/NNSA.

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

8.2 Portfolio Management

DOE/NNSA is undertaking a risk-informed, complex, time-constrained modernization and recapitalization effort. The President's Budget Request for Weapons Activities funds a set of programs (described in Chapters 2 through 6) based on the analysis of what is necessary to accomplish DOE/NNSA's statutory mission to manage the current and future stockpile without nuclear explosive testing. DOE/NNSA uses a rigorous portfolio management approach to determine funding levels for Weapons Activities. During the programming process, funding levels are established at various levels of detail for the FYNSP period[2] to align anticipated resources with DOE/NNSA priorities. During the FY 2021 PPBE process, DOE/NNSA restructured the Weapons Activities budget to better align portfolios with resources, thereby improving prioritization within those portfolios that have multiple programs and interdependencies.

As part of its portfolio management approach for Weapons Activities, DOE/NNSA continuously evaluates the health of the Weapons Activities capabilities described in Appendix B and further enumerated in the summary version of the SSMP.[2] Weapons Activities capabilities are vital to the successful conduct of DOE/NNSA's nuclear deterrence mission and are comprised of four elements:

- Human capital (experience, skill, people)
- Physical assets (facilities, infrastructure, equipment)
- Resources (resources, materials)
- Enabling processes (knowledge, technology, processes)

All four elements 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.

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[1] The FY 2022 budget request does not include program-informed budget levels beyond the budget year.

[2] For additional information on Weapons Activities capabilities, see the FY 2021 SSMP, Chapter 3, "Weapons Activities Capabilities That Support the Nuclear Security Enterprise."

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. These capabilities underpin the Weapons Activities portfolio and are managed by the Weapons Activities programs described in this document.

8.3 Fiscal Year 2022 President's Budget

Weapons Activities provides for maintenance and refurbishment of nuclear weapons to continue sustained confidence in their safety, reliability, and performance; continued investment in scientific, engineering, and manufacturing capabilities to enable production and certification of the enduring nuclear weapons stockpile; and manufacture of nuclear weapon components. Weapons Activities also provides continued maintenance and investment in the nuclear security enterprise to be more responsive and resilient. A key priority is rebuilding the production capability and capacity to produce necessary warhead components.

The FY 2022 President's Budget for Weapons Activities is aligned with DoD requirements to ensure the U.S. nuclear deterrent continues to be safe, secure, and effective. **Table 8–1** displays the FY 2021 enacted budget and program budget requests for Weapons Activities for FY 2022. The figures and narrative in Sections 8.4 through 8.8 describe the FY 2022 budget request in more detail.

Table 8–1. Overview of FY 2022 President's Budget for Weapons Activities

Activity	*Fiscal Year (dollars in millions)*					
	2021 Enacted	*2022 Request*	*2023 Request*	*2024 Request*	*2025 Request*	*2026 Request*
Stockpile Management	4,290.2	4,632.7	Estimates for the FY 2023 – FY 2026 budget for DOE/NNSA do not reflect a policy judgment. Instead, the Administration will make a policy judgment on amounts for DOE/NNSA's FY 2023 – FY 2027 topline in the FY 2023 Budget Request, in accordance with ongoing policy reviews.			
Production Modernization	2,547.9	2,911.0				
Stockpile Research, Technology, and Engineering	2,813.7	2,690.6				
Infrastructure and Operations	4,087.5	3,586.4				
Secure Transportation Asset	348.7	330.8				
Defense Nuclear Security	789.1	847.6				
Information Technology and Cybersecurity	366.2	406.5				
Legacy Contractor Pensions and Settlement Payments	101.7	78.7				
Adjustments	0.0	0.0				
Weapons Activities Total	**15,345.0**	**15,484.3**				

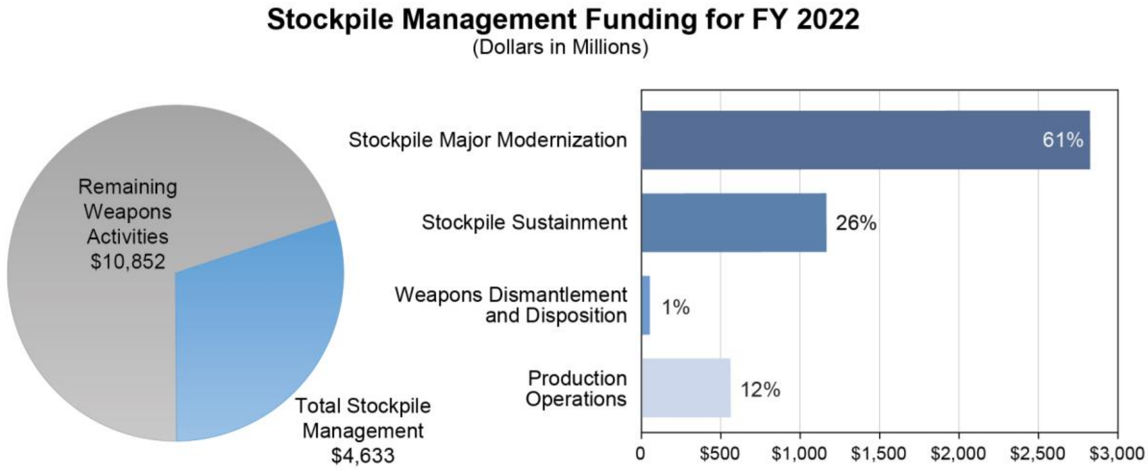
[a] Totals may not add because of rounding.

8.4 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. Additional information about the Stockpile Management program can be found in Chapter 2, "Stockpile Management."

8.4.1 Budget

The budget request for Stockpile Management increased 8 percent from the FY 2021 enacted budget and is illustrated in **Figure 8–1**.



	Fiscal Year ($M)	
	2021	**2022**
Stockpile Major Modernization	2,666.9	2,832.3
Stockpile Sustainment	998.4	1,180.5
Weapons Dismantlement and Disposition	56.0	51.0
Production Operations	568.9	568.9
Total Stockpile Management	4,290.2	4,632.7

Note: Numbers may not add due to rounding

Figure 8–1. FY 2022 President's Budget Request for Stockpile Management

8.4.2 FY 2022 Budget Request Compared to FY 2021 Enacted Budget

8.4.2.1 Stockpile Major Modernization

Stockpile Major Modernization extends the lifetime of the nation's nuclear stockpile while addressing required updates, replacing aging or obsolete components to ensure continued service life, and enhancing security and safety features. Stockpile Major Modernization includes: (1) B61 Life Extension Program (LEP); (2) W88 Alteration (Alt) Program; (3) W80-4 LEP; (4) W80-4 Alteration (Sea-Launched Cruise Missile [SLCM]); (5) W87-1 Modification (Mod) Program; and (6) W93 Program (formerly W93).

The budget request for Stockpile Major Modernization increased to support:

- W80-4 ramp-up for entrance to Phase 6.4 (*Production Engineering*) including readiness activities
- Start of Phase 6.2 (*Feasibility Study and Design Options*) and 6.2A (*Design Definition and Cost Study*) for the W80-4 Alteration for the Navy's SLCM
- Continued planned ramp-up of the W87-1 Modification Program as transition occurs from Phase 6.2A to Phase 6.3 (*Development Engineering*)
- Continued planned ramp-up of the W93 Program including transition from Phase 1 (*Concept Assessment*) to Phase 2

8.4.2.2 Stockpile Sustainment

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

The budget request for Stockpile Sustainment increased to support:

- Development and qualification for W76-1/2 Mk4B Shape Stable Nose Tip retrofit
- Retaining the B83-1 past its planned retirement date
- An increase in Integrated Surety Architecture (ISA) activities, including development, qualification, and production for the Stockpile Systems and execution of ISA Hub Operations for Multi-Weapon Systems
- Increased joint test assembly activities

8.4.2.3 Weapons Dismantlement and Disposition

WDD dismantles retired weapons and dispositions retired components from the stockpile. It provides an integrated program to safely dismantle and dispose of warhead components that have been retired, while some limited number of components from the dismantled warheads are preserved for potential reuse in stockpile modernization and safety testing programs.

The decreased budget request for WDD represents a reduction in disposition of legacy component inventories, while safe and secure dismantlement of nuclear weapons and components remains level.

8.4.2.4 Production Operations

Production Operations provides the manufacturing-based program that drives individual site production capabilities for LEPs, limited life component exchanges, surveillance, and weapon assembly and disassembly. Production Operations scope covers sustainment of all weapon systems capabilities that enable individual weapon production and are not specific to one material stream.

There was no change to the budget request for Production Operations. DOE/NNSA will continue to prioritize production operation capabilities to ensure stockpile requirements are met.

8.4.3 Key Milestones

To sustain and modernize the stockpile, DOE/NNSA must meet the key Stockpile Management milestones illustrated in **Figure 8–2**.[3] There were no substantive changes to the Stockpile Management milestones from last year's SSMP. Milestones from last year's SSMP completed in FY 2021 are:

- *Complete Phase 6.2 activities for the W87-1 Modification Program.* Phase 6.2 is complete and Phase 6.2A began in the fourth quarter of FY 2021
- *Deliver first production unit of the W88 Alteration Program.* The W88 Alteration Program system level first production unit was achieved in July 2021.
- *Conduct Phase 6.3 activities for the W80-4 LEP in support of the Long Range Standoff (LRSO) cruise missile.* Phase 6.3 activities are ongoing with Phase 6.4 anticipated in FY 2022.

[3] These key milestones do not include key annual deliverables, such as completing the Annual Assessment Process culminating in the national security laboratory (Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories) 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.

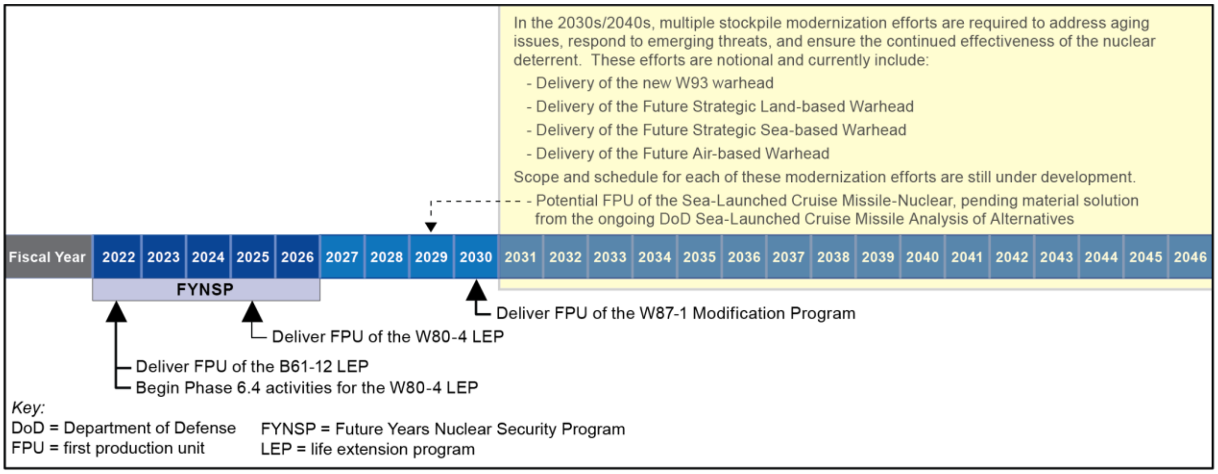


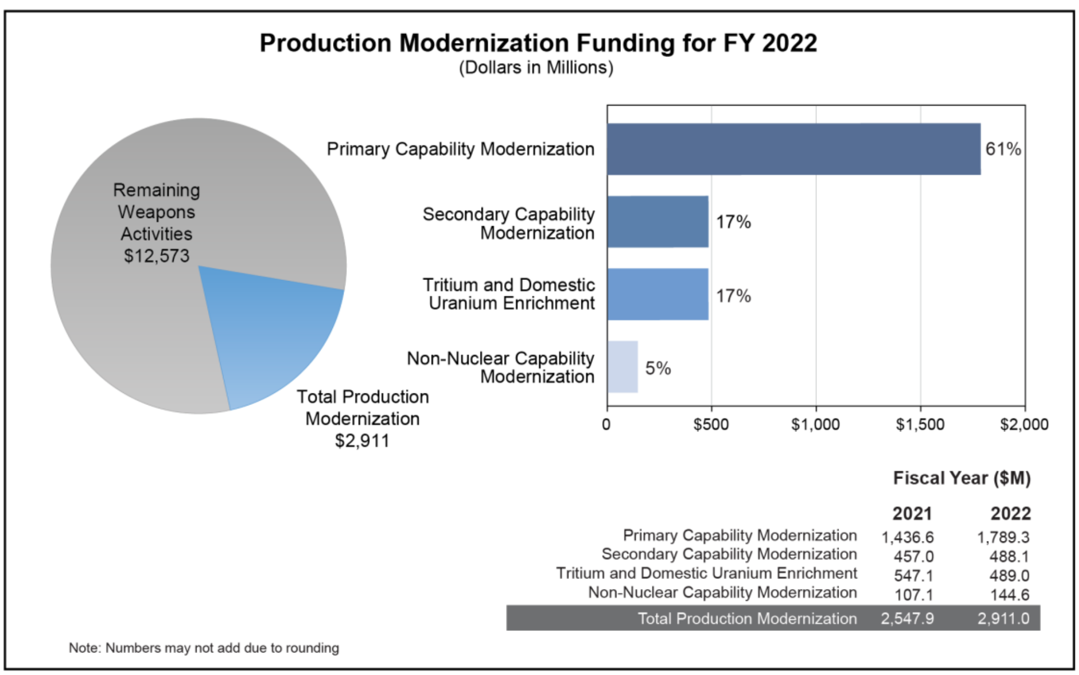
Figure 8–2. Key milestones for Stockpile Management

8.5 Production Modernization

Production Modernization focuses on the production capabilities of nuclear weapon components critical to weapon performance, including primaries, secondaries, radiation cases, and non-nuclear components. It consists of four major subprograms that sustain the Nation's nuclear weapons stockpile: (1) Primary Capability Modernization; (2) Secondary Capability Modernization; (3) Tritium Modernization and Domestic Uranium Enrichment; and (4) Non-Nuclear Capability Modernization. Additional information about the Production Modernization program can be found in Chapter 3, "Production Modernization."

8.5.1 Budget

The budget request for Production Modernization increased 14 percent from the FY 2021 enacted budget and is illustrated in **Figure 8–3**.



Fiscal Year ($M)	2021	2022
Primary Capability Modernization	1,436.6	1,789.3
Secondary Capability Modernization	457.0	488.1
Tritium and Domestic Uranium Enrichment	547.1	489.0
Non-Nuclear Capability Modernization	107.1	144.6
Total Production Modernization	2,547.9	2,911.0

Figure 8–3. FY 2022 President's Budget for Production Modernization

8.5.2 FY 2022 Budget Request Compared to FY 2021 Enacted Budget

8.5.2.1 Primary Capability Modernization

Primary Capability Modernization consolidates management of primary stage material processing and component production capabilities in the nuclear security enterprise. The program includes: (1) Plutonium Modernization and (2) High Explosives (HE) and Energetics Modernization. Plutonium Modernization includes activities at Los Alamos National Laboratory (LANL), the Savannah River Site (SRS), and across the nuclear security enterprise. The Los Alamos Plutonium Pit Production Project (LAP4) and the Savannah River Plutonium Processing Facility (SRPPF) are currently included under Primary Capability Modernization to encompass the full scope of Plutonium Modernization. High Explosives and Energetics Modernization consists of activities at Lawrence Livermore National Laboratory (LLNL), LANL, the Nevada National Security Site, Pantex Plant (Pantex), Sandia National Laboratories (SNL), and DoD vendors.

The budget request for this program increased to support:

- Funding for design activities supporting LAP4 and SRPPF
- Additional support for expanding plutonium pit production capabilities and process development
- Additional investments for the modernization of high explosives and energetics capabilities

8.5.2.2 Secondary Capability Modernization

Secondary Capability Modernization is responsible for restoring and improving manufacturing capabilities for the secondary stage of nuclear weapons in the nuclear security enterprise. This includes ensuring the availability of strategic materials and other sub-component streams necessary for the secondary stage, as well as modernizing the facilities and operations required to process these materials, fabricate them into parts, and assemble the final components. The program includes three subprograms: (1) Uranium Modernization (formerly Uranium Sustainment); (2) Depleted Uranium Modernization; and (3) Lithium Modernization.

The budget request for Secondary Capability Modernization increased due to:

- New depleted uranium scope to meet near-team mission requirements and support future weapon systems
- Additional scope to supply the current stockpile with purified enriched uranium metal, as well as support the transition of new capabilities into new and enduring facilities
- Growth in Lithium Modernization scope and processing requirements to meet national security requirements

8.5.2.3 Tritium Modernization and Domestic Uranium Enrichment

Tritium Modernization and Domestic Uranium Enrichment consists of two parts: (1) Tritium Modernization, which produces, recovers, and recycles tritium to support national security requirements, and (2) the Domestic Uranium Enrichment Program, which is responsible for establishing a reliable supply of enriched uranium to support U.S. national security and nonproliferation needs.

The budget requests for Tritium Modernization and Domestic Uranium Enrichment decreased, which reflects the absence of funding for the Uranium Reserve program. The decrease also reflects that highly enriched uranium downblending activities required advance funding provided in prior fiscal years, reducing the FY 2022 request level.

8.5.2.4 Non-Nuclear Capability Modernization

Non-Nuclear Capability Modernization consolidates management and oversight of strategic investments to modernize capabilities for design, qualification, and production of non-nuclear components for multiple weapon systems.

The budget request for this program increased to support:

- Equipment procurements at the Kansas City National Security Campus (KCNSC) that are necessary to modernize capabilities for development and production of non-nuclear components for multiple weapon systems
- Other Project Cost (OPC) activities for the Non-Nuclear Component Capacity and the Power Sources Capability Line Items and added OPC funding for the Heterogeneous Integration Facility project, which is needed to provide future trusted and strategic radiation-hardened microelectronics
- At-risk materials efforts to identify supply issues for those materials for which obsolescence, discontinuation, scarceness, or unavailability is likely to occur over the timeline for which it is needed or required
- Equipment for the neutron generator and power sources facilities at SNL
- Continued development and implementation of an assurance system model for commercial off-the-shelf (COTS) parts to avoid delays in weapons modernization programs
- Development of a thermal spray production capability needed for the W87-1 Modification Program and future systems

8.5.3 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.[4] Key milestones for Production Modernization are presented by program in Sections 8.5.3.1 – 8.5.3.4.

8.5.3.1 Primary Capability Modernization

Key milestones for Primary Capability Modernization are illustrated in **Figure 8–4**. Major changes from last year's plan related to Primary Capability Modernization are:

- Based on information developed to support the Critical Decision 1 (CD-1) (*Approve Alternative Selection and Cost Range*) milestone for the SRPPF project, DOE/NNSA has determined that the required 50 War Reserve pits per year production rate at SRS will not be achieved in 2030. Establishing required SRPPF pit production capacity as close as possible to 2030 remains a high priority and is required for sustaining the effectiveness of the Nation's nuclear deterrent. As described in Chapter 3, Section 3.2.1.3, further design activities conducted in support of CD-2 (*Approve Performance Baseline*) will identify multiple opportunities to achieve required production capacity closer to 2030.
- The FY 2025 milestone, *Obtain CD-4 (Approve Start of Operations or Project Completion) for High Explosives Science and Engineering facility*, is delayed to FY 2026 due to receiving no qualified bids to the original main works Requests for Proposals and the resulting need to go out for a rebid.

[4] Although most 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.

- The FY 2025 milestone, *Obtain CD-4 for High Explosives Synthesis Formulation and Production facility for future LEPs*, is delayed to FY 2030 due to growth in the facility footprint following completion of conceptual design and a better understanding of process requirements through design evolution.
- The FY 2026 milestone, *Obtain CD-4 for Energetic Materials Characterization*, is delayed to FY 2028 based on its Analysis of Alternatives (AoA) results.

Three milestones from last year's SSMP were completed in FY 2021:

- *Obtain CD-1 for Los Alamos Plutonium Pit Production Project*
- *Obtain CD-1 for Savannah River Plutonium Processing Facility*
- *Complete specification for* triaminotrinitrobenzene – *TATB/PBX-9502*

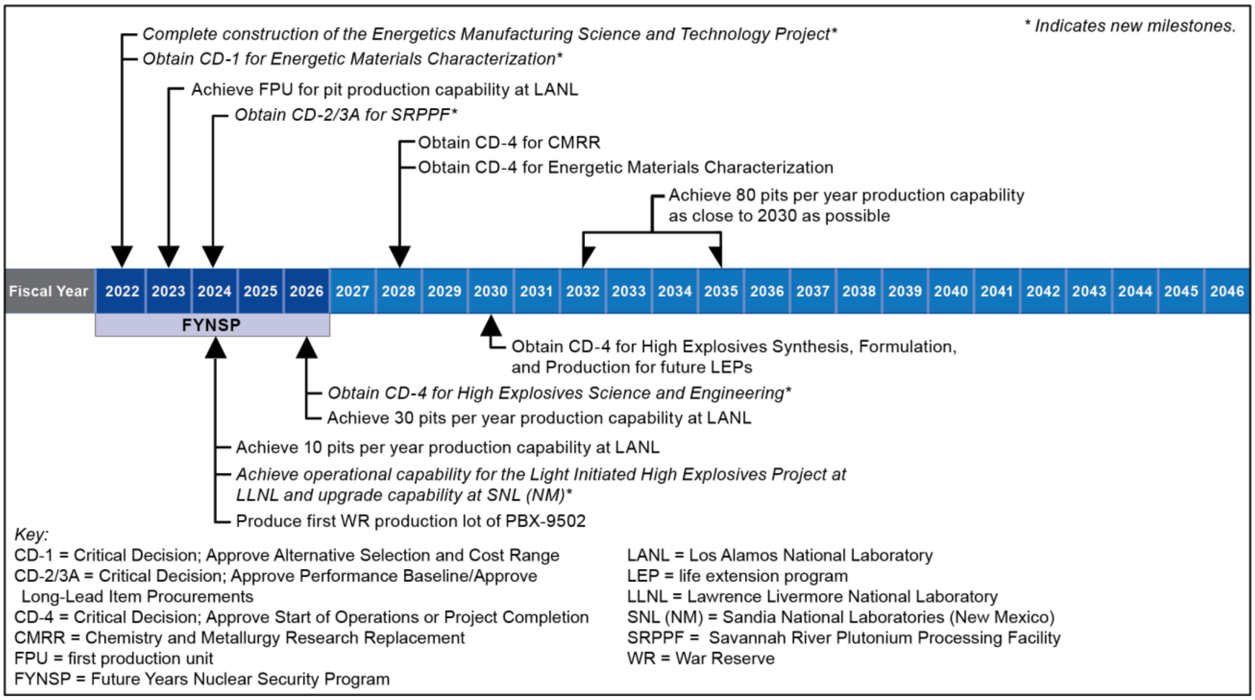


Figure 8–4. Key Milestones for Primary Capability Modernization

8.5.3.2 Secondary Capability Modernization

Key milestones for Secondary Capability Modernization are illustrated in **Figure 8–5**. Major changes from last year's plan related to Secondary Capability Modernization are:

- The FY 2024 milestone, *Obtain CD-2/3 (Approve Performance Baseline/Approve Start of Construction) for Lithium Processing Facility*, has been updated to FY 2026 to reflect schedule contingency previously not incorporated into the associated milestone date reported in the project data sheet.
- The FY 2025 milestone, *Start full scale conversion activities at Portsmouth*, has been removed due to growth in project cost estimates that require further analysis of options.

One milestone from last year's SSMP was completed in FY 2021:

- *Install development direct cast furnace.* Operations are expected to start in FY 2022.

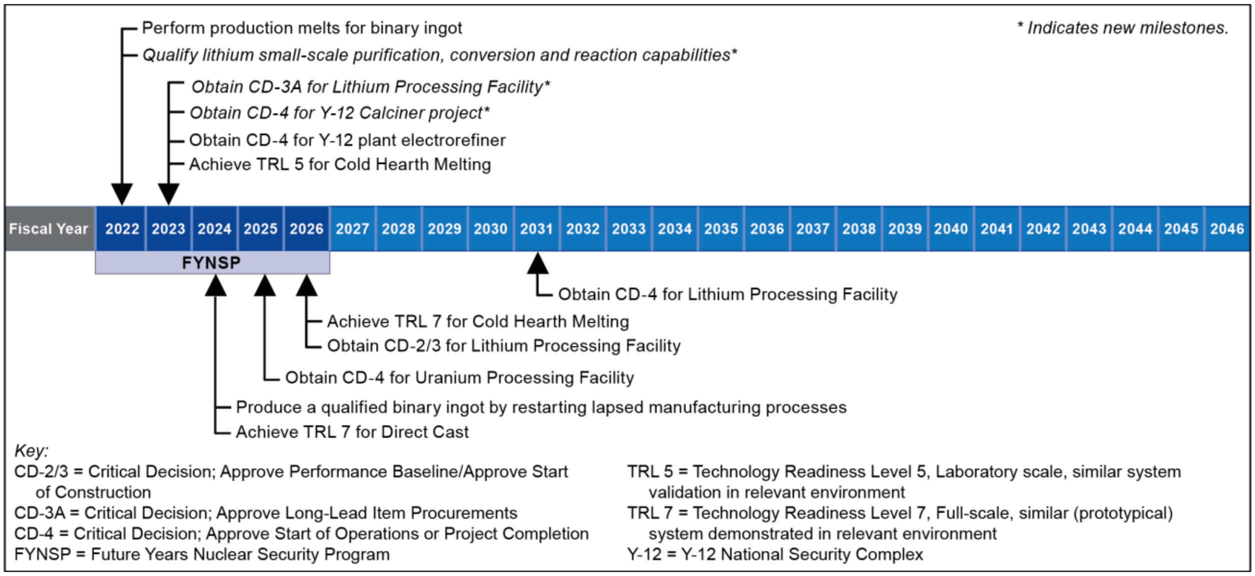


Figure 8–5. Key Milestones for Secondary Capability Modernization

8.5.3.3 Tritium Modernization and Domestic Uranium Enrichment

Key milestones for Tritium Modernization and Domestic Uranium Enrichment are illustrated in **Figure 8–6**. Major changes from last year's plan related to Tritium Modernization and Domestic Uranium Enrichment are:

- The FY 2021 milestone, *Obtain CD-3A (Approve Long Lead Item Procurements) for Tritium Finishing Facility*, is delayed to FY 2024 as a result of the separation of site preparation work into a discrete subproject.[5]
- The FY 2031 milestone, *Obtain CD-4 for Tritium Finishing Facility*, has a completion range of FY 2029 – FY 2031.
- The FY 2040 milestone, *Obtain CD-4 for Domestic Uranium Enrichment Facility*, is delayed to FY 2041 because additional unobligated low-enriched uranium was identified that extends the need date for a new enrichment capability.

One milestone from last year's SSMP was completed in FY 2021:

- *Begin irradiation of tritium-producing burnable absorber rods (TPBARs) in a second reactor*

[5] No longer tied to site preparation work, the CD-3A milestone for the Tritium Finishing Facility was moved to better align with the overall schedule so that the procurement will be ready when needed.

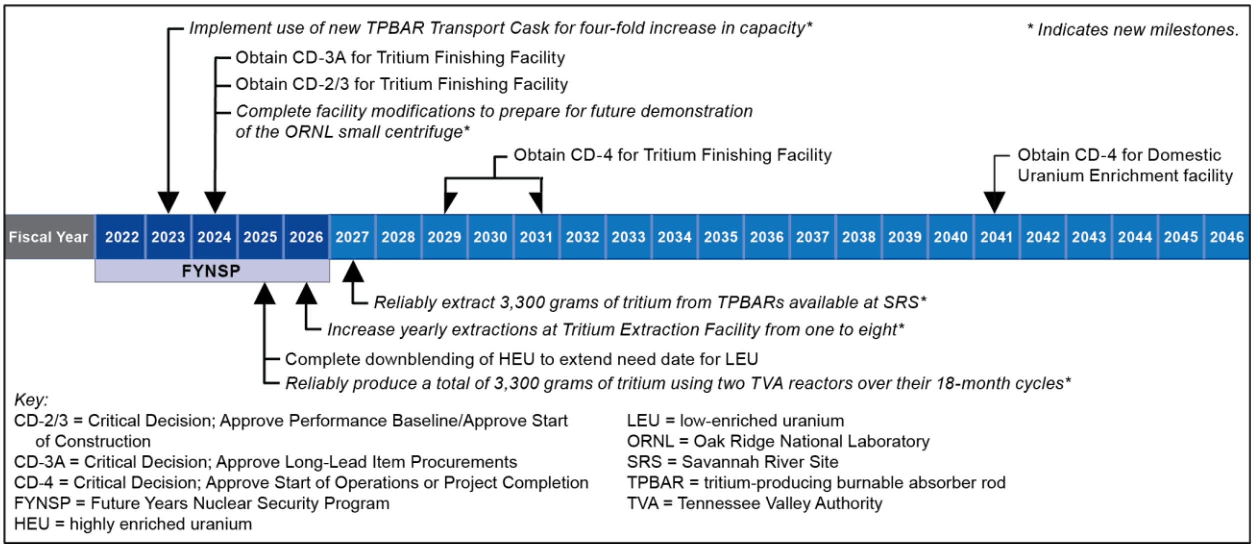


Figure 8–6. Key milestones for Tritium Modernization and Domestic Uranium Enrichment

8.5.3.4 Non-Nuclear Capability Modernization

Key milestones for Non-Nuclear Capability Modernization are illustrated in **Figure 8–7**. There is one major change from last year's plan related to Non-Nuclear Capability Modernization:

- The FY 2021 milestone, *Obtain CD-1 for Power Sources Capability Facility*, is now scheduled to be achieved in FY 2022.

One milestone from last year's SSMP was completed in FY 2021:

- *Provide the tooling and equipment, facility, and infrastructure investments necessary to sustain the MESA complex*

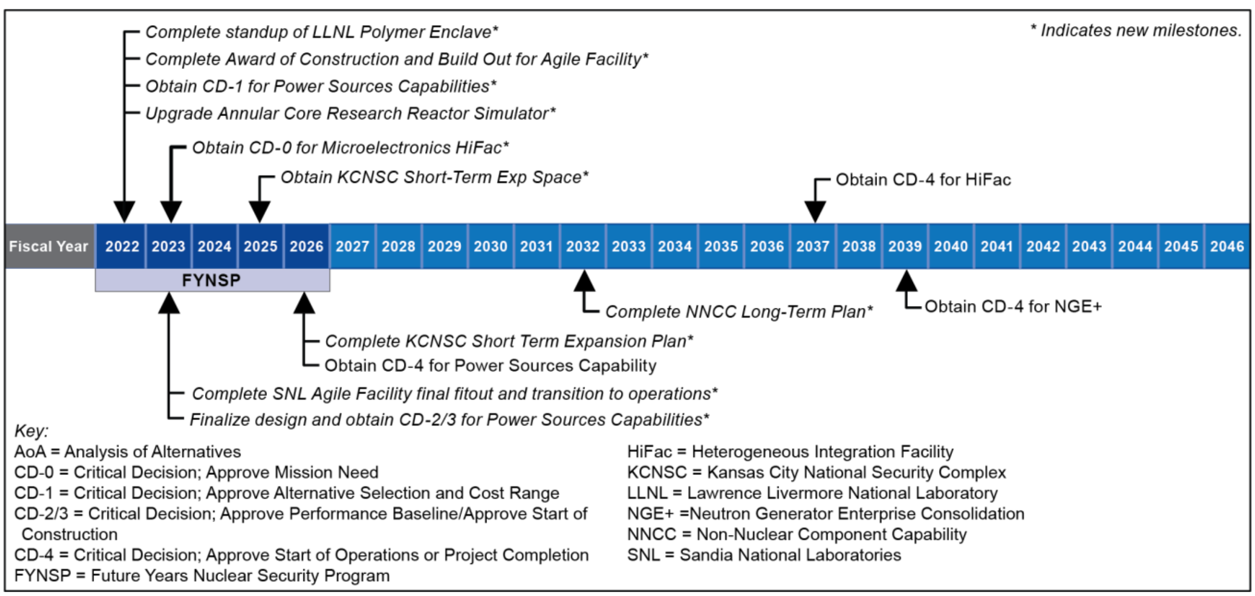


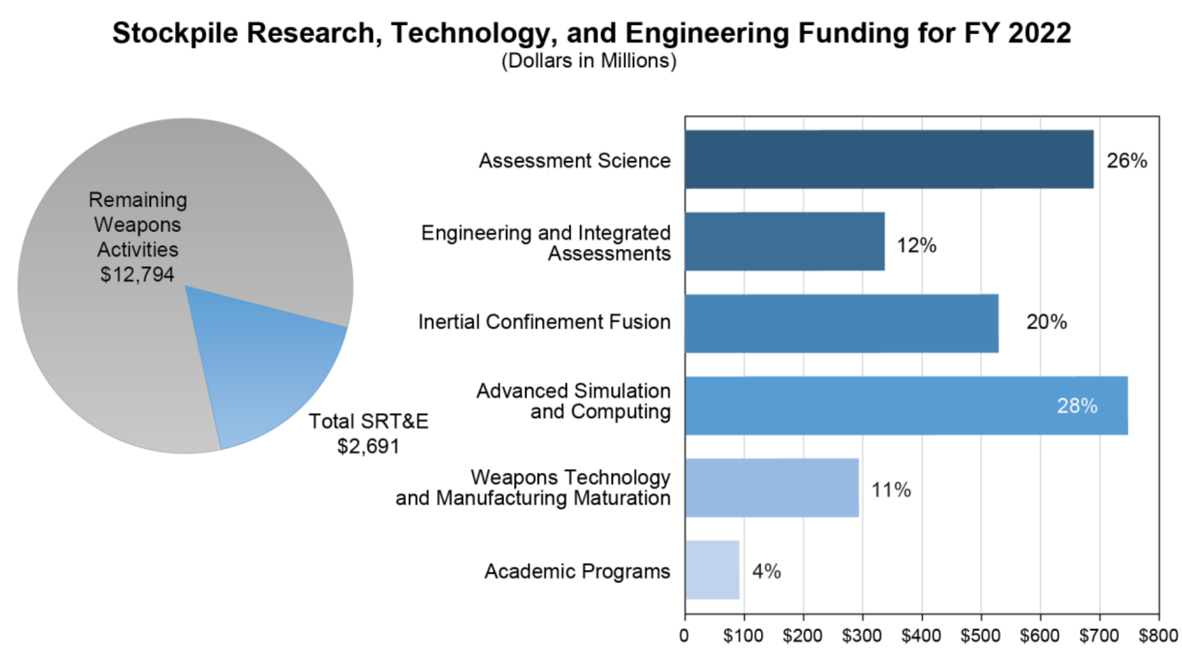
Figure 8–7. Key milestones for Non-Nuclear Capability Modernization

8.6 Stockpile Research, Technology, and Engineering

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

8.6.1 Budget

The budget request for SRT&E decreased 4 percent from the FY 2021 enacted budget (comparable) and is illustrated in **Figure 8–8**.



Fiscal Year ($M)	2021	2022
Assessment Science	769.4	689.6
Engineering and Integrated Assessments	337.4	336.8
Inertial Confinement Fusion	575.0	529.0
Advanced Simulation and Computing	732.0	747.0
Weapons Technology and Manufacturing Maturation	298.0	292.6
Academic Programs	101.9	95.6
Total SRT&E	2,813.7	2,690.6

Note: Numbers may not add due to rounding

Figure 8–8. FY 2022 President’s Budget Request for Stockpile Research, Technology, and Engineering

8.6.2 FY 2022 Budget Request Compared to FY 2021 Enacted Budget

8.6.2.1 Assessment Science

Assessment Science provides the knowledge and expertise needed to maintain confidence in the nuclear stockpile in the absence of nuclear explosive testing. The program is comprised of six subprograms: (1) Primary Assessment Technologies; (2) Dynamic Materials Properties; (3) Advanced Diagnostics; (4) Secondary Assessment Technologies; (5) Enhanced Capabilities for Subcritical Experiments (ECSE); and (6) Hydrodynamic and Subcritical Experiment Execution Support.

The budget request for Assessment Science decreased to reflect a reallocation to higher priority DOE/NNSA programs and projects. This also includes a rebalancing within Primary Assessment Technologies to support a subcritical experiments schedule that fully utilizes the investment in ECSE.

8.6.2.2 Engineering and Integrated Assessments

Engineering and Integrated Assessments is responsible for ensuring system agnostic survivability in present and future stockpile-to-target sequences (STS) and ensures a responsive nuclear deterrent through collaborative partnerships, proactive integration, and assessments. This program includes seven subprograms: (1) Archiving and Support; (2) Delivery Environments; (3) Weapons Survivability (previously Nuclear Survivability); (4) Studies and Assessments; (5) Aging and Lifetimes; (6) Stockpile Responsiveness; and (7) Advanced Certification and Qualification.

The decreased budget request for Engineering and Integrated Assessments reflects the current schedule of survivability experiments supporting the FY 2023 mission objective for Hostile Mitigation Capability[6] and reduced high impact experiments in the Delivery Environments program. The decrease is offset by slight increases to qualification activities supporting improved methodologies, and the development of new approaches for designing, manufacturing, certification, and qualification to accelerate the nuclear weapons lifecycle process.

8.6.2.3 Inertial Confinement Fusion

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

The budget request for ICF decreased to reflect the forward funding in FY 2021 for acceleration of FY 2022 scope.

8.6.2.4 Advanced Simulation and Computing

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

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[6] For more information about mission objectives, see Chapter 4, Section 4.2.1.

The budget request for Advanced Simulation and Computing increased to support pursuing new validated integrated design codes and advanced high-performance computing capabilities, including the El Capitan exascale system procurement.

8.6.2.5 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 to enable the future success of the nuclear security enterprise. It is comprised of three subprograms: (1) Surety Technologies; (2) Weapon Technology Development; and (3) Advanced Manufacturing Development.

The decreased budget request for Weapons Technology and Manufacturing Maturation reflects a reallocation to address higher priority DOE/NNSA programs and projects. The decrease to Surety Technologies and Weapon Technology Development is partially offset by an increase in Advanced Manufacturing Development to address material obsolescence and develop new manufacturing diagnostic tools, production methods, and manufacturing techniques.

8.6.2.6 Academic Programs

Academic Programs support investments in science and engineering disciplines of critical importance to the nuclear security enterprise. The program's grants, centers, fellowships, and other funding options offer an introduction to the mission and people in the national laboratories to help establish a workforce pipeline to strengthen the future enterprise. Academic Programs includes five subprograms: (1) Stewardship Science Academic Alliance; (2) Minority Serving Institution Partnership Program; (3) Joint Program in High Energy Density Laboratory Plasmas; (4) Computational Science Graduate Fellowships; and (5) Predictive Science Academic Alliance Program.

The decreased budget request for Academic Programs reflects a nonrecurring increase in FY 2021 to develop the National Laboratory Jobs ACCESS program.

8.6.3 Key Milestones

As described in Chapter 4, Section 4.2.1, the Stewardship Capability Delivery Schedule is used to align SRT&E programs with mission objectives, coordinate efforts across Defense Programs, and communicate with internal and external stakeholders. Key milestones for SRT&E are illustrated in **Figure 8–9**. Major changes from last year's plan are:

- The FY 2021 milestone, *Qualify and deploy a new scintillator for Confined Large Optical Scintillator Screen and Imaging System* (*CoLOSSIS) I and II* is delayed to FY 2022 due to scheduling needs for upgrades and authorization for use.
- The FY 2022 milestone, *Complete Red Sage and Nimble subcritical experiment campaigns*, is delayed to FY 2025 due to an added subcritical experiment to the Nimble series to inform the ongoing modernization program.
- The FY 2025 milestone, *Complete assembly of a 7-megaelectronvolt neutron imaging machine at LLNL for plant installation* has been removed due to a change in implementation.

One milestone from last year's SSMP was completed in FY 2021:

- *Obtain CD-3A for ASD-Scorpius*

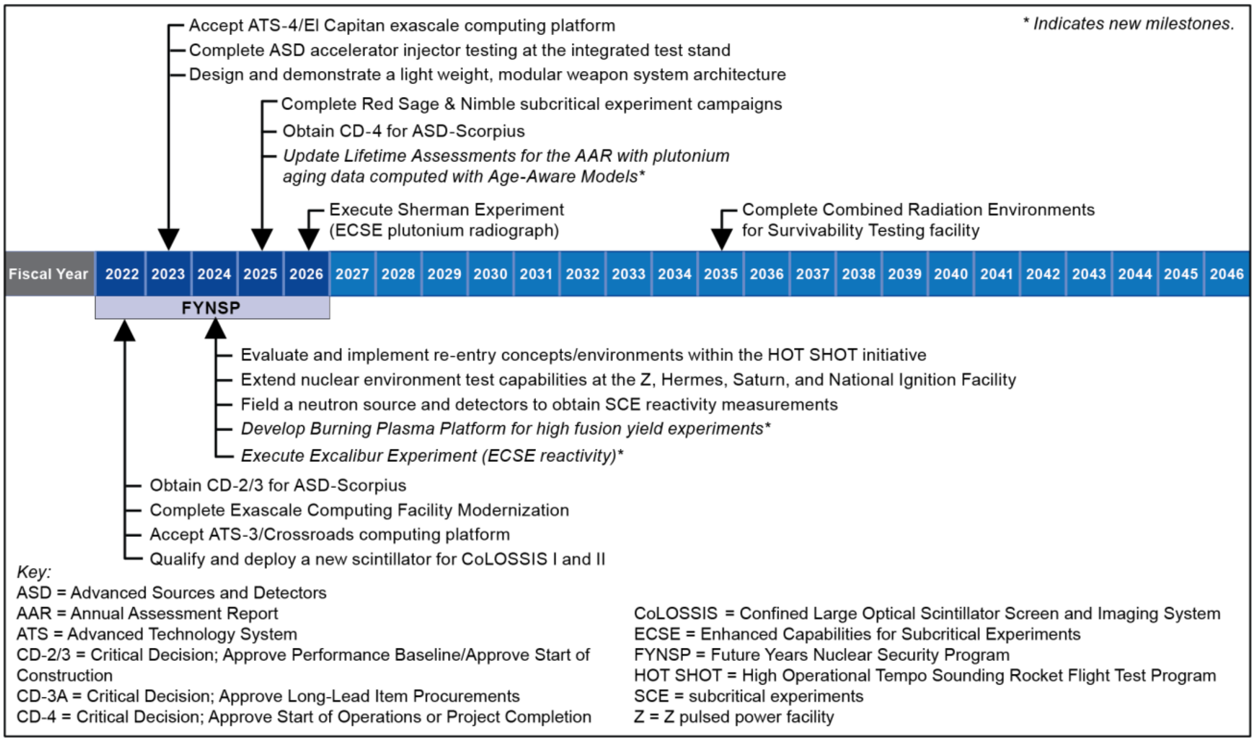


Figure 8–9. Key milestones for Stockpile Research, Technology, and Engineering

8.7 Infrastructure and Operations

Infrastructure and Operations maintains, operates, and modernizes DOE/NNSA's infrastructure in a safe, secure, and cost-effective manner to support all DOE/NNSA programs. Infrastructure and Operations efforts provide a comprehensive approach to modernizing DOE/NNSA's infrastructure while maximizing return on investment, enabling program results, and reducing enterprise risk. The program also plans, prioritizes, and constructs state-of-the-art facilities, infrastructure, and scientific tools. It includes: (1) Operations of Facilities; (2) Safety and Environmental Operations; (3) Maintenance and Repair of Facilities; (4) Recapitalization; and (5) Construction. Additional information about Infrastructure and Operations can be found in Chapter 6, "Infrastructure and Operations."

8.7.1 Budget

The budget request for Infrastructure and Operations decreased 12 percent from the FY 2021 enacted budget and is illustrated in **Figure 8–10**.

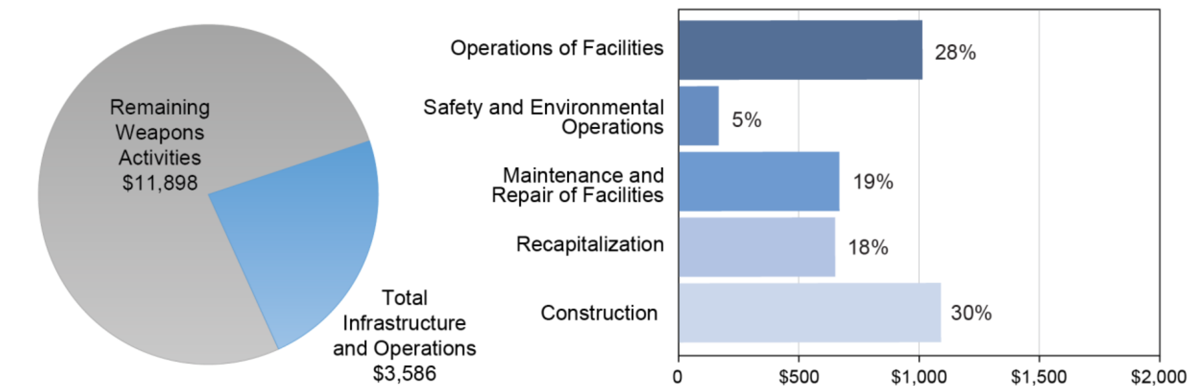
8.7.2 FY 2022 Budget Request Compared to FY 2021 Enacted Budget

8.7.2.1 Operations of Facilities

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

There was no change to the budget request for Operations of Facilities.

Infrastructure and Operations Funding for FY 2022
(Dollars in Millions)



	Fiscal Year ($M) 2021	2022
Operations of Facilities	1,014.0	1,014.0
Safety and Environmental Operations	165.4	165.4
Maintenance and Repair of Facilities	667.0	670.0
Recapitalization	732.8	651.7
Construction	1,508.3	1,085.4
Total Infrastructure and Operations	4,087.5	3,586.4

Note: Numbers may not add due to rounding

Figure 8–10. FY 2022 President's Budget for Infrastructure and Operations

8.7.2.2 Safety and Environmental Operations

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

There was no change to the budget request for Safety and Environmental Operations.

8.7.2.3 Maintenance and Repair of Facilities

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

The budget request for Maintenance and Repair of Facilities increased, reflecting the transfer of the Waste Solidification Building at SRS from the Material Management and Minimization's Material Disposition subprogram within Defense Nuclear Nonproliferation.

8.7.2.4 Recapitalization

Recapitalization modernizes DOE/NNSA's infrastructure by prioritizing investments to improve the condition and extend the life of structures, capabilities, and systems, thereby improving the safety and quality of the workplace. Recapitalization is comprised of the Infrastructure and Safety subprogram and the Capability Based Investments (CBI) subprogram. Funding is used to address numerous obsolete support and safety systems; revitalize facilities that are beyond the end of their design life; and improve the reliability, efficiency, and capability of infrastructure to meet mission requirements. Recapitalization investments help achieve operational efficiencies and reduce safety, security, environmental, and program risk. The Recapitalization program includes minor construction projects, real property purchases, capital equipment, planning, OPCs for mission enabling infrastructure, and deactivation and disposal of excess infrastructure.

The budget request for Recapitalization decreased as part of a realignment of resources to address higher Weapons Activities priorities, such as plutonium pit production support. Within CBI, the decrease reflects the transfer of Other Project Costs for LANL's Technical Area 55 (TA-55) Reinvestment Project, Phase 3 (TRP III) and Transuranic Liquid Waste Facility line item projects to Plutonium Modernization and transfer portions of the SNL CBI project scope to the new Non-Nuclear Capability Modernization program.

8.7.2.5 Line Item Construction

Line item construction projects and line item purchases are critical to revitalizing the infrastructure and program-specific capabilities that directly support the nuclear weapons programs. These projects will replace obsolete, unreliable facilities and infrastructure to reduce safety and program risk while improving responsiveness, capacity, and capabilities.

The budget request for Programmatic Construction includes funding in FY 2022 for:

- 04-D-125 Chemistry and Metallurgy Research Replacement Project, LANL
- 06-D-141 Uranium Processing Facility, Y-12 National Security Complex (Y-12)
- 15-D-302 TRP III, LANL
- 17-D-640 U1a Complex Enhancements Project, Nevada National Security Site
- 18-D-650 Tritium Finishing Facility, SRS
- 18-D-690 Lithium Processing Facility, Y-12
- 21-D-510 HE Synthesis, Formulation, and Production, Pantex
- 22-D-513 Power Sources Capability, SNL

The budget request for Mission Enabling Construction includes funding in FY 2022 for:

- 22-D-514 Digital Infrastructure Capability Expansion, LLNL

Additional information on planned line item investments can be found in Chapter 6, "Infrastructure and Operations."

8.7.3 Key Milestones

Key milestones for Programmatic Construction are shown in the relevant program sections, as many of their 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 6–8 through 6–15. Projects proposed in the near term have higher-fidelity estimates; some planned projects in the out-years may decide to use alternative strategies (other than a line item project) once each respective AoA 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, Maintenance and Repair of Facilities, and Construction programs. The initial plan was transmitted to Congress in September 2018.

8.7.4 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. As depicted in **Table 8–2**, DOE/NNSA's new calculated RPV is $116.3 billion based on end-of-year data. The DM backlog is tied to RPV (it costs more to repair a more expensive facility); therefore, as expected, DM increased with the deployment of our new, more accurate, data-driven approach from $2.5 billion as of FY 2018 to $5.8 billion as of FY 2020. The overall physical condition of DOE/NNSA's infrastructure did not decline.

Table 8–2. DOE/NNSA deferred maintenance as a percentage of Replacement Plant Value

Metric	*FY 2018*	*FY 2019*	*FY 2020*
RN	$5.1B	$8.9B	$9.4B
DM	$2.5B	$4.8B	$5.8B
RPV	$55B	$124.3B	$116.3B
RN/RPV Ratio	9.27%	7.16%	8.08%
DM/RPV Ratio	4.63%	3.85%	4.99%

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

In response to GAO recommendations, this information is provided to improve transparency in the budget. **Table 8–3** compares investments in Maintenance and Recapitalization to benchmarks (based on the percentage of beginning of the year RPV) derived from the DOE Real Property Asset Management Plan and associated guidance. To address other high priority needs, DOE/NNSA has decreased recapitalization investments by $84.6 million from FY 2021 to FY 2022. Recapitalization continues to include deactivation and demolition of excess and underutilized facilities to reduce DOE/NNSA's footprint. Maintenance investments reflect a flat funding level from FY 2021 to FY 2022. Overall funding for maintenance has grown significantly, but appropriately, over the last several years. This sustained funding level will support current maintenance staffing levels to maintain and preserve facilities in a condition 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).

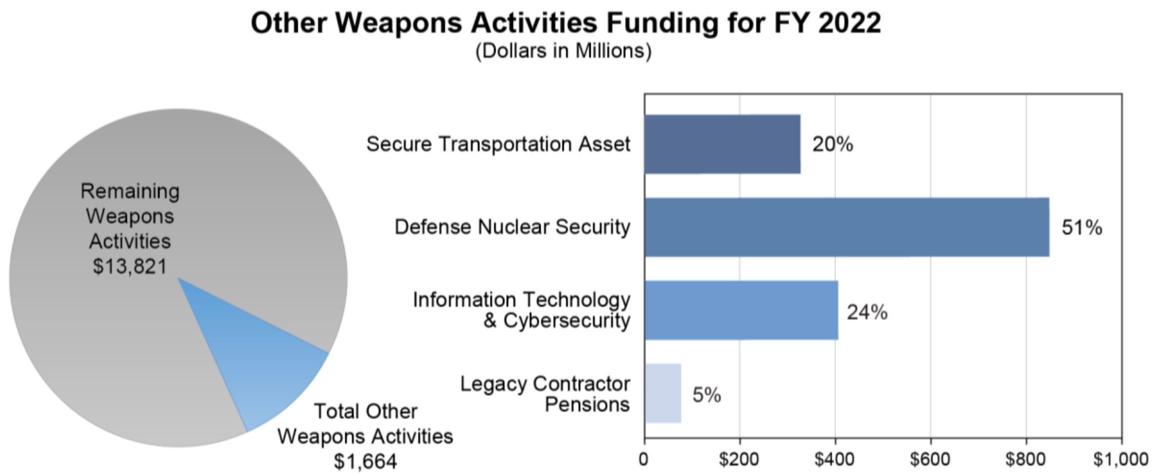
Table 8–3. Projected FY 2022 DOE/NNSA infrastructure maintenance and recapitalization investments

		FY 2020	*FY 2021*	*FY 2022*
Replacement Plant Value (RPV) ($B)		124.3	116.3	117.3
Maintenance Benchmark 2 – 4% RPV	Infrastructure and Safety Maintenance Investments ($K)	456,000	667,000	670,000
	Other NNSA Maintenance Investments (direct and indirect funded) ($K)	298,008	265,978	269,149
	Total NNSA Maintenance Investments ($K)	754,008	932,978	939,149
	Maintenance as % RPV	0.61%	0.80%	0.80%
Recapitalization Benchmark 1%	Infrastructure and Safety Recapitalization Investments ($K)	447,657	573,717	508,664
	Other NNSA Recapitalization Investments ($K)	135,341	289,933	264,374
	Total NNSA Recapitalization Investments ($K)	582,998	857,650	773,038
	Recapitalization as % RPV	0.47%	0.74%	0.66%

8.8 Other Weapons Activities

8.8.1 Budget

The funding schedule for Other Weapons Activities is illustrated in **Figure 8–11**.



	Fiscal Year ($M) 2021	2022
Secure Transportation Asset	348.7	330.8
Defense Nuclear Security	789.1	847.6
Information Technology & Cybersecurity	366.2	406.5
Legacy Contractor Pensions	101.7	78.7
Total Other Weapons Activities	1,605.7	1,663.6

Note: Numbers may not add due to rounding

Figure 8–11. FY 2022 President's Budget for Other Weapons Activities

8.8.2 Secure Transportation Asset

Secure Transportation Asset (STA) provides safe, secure transport of the Nation's nuclear weapons, weapon components, and special nuclear material throughout the nuclear security enterprise to meet nuclear security requirements and support the broader DOE and NNSA operations. STA includes two subprograms: (1) Operations and Equipment and (2) Program Direction. Additional information about STA can be found in Chapter 5, "Security."

8.8.2.1 FY 2022 Budget Request Compared to FY 2021 Enacted Budget

The budget request for Operations and Equipment decreased as a result of one-time FY 2021 costs associated with the aircraft procurement, and completion of the Baseline Design Review, timeline, and testing results of Test Article 1 for the Mobile Guardian Transporter (MGT). FY 2022 funding supports delivery of the MGT's Pre-Production Unit Rolling Chassis, completion of Test Article 2 assembly, and start of the Pre-Production Unit Assembly.

The budget request for Program Direction decreased as a result of additional workers' compensation costs associated with a non-mission vehicle accident in FY 2018 and lower funding requirements in salaries due to cancelled Nuclear Materials Courier Basic courses in FY 2020 and FY 2021 as a result of COVID-19.

8.8.2.2 Key Milestones

Aging transportation assets must be replaced to meet and maintain convoy safety and security requirements. The STA milestones illustrated in **Figure 8–12** will enable DOE/NNSA to support evolving transportation requirements for the current and future stockpile. Changes from last year's plan include:

- The FY 2021 milestone*, Design and begin production of the next generation armored tractor (T4) and escort vehicle (EV4),* shifted to FY 2022 due to contracting delays.
- The FY 2025 milestone, *Begin MGT production,* is delayed based on the Integrated Master Schedule adjustments and COVID-19 effects resulting in delivery of the first production unit in FY 2026.
- The FY 2025 milestone, *Replace first 737 aircraft*, is delayed to FY 2027 based on the Business Case Analysis and STA requirements modifying the life cycle replacement schedule.
- The FY 2029 milestone, *Replace second 737 aircraft*, is delayed to FY 2032 based on the Business Case Analysis and STA requirements modifying the life cycle replacement schedule.
- The FY 2034 milestone, *Complete MGT production*, is delayed to FY 2037 based on full scale production beginning in FY 2027.

One milestone from last year's SSMP was completed in FY 2021:

- *Begin procurement of a new aircraft to replace the aging DC-9 aircraft*

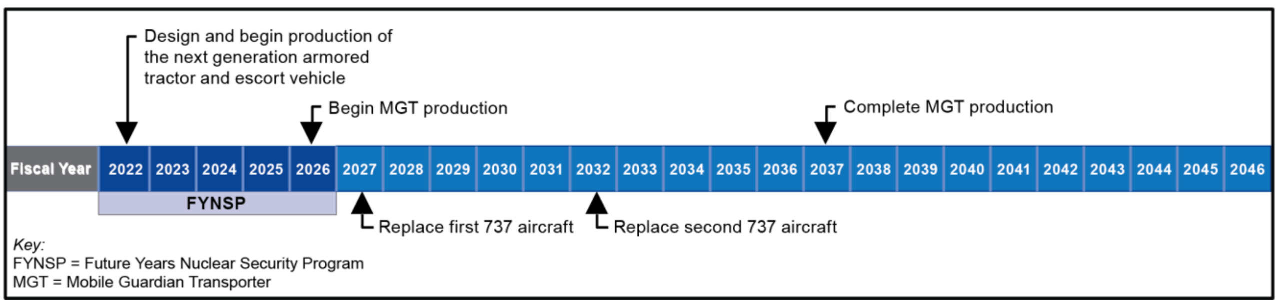


Figure 8–12. Key milestones for Secure Transportation Asset

8.8.3 Defense Nuclear Security

Defense Nuclear Security (DNS) leads, develops, and implements NNSA's security program to enable DOE/NNSA's nuclear security enterprise missions. DNS funding provides protection for DOE/NNSA personnel, facilities, nuclear weapons, and materials from a full spectrum of threats, ranging from minor security incidents to acts of terrorism, at its national laboratories, production plants, processing facilities, and the Nevada National Security Site. Additional information about DNS can be found in Chapter 5, "Security."

8.8.3.1 FY 2022 Budget Request Compared to FY 2021 Enacted Budget

The budget request for DNS increased based on additional security needs associated with growth across the nuclear security enterprise, including:

- Plutonium pit production efforts and other mission growth
- Efforts to implement additional security requirements resulting from completed Design Basis Threat analysis
- Support for highest priority milestones for the Caerus system, which replaces the aging Argus security system

Funding for the DNS construction project, 17-D-710, West End Protected Area Reduction (WEPAR) decreased due to use of carryover funding to cover FY 2022 requirements.

8.8.3.2 Key Milestones

The Security Infrastructure Revitalization Program (SIRP) addresses the security systems across DOE/NNSA and is a primary driver to support enterprise physical security system upgrades and life cycle management at each DOE/NNSA laboratory, plant, and site. SIRP project requirements were derived from a detailed condition assessment that identified the oldest systems and systems with the highest risk for failure, and assessed these systems' contributions to the overall security posture. The SIRP long-range plan is modified periodically based on DOE/NNSA's budget, mission, and needs.

The DNS milestones illustrated in **Figure 8–13** are directly linked to modernization of the national security infrastructure and will assure that DOE/NNSA mission requirements for the current and future stockpile are carried out in a safe and secure environment. Changes from last year's plan are:

- The FY 2023 milestone, *Complete Y-12 WEPAR, Perimeter Intrusion Detection and Assessment System (PIDAS) modernization, and entry control facility upgrade*, is delayed to FY 2024 to align with the baselined project.
- The FY 2024 milestone, *Complete critical SIRP priorities*, is delayed to FY 2027 due to COVID-19 effects and reprioritization within the DNS portfolio.
- The FY 2024 milestone, *Complete LANL PIDAS*, is delayed to FY 2032 as the currently planned plutonium Pit production ramp up and capital line item projects are not scheduled to be completed until FY 2027.
- They FY 2025 milestone, *Complete SRS PIDAS*, is delayed to FY 2030 due to the delay in obtaining CD-1 for SRPPF.
- The FY 2026 milestone, *Complete Pantex PIDAS physical security system components and infrastructure refresh for Zone 12*, is delayed to FY 2027 due to reprioritization within the DNS portfolio.
- The FY 2028 milestone, *Complete Pantex PIDAS physical security system components and infrastructure refresh for Zone 4,* is delayed to FY 2029 due to reprioritization within the DNS portfolio.
- The FY 2035 milestone, *Complete first iteration of SIRP*, is delayed to FY 2036 due to reprioritization within the DNS portfolio.

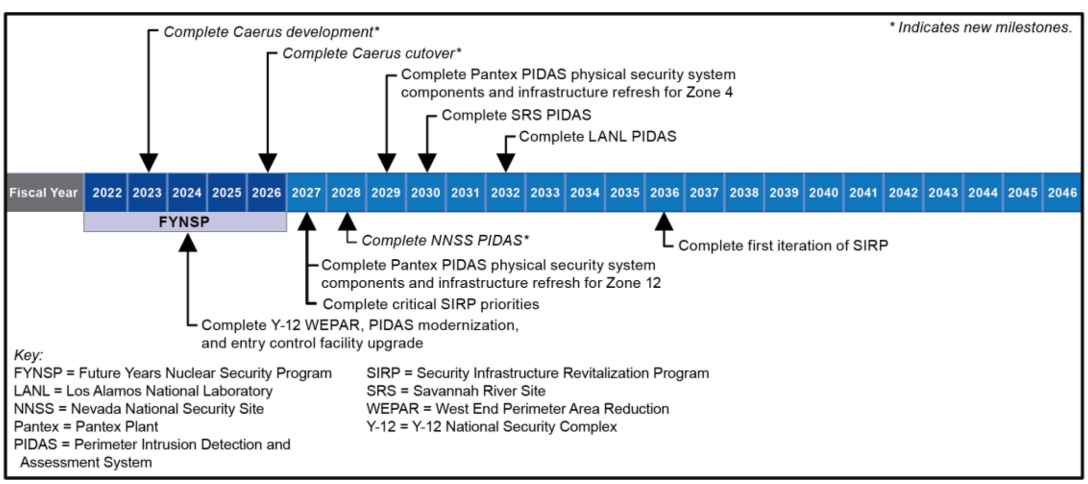


Figure 8–13. Key milestones for Defense Nuclear Security

8.8.4 Information Technology and Cybersecurity

Funding for Information Technology (IT) and Cybersecurity is used to operate cyber infrastructure at DOE/NNSA sites, implement departmental policies and procedures, implement Committee on National Security Systems requirements for the classified computing environment, and execute IT services, software, and hardware solutions for both unclassified and classified computing environments. Additional information about IT and Cybersecurity can be found in Chapter 5, "Security."

8.8.4.1 FY 2022 Budget Request Compared to FY 2021 Enacted Budget

The budget request for Cybersecurity appears as an overall increase compared to the FY 2021 level in part due to the transfer of operations and maintenance responsibilities for legacy classified network systems from other DOE/NNSA program offices to DOE/NNSA's Office of the Chief Information Officer (OCIO). Therefore, additional funding is simply tied to this particular increase in scope. Additional budget increases reflect funding for remaining requirements for M&O cybersecurity infrastructure, including full scope enhancements to the Enterprise Secure Network infrastructure; recapitalizing aging logical infrastructure; strengthening inherited legacy networks, systems, and applications; and enhancing cybersecurity capabilities to detect, prevent, counter, and respond to emerging threats and vulnerabilities.

The decreased budget request for IT reflects the implementation of Phase I requirements for the IT Modernization Project, development and implementation of services and solutions to provide operational connectivity during COVID-19, and launching Phase I for the IT infrastructure upgrades in coordination with the DOE CIO and improving application development and implementation with updated tools and technologies. Specifically, IT funding will support the IT Infrastructure for DOE/NNSA to enable efficient collaboration and mission support across the nuclear security enterprise. This includes IT associated with the Classified Infrastructure to address risks related to software assurance and supply chain management. Also, IT includes requirements related to implementation of classified networks.

8.8.4.2 Key Milestones

The milestones in **Figure 8–14** are necessary steps toward achieving a fully modernized IT infrastructure and cybersecurity posture for the nuclear security enterprise. One milestone from last year's SSMP was completed in FY 2021:

- *Complete the phase 1 security architecture of the wireless pit production network*

The following milestones were anticipated to be completed in FY 2021 and are ongoing into FY 2022:

- *Implement Phase II of DOE/NNSA's IT Modernization Plan*
- *Begin development of the architecture of the classified wireless network for non-pit production facilities*
- *Deploy KCNSC hybrid cloud platform in support of Joint Technology Demonstrator project*
- *Perform cybersecurity program budget re-baseline site assessments*
- *Develop phase II system architecture for modernizing the Enterprise Secure Computing environment*
- *Implement special network access*
- *Implement the DOE/NNSA Application Modernization Strategy*
- *Implement a Telecommunications Security Program within DOE/NNSA*
- *Complete the modernization of the Information Assurance Response Center cybersecurity infrastructure*

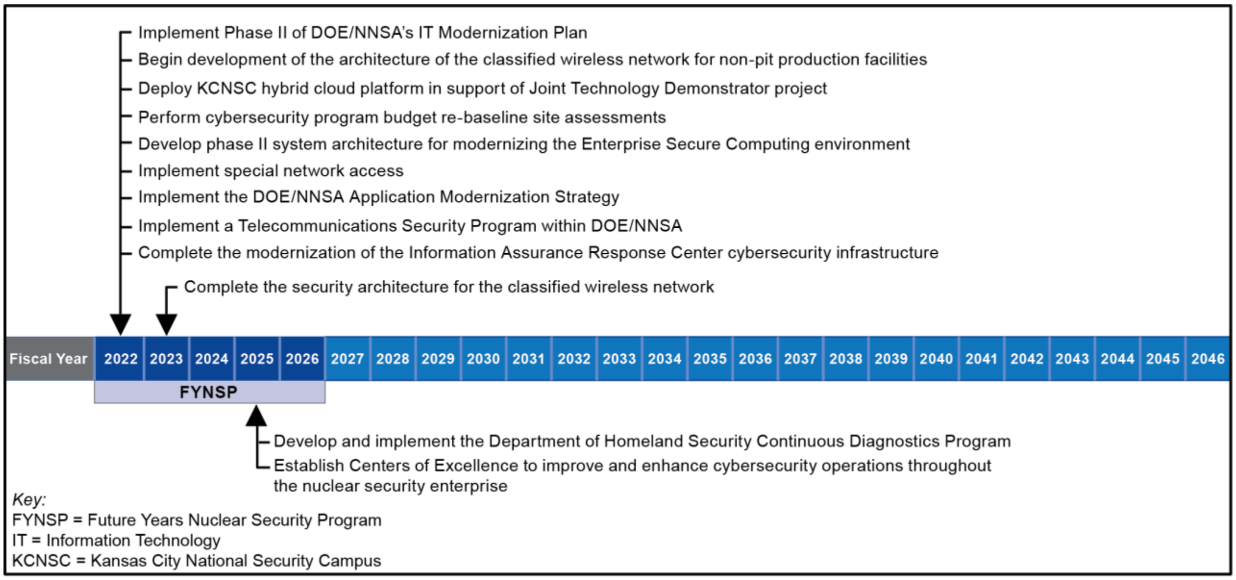


Figure 8–14. Key milestones for Information Technology and Cybersecurity

8.8.5 Legacy Contractor Pensions and Settlement Payments

Starting in FY 2022, Legacy Contractor Pensions and Settlement Payments includes funding to reimburse the University of California for a portion of a settlement reached in 2019 with former University of California employees of LLNL related to health care plans, as well as funding for DOE/NNSA's share of the unfunded liability of the Savannah River Nuclear Solutions pension plan. Benefits accrued by active employees during the year of execution will continue to be addressed through Savannah River Nuclear Solution's indirect pools.

8.9 Budget Projections Beyond FY 2022

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 8.10).

8.9.1 Basis for Budget Projections

The FY 2022 budget request was generated as part of the DOE/NNSA planning and programming process and reflects a compilation of individual estimates developed interactively by Federal program managers and DOE/NNSA's M&O partners using historical cost data, current plans for programs and projects, and expert judgment. Beyond FY 2022, the projected cost estimates for Stockpile Major Modernization programs are informed by the processes described in Section 8.9.2 and the major programmatic construction projects in Section 6.3.1. Some portions of the Weapons Activities portfolio are assumed to continue beyond the FY 2022 at the same level of effort.[7] For these cost projections, an escalation factor of 2.1 percent is used.

[7] Projection of budget estimates for these efforts in this way assumes the continued manageability of whatever risks are present during FY 2022 at the same level of effort over the 25-year time period, as is typically represented by the funding level of the last year of the FYNSP.

8.9.2 Stockpile Major Modernization

Stockpile Major Modernization programs have the goal of extending the lives of warheads for several more decades and improving their safety and security as possible. Figure 2–3 in Chapter 2, "Stockpile Management," provides a summary of planned Stockpile Major Modernization activities.

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

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

Figure 8–15 delineates the governing cost estimate type for each phase of the *Phase 6.x Process* and, as currently planned, the *Phase X Process*. DOE/NNSA works in conjunction with DoD and M&O partners to develop, refine, and update the estimates throughout these processes.

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

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

Figure 8–15. Cost estimates across the *Phase 6.X Process*

The DOE/NNSA Office of Management and Budget, Office of Analysis and Evaluation develops and publishes planning cost estimates for the SSMP. These cost estimates are 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. These planning estimates for Stockpile Major Modernization are:

- Based on a known scope and cost uncertainty at the time and updated annually for the SSMP[8]
- 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)[9]
- Unconstrained by future budget availability, which may differ from future budget requests

[8] 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.

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

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 8.9.2.2.

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

The Baseline Cost Report (BCR), which is also developed by the program team, formally updates the WDCR based on late development and pre-production activities. The BCR is updated based on refined scopes and schedule definitions (reflecting the increased maturity of the program) and represents a more definitive cost estimate than either the planning estimate or WDCR. The NNSA Administrator approves a program baseline, including the 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 DOE/NNSA Office of Cost Estimating and Program Evaluation conducts an independent cost review prior to Phase 6.2A, and independent cost estimates prior to entry into Phase 6.3, Phase 6.4 (*Production Engineering*), and 6.5 (*First Production*).

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

The DOE/NNSA Office of Management and Budget planning estimates for Stockpile Major Modernization programs are developed in the following manner:

- Performed using a "top-down" analogy method that is consistent with early-stage planning[10]
- Informed by ongoing and past program costs (such as the development of the W76-1, B61-12, W88 Alt 370, and production of the W76-1) and the evaluation of the relative complexities of future systems[11]
- Based on time-phased development costs using a standard profile,[12] as well as production costs using a nonlinear cost growth profile similar to that of the W76-1
- 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

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

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

[12] 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.

8.9.2.3 Current Estimates

Figures 8–16 through 8–20 and Tables 8–5 through 8–14 provide cost estimates for each Stockpile Major Modernization program for the 25-year SSMP timeframe. **Table 8–4** delineates the type of cost estimate for each of the warhead modernization programs included in the 25-year plan. Additional details on the basis for each estimate are provided for each individual program in Sections 8.9.2.4 through 8.9.2.12.

Table 8–4. Cost estimates for Stockpile Major Modernization programs within the 25-year program of record[13]

Stockpile Major Modernization Program	*Type of Cost Estimate*	*Total Estimated Cost (FY 2021 dollars in billions)*	*Total Estimated Cost (then-year dollars in billions)*
B61-12 LEP	BCR/SAR	8.6	8.3
W88 Alteration Program	BCR/SAR	2.9	2.8
W80-4 LEP	WDCR	9.9	11.0
W80-4 Alteration (SLCM)	Planning Estimate	3.1	3.7
W87-1 Modification Program[14]	Planning Estimate	9.8	12.1
W93 Program[15]	Planning Estimate	9.4	14.0
Future Strategic Land-Based Warhead	Planning Estimate	12.0	19.0
Future Strategic Sea-Based Warhead	Planning Estimate	12.6	20.9
B61 Follow-On	Planning Estimate	11.4	21.5

BCR/SAR = Baseline Cost Report/Selected Acquisition Report
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 2021 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.[16] 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 the estimate increased to the 90th percent (p90) for the W87-1 Modification Program to reflect the greater uncertainty.

For early-stage programs using planning estimates (such as the W87-1 Modification Program), the figures and tables reflect the current proposed FY 2022 budget and, for years beyond FY 2022, 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

[13] SAR and WDCR values are provided when available. For programs that only have a planning estimate, the proposed budget is provided; for programs pre-phase 1/6.1 the p90 value of a representative design and quantity is provided. Tables 8-5 through 8–13 provide values for a high and low estimate range, in addition to the SAR, WDCR, or planning estimate totals. Due to the differing types of cost estimates, the accuracy of these total program cost estimates varies.
[14] The total estimated costs for the W87-1 Modification program represent the midpoint between the p50 and p85 values.
[15] For future systems, including the W93 Program, the p90 value is used due to uncertainties in scope and design.
[16] DoD amounts reflect the costs for weapon components for which DoD is responsible, such as arming and fuzing. While not budgeted or executed by DOE/NNSA, these costs reflect the program's best approximation and are published for transparency to better reflect anticipated all-in costs. The total estimated cost is provided because warhead modernization program profiles often have later portions that extend beyond the published 25-year SSMP timeframe.

be given to the varying quantities of warheads being refurbished for each system. The FY 2022 SSMP's classified Annex provides additional information on production quantities.

- The then-year planning estimates in the tables and figures are derived from constant-year estimates using an escalation rate of 3.0 percent. This 3.0 percent rate represents an average of the individual site escalation rates as documented in current WDCR/BCR estimates. The WDCR and BCR program office estimates are developed at the site and component level and therefore use the escalation rates specific to each site and function rather than an average.
- Published estimate ranges are meant to reflect the underlying technical and cost uncertainty of the assumed scope. Early-stage programs, particularly those before Phase 6.3, may experience significant scope changes, as the Nuclear Weapons Council may update and/or down-select design options that significantly affect the work scope and cost estimate.
- Only the planning estimates include pre-Phase 6.2 costs. The WDCR and BCR/SAR estimates do not include these costs.

8.9.2.4 B61-12 Life Extension Program Cost Estimate

The B61-12 LEP is currently in Phase 6.5 and reached its first production unit in November 2021. Additionally, all COTS Base Metal Electrode (BME) capacitor components that experienced an issue in late 2019 are either on or ahead of their revised schedule. The values for development and production costs in **Figure 8–16** and **Table 8–5** reflect DOE/NNSA's FY 2020 BCR update issued in November 2020, with an overall cost estimate of $8.3 billion (then-year dollars), and are unchanged from last year's SSMP. The B61-12 LEP 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.

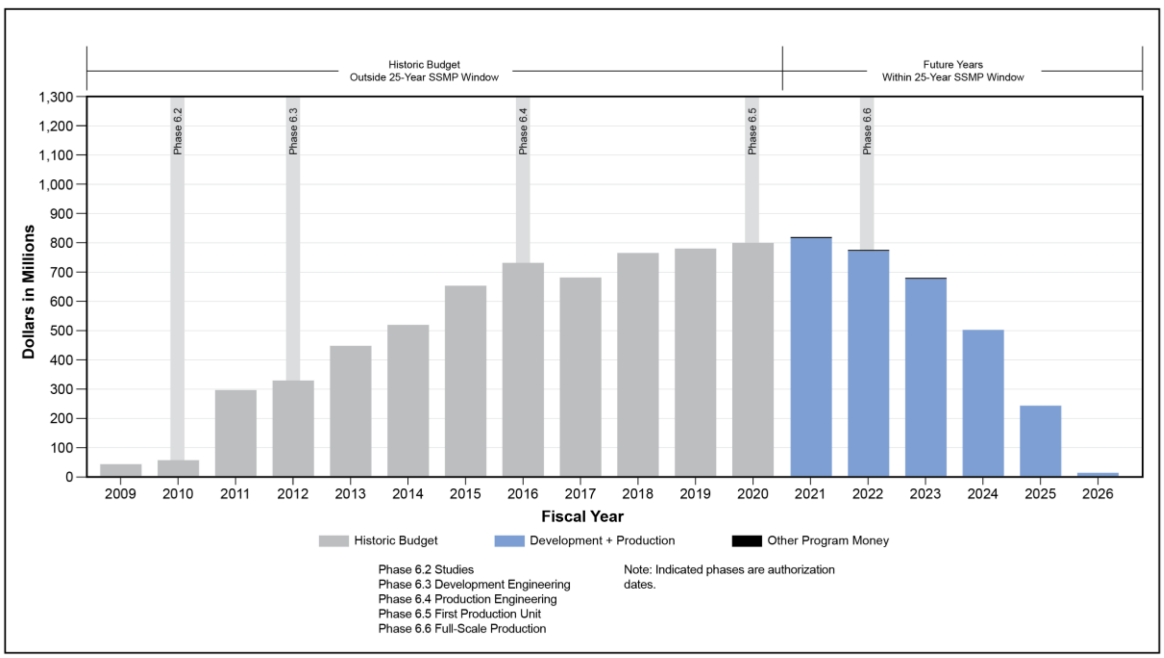


Figure 8–16. B61-12 Life Extension Program cost from FY 2009 to completion[17]

[17] 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.

Table 8–5. Total estimated cost for B61-12 Life Extension Program

	DOE/NNSA		*DoD*[18]	
Dollars in Billions	***FY 2021 Dollars***	***Then-Year Dollars***	***FY 2021 Dollars***	***Then-Year Dollars***
Pre-SAR Cost	0.5	0.4	N/A	N/A
FY 2012 – FY 2026				
SAR Total	8.6	8.3	N/A	N/A
SAR Other Program Money Total	0.7	0.6	N/A	N/A
Planning Estimate (High)[a]	9.9	9.6	0.2	0.2
Planning Estimate (Low)[a]	8.9	8.9	0.2	0.2

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

8.9.2.5 W88 Alteration 370 Program Cost Estimate

The W88 Alt 370 Program is currently in Phase 6.5 and met the July 2021 first production unit. Additionally, all COTS BME capacitor components that experienced an issue in late 2019 are either on or ahead of their revised schedule. DOE/NNSA issued an updated BCR in September 2020, with an estimate of $2.8 billion (then-year dollars), and is unchanged from last year's SSMP. The revised BCR was reconciled with the independent cost estimate performed by DOE/NNSA's Office of Cost Estimating and Program Evaluation. The W88 Alt 370 Program is continuing to use other DOE/NNSA programs for multi-system production process improvements. The estimated costs of these related programs (Other Program Money) remain unchanged at $171 million. The numbers in **Figure 8–17** and **Table 8–6** reflect the changes that were in the BCR update.

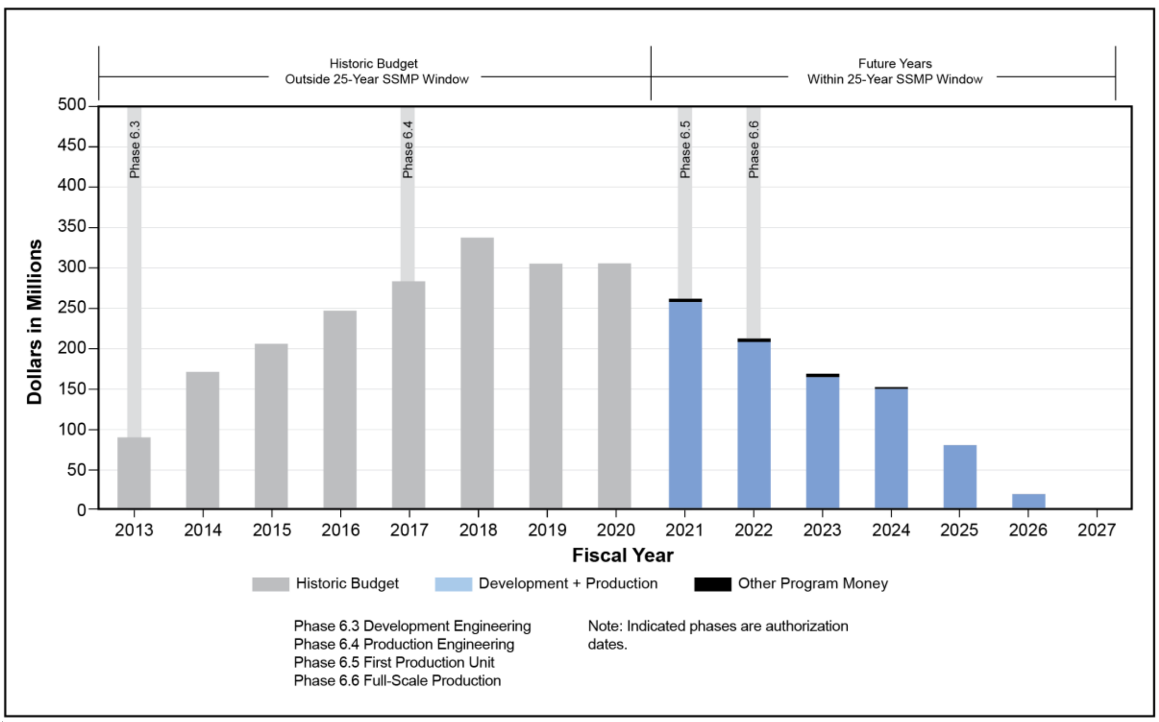


Figure 8–17. W88 Alteration 370 Program (with conventional high explosive refresh) from FY 2013 to completion

[18] The DoD costs in this table represent funds provided by DoD for work by DOE/NNSA on specific components, per cost sharing agreements between DoD and DOE/NNSA, and does not include work done exclusively by DoD, such as the B61-12 tailkits.

Table 8–6. Total estimated cost for W88 Alteration Program (with conventional high explosive refresh)

Dollars in Billions	DOE/NNSA		DoD	
	FY 2021 Dollars	Then-Year Dollars	FY 2021 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
Planning Estimate (High)[a]	3.3	3.2	1.1	1.1
Planning Estimate (Low)[a]	3.2	3.0	1.1	1.1

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

8.9.2.6 W80-4 Life Extension Program Cost Estimate

In FY 2019, the W80-4 LEP completed its WDCR and entered Phase 6.3 where the design will continue to be refined. The W80-4 LEP is on track to support fielding of the LRSO cruise missile initial operational capability in FY 2030. The current cost estimate is displayed in **Figure 8–18** and **Table 8–7**.

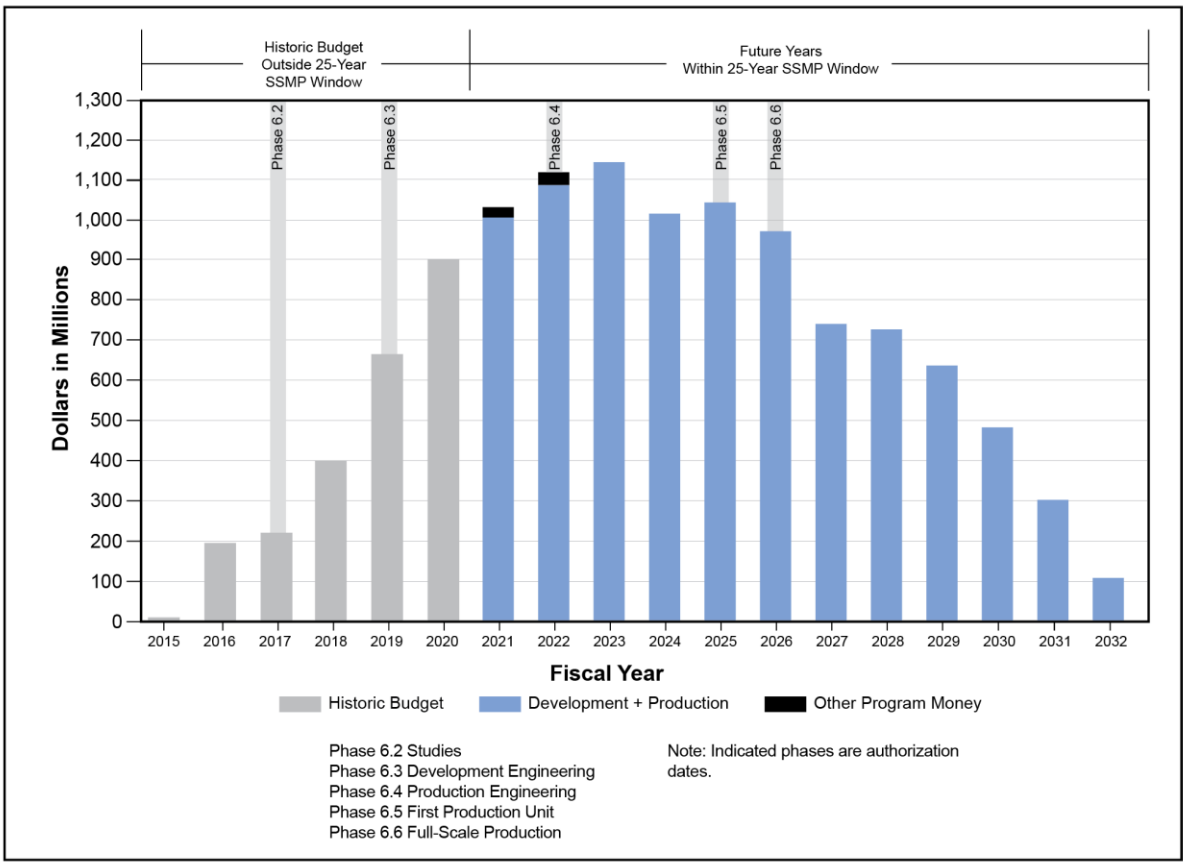


Figure 8–18. W80-4 Life Extension Program cost from FY 2015 to completion

Table 8–7. Total estimated cost for W80-4 Life Extension Program

FY 2015 – FY 2032	*DOE/NNSA*		*DoD*	
Dollars in Billions	***FY 2021 Dollars***	***Then-Year Dollars***	***FY 2021 Dollars***	***Then-Year Dollars***
SAR Total	9.9	11.0	N/A	N/A
SAR Other Program Money Total	0.2	0.2	N/A	N/A
Planning Estimate (High)[a]	11.0	11.9	0.2	0.3
Planning Estimate (Low)[a]	9.8	10.6	0.1	0.1

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

8.9.2.7 W80-4 Alteration (SLCM) Cost Estimate

To meet a FY 2029 first production unit and fit within the existing nuclear enterprise production footprint, the Nuclear Weapons Council issued notice of a preferred warhead solution, a W80-4-like variant, to minimize effects to the strategic nuclear stockpile. However, the final selection will be determined at the conclusion of the Analysis of Alternatives. The W80-4 Alteration program would need to start in FY 2022 with a Phase 6.2/6.2A-like effort to integrate the Alteration with the W80-4. The major objectives in FY 2022 include assisting the Navy in defining operational requirements and translating those requirements into specific warhead performance characteristics, including the electrical and mechanical system interfaces. This will define the extent of the warhead alteration. DOE/NNSA funding assumptions are that this will be an alteration of the existing W80-4 with minimal change in design, size, or missile interface and that the military characteristics and STS are either identical or only slightly modified. The funding estimate is at a low level of maturity until the Navy determines the employment platform and delivery vehicle and develops draft military characteristics and STS as noted.[19] The current cost estimate is displayed in **Figure 8–19** and **Table 8–8**.

[19] Navy AoA for SLCM platform and delivery vehicle scheduled for completion in mid-FY 2021. Specific warhead choices, including deviation from W80-4 Alteration, could drive significant development/qualification costs.

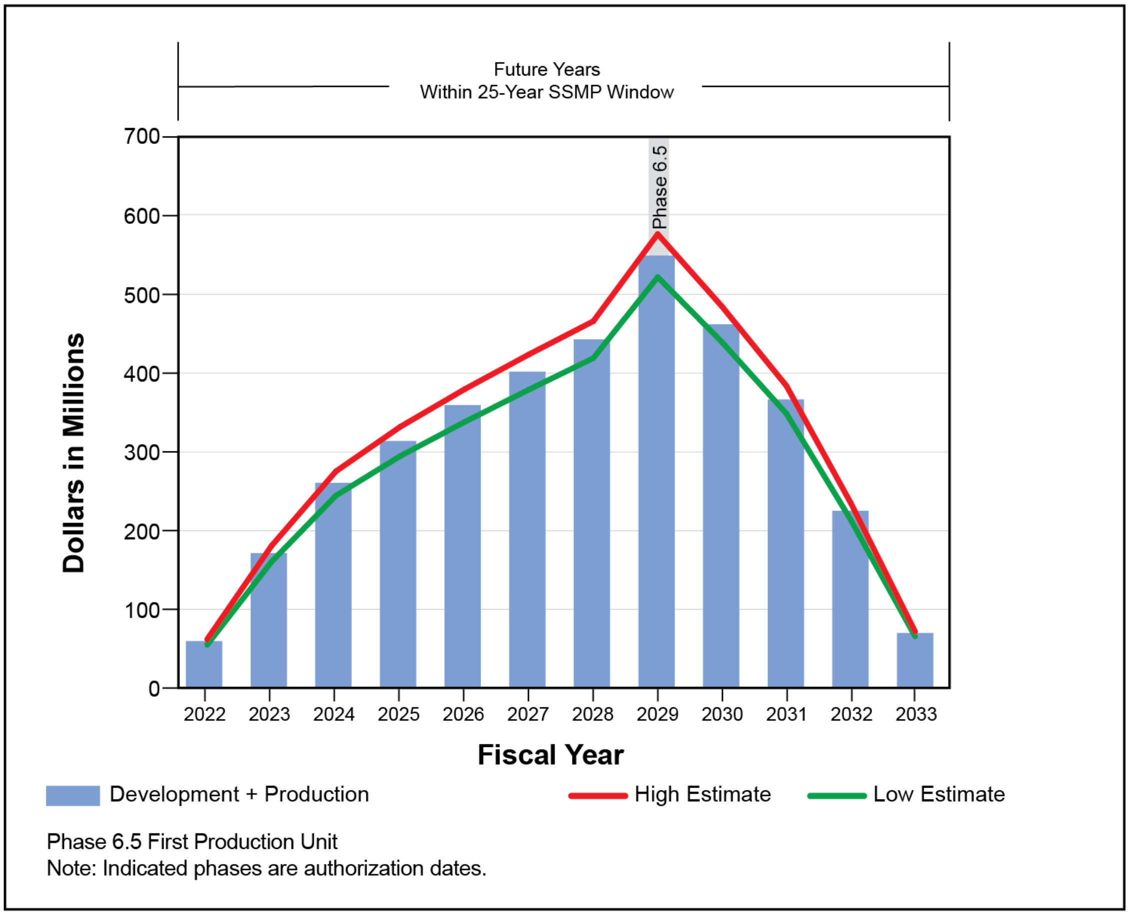


Figure 8–19. W80-4 Alteration (SLCM) cost from FY 2022 to completion

Table 8–8. Total estimated cost for W80-4 Alteration (SLCM)

FY 2022– FY 2034 (dollars in billions)	DOE/NNSA		DoD	
	FY 2021 Dollars	Then-Year Dollars	FY 2021 Dollars	Then-Year Dollars
Planning Estimate (High)[a]	3.2	3.9		
Planning Estimate (Low)[a]	2.9	3.5		
Proposed Budget	N/A	3.7		

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

8.9.2.8 W87-1 Modification Program Cost Estimate

In February 2019, the Nuclear Weapons Council authorized a restart of Phase 6.2 activities for the W87-1 Modification Program, and the program is 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 risk/benefit and cost analyses before selecting a single surety option for the W87-1 Modification Program. DOE/NNSA continues to evaluate other component design options and trades. In FY 2021, the W87-1 Modification Program will complete Phase 6.2 and enter Phase 6.2A. The cost estimate in **Figure 8–20** represents the latest projected program cost reflecting downselect and trade studies completed in early Phase 6.2. The estimates in Figure 8–20 and **Table 8–9** do not include costs associated with the production of plutonium pits for the W87-1 Modification Program 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.

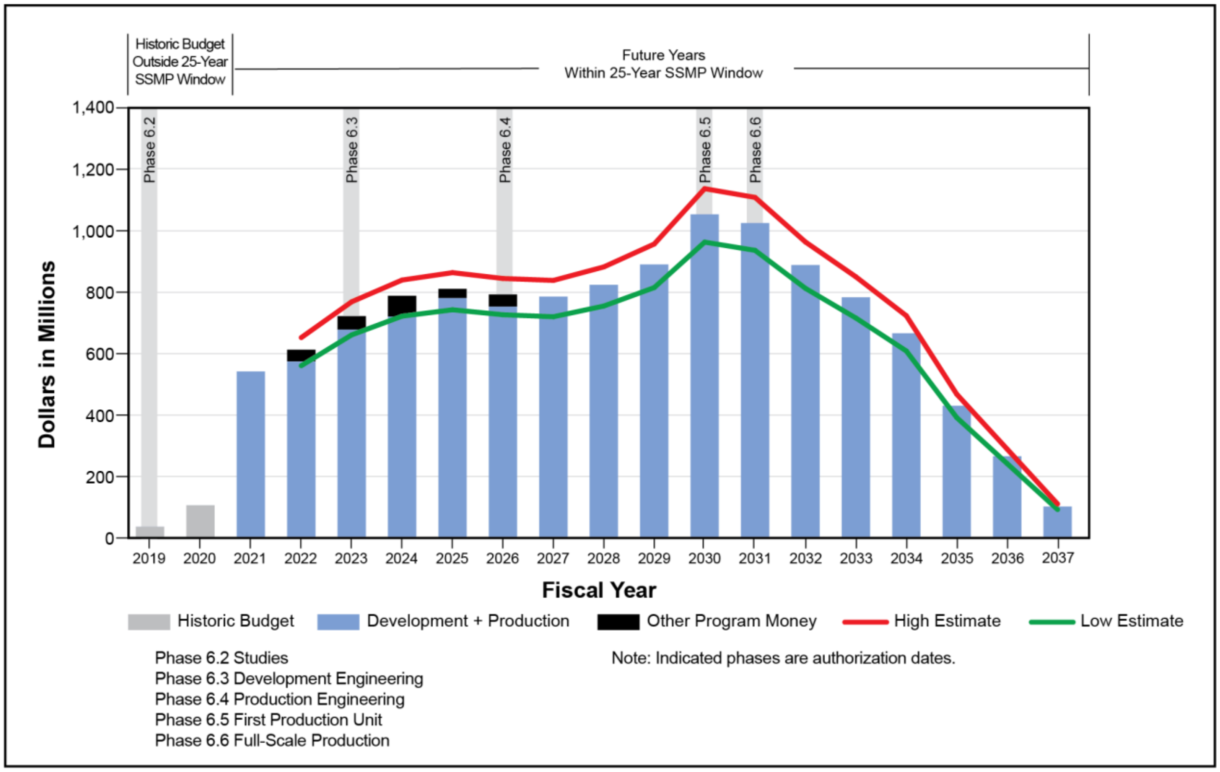


Figure 8–20. W87-1 Modification Program cost from FY 2019 to completion

Table 8–9. Total estimated cost for W87-1 Modification Program

FY 2019 – FY 2037 (dollars in billions)	DOE/NNSA FY 2021 Dollars	DOE/NNSA Then-Year Dollars	DoD FY 2021 Dollars	DoD Then-Year Dollars
Planning Estimate (High)[a]	10.6	13.0	0.9	1.2
Planning Estimate (Low)[a]	9.0	11.1	0.9	1.1
Proposed Budget	N/A	12.1	N/A	1.1

[a] Including Other Program Money

8.9.2.9 W93 Program Cost Estimate

The W93 Program will mitigate future risk to the sea leg of the nuclear triad and address the changing strategic environment. DOE/NNSA is coordinating with DoD on specific requirements and design options for the W93 program of record and anticipate completing a Phase 1 study in early 2022. The W93 Program cost estimate (see **Table 8–10**) provides a planning estimate only. It is based on preliminary assumptions for the W93 design, with increased uncertainty. This estimate will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

Table 8–10. Total estimated cost for W93 Program

Dollars in Billions	DOE/NNSA FY 2021 Dollars	DOE/NNSA Then-Year Dollars	DoD FY 2021 Dollars	DoD Then-Year Dollars
Planning Estimate (High) [a]	9.1	14.0	1.0	1.5
Planning Estimate (Low) [a]	8.0	12.0	0.9	1.4
Proposed Budget	N/A	12.8	N/A	N/A

[a] Including Other Program Money

8.9.2.10 Future Strategic Missile Warhead Cost Estimates

DOE/NNSA is also coordinating with DoD to define the appropriate ballistic missile warheads to support threats anticipated through 2030 and beyond. 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 8–11** and **Table 8–12**) provide a planning estimate for notional systems based on an existing stockpile weapon scope with increased uncertainty in design scope and quantities, adjusted for out-year escalation. These estimates will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

Table 8–11. Total estimated cost for Future Strategic Missile – Land-Based Warhead (FSLW)

Dollars in Billions	DOE/NNSA FY 2021 Dollars	DOE/NNSA Then-Year Dollars	DoD FY 2021 Dollars	DoD Then-Year Dollars
Planning Estimate (High) [a]	12.0	19.0	1.0	1.6
Planning Estimate (Low) [a]	10.0	15.9	0.9	1.5
Proposed Budget	11.0	17.5	N/A	N/A

[a] Including Other Program Money

Table 8–12. Total estimated cost for Future Strategic Missile – Sea-Based Warhead

Dollars in Billions	DOE/NNSA FY 2021 Dollars	DOE/NNSA Then-Year Dollars	DoD FY 2021 Dollars	DoD Then-Year Dollars
Planning Estimate (High) [a]	12.6	20.9	1.0	1.6
Planning Estimate (Low) [a]	10.4	17.3	0.9	1.5
Proposed Budget	11.5	19.1	N/A	N/A

[a] Including Other Program Money

8.9.2.11 B61 Follow-On Cost Estimate

The B61 Follow-On cost estimate (see **Table 8–13**) 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 8–13. Total estimated cost for B61 Follow-On

Dollars in Billions	DOE/NNSA		DoD	
	FY 2021 Dollars	Then-Year Dollars	FY 2021 Dollars	Then-Year Dollars
Planning Estimate (High) [a]	11.4	21.5	0.2	0.4
Planning Estimate (Low) [a]	9.9	18.5	0.2	0.3
Proposed Budget	10.7	20.0	N/A	N/A

[a] Including Other Program Money

8.9.2.12 Summary of Cost Estimates

Figure 8–21 represents a summary of cost estimate ranges for all presently known warhead modernization programs from FY 2021 through FY 2046 based on schedule assumptions that are subject to change. Changes from the FY 2021 SSMP are the result of shifts in production schedules and the addition of the W80-4 Alteration Program (SLCM).

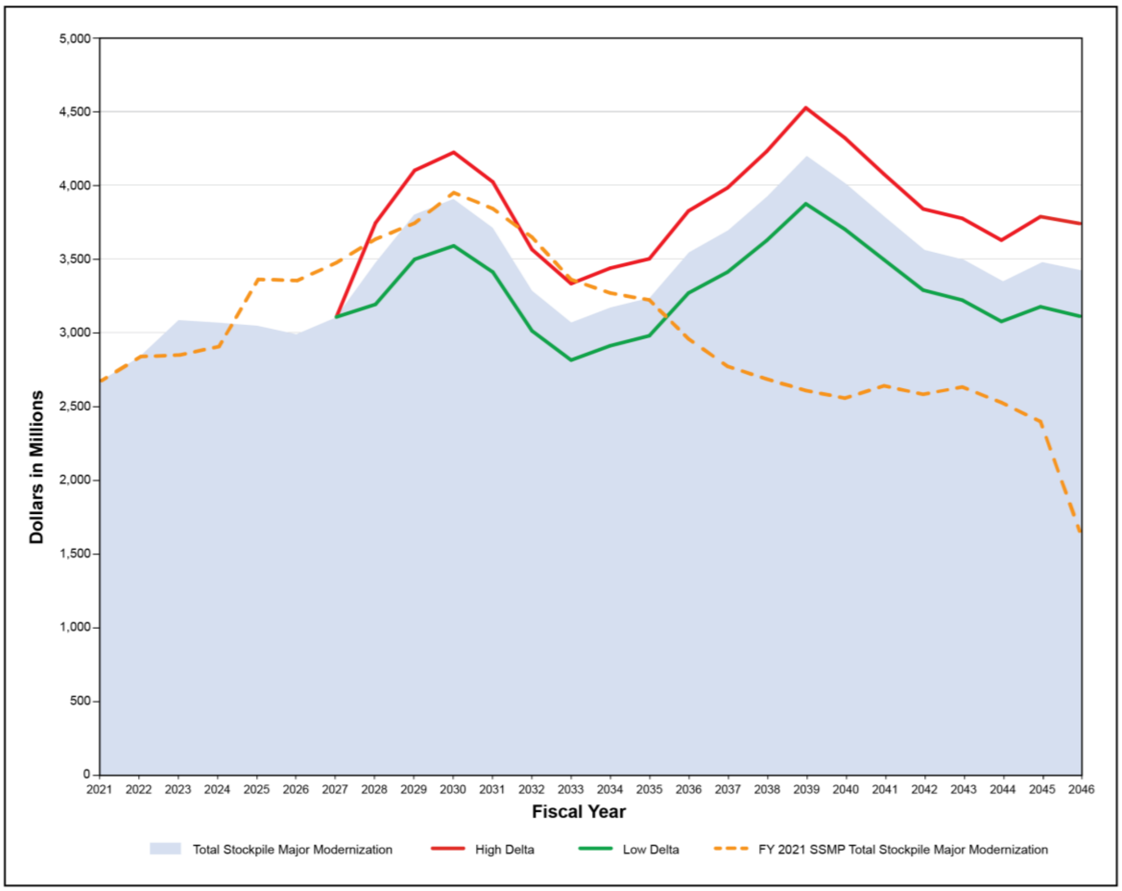


Figure 8–21. Total projected Stockpile Major Modernization costs for FY 2021 – FY 2046 with high and low estimates (then-year dollars)

8.9.3 Construction

8.9.3.1 Cost Estimation for Capital Acquisitions

In FY 2020, DOE/NNSA began publishing cost estimates for early-stage capital acquisitions.[20] These early planning estimates, published as long as a decade or more before a project's initial mission approval, primarily inform long-term cost projections for programmatic construction and are supplemental to DOE acquisition requirements in DOE Order 413.3B.

Notably, these cost estimates are:

- Performed by an organization separate from the Federal program office[21]
- Performed using a top-down parametric method that is consistent with early-stage planning[22]
- 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 (*Approve Mission Need*) supersede previous estimates and becomes the basis for resource planning. The project then progresses as described in DOE Order 413.3B (i.e., alternative selection and cost range at CD-1, performance baseline at CD-2, etc.). Per DOE Order 413.3B, 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 AoAs. The assumed scope should be considered notional until the project reaches and defines performance baseline at CD-2.

The cost estimation professional society, American Association of Cost Engineering (AACE) International, has published a cost estimate classification system[23] 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.[24] **Table 8–14** 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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[20] 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.

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

[22] 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*.

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

[24] DOE Guide 413.3-21A, *Cost Estimating Guide*.

Table 8–14. Capital Acquisition Cost Estimate Classification System

Estimate Class	*Primary Characteristic*	*Secondary Characteristic*			
	Maturity Level of Project Definition (percent)	*DOE Capital Acquisition Milestone*	*Typical Types of Estimate*	*Methodology*	*Expected Accuracy Range (percent)*
Class 5	0 to 2	Mission Need (CD-0)	Planning Estimate, Rough Order of Magnitude	Capacity factored, parametric models, judgment, or analogy	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

8.9.3.2 FY 2022 through FY 2046 Estimates

The budget request for capital acquisitions in FY 2022 reflects the latest estimates for existing construction projects. DOE/NNSA continues to execute the schedules of multiple ongoing major capital acquisition projects, such as the Uranium Processing Facility and U1a Complex Enhancements projects. A list of major capital acquisition project proposals has been developed through the efforts of a series of working groups and deep dives with representatives from DOE/NNSA sites and responsible Federal offices. The schedule for the highest-priority project proposals is depicted by major capital acquisition projects and project proposals listed in Chapter 6, "Infrastructure and Operations." This planning schedule will be updated annually. Changes will be made based on available funding and programmatic priorities.

The current program of record and the vetted programmatic construction project proposals included in Figures 6–8 through 6–13 are the basis for the aggregated cost estimates shown in **Table 8–15**.[25] Table 8–15 lists low and high estimate projections in then-year dollars for planned and proposed programmatic capital acquisition projects from FY 2022 through FY 2046.

Table 8–15. Weapons Activities programmatic construction estimated costs, FY 2022 – FY 2046

Then-Year Dollars, in Billions	*Low*[a]	*High*[b]
Weapons Activities capital acquisition estimated costs	63.7	73.7

[a] The "Low" estimate reflects the base capital acquisition estimate captured in Figure 8–22. The low value is programmatically informed and represents the 70th percentile for the planned and proposed major construction projects listed in Section 6.3.1.

[b] The "High" estimate represents the 85th percentile for the planned and proposed major construction projects listed in Section 6.3.1.

[25] At this time, only programmatic construction cost estimates are included in the values shown in Table 8-15. It does not include mission enabling or DNS construction projects.

The difference in the estimates as compared to the FY 2021 SSMP are a result of using the 70th percentile as the low for the cost estimates[26] and the refinement of included project proposals to create a more affordable and executable infrastructure modernization plan.[27]

8.10 Affordability

DOE/NNSA's method for evaluating potential affordability is part of the Weapons Activities portfolio management approach while considering the level of uncertainty affecting the out-years. The projected cost of continuing the program beyond FY 2022 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.

As described throughout this document, DOE/NNSA is undertaking a risk-informed, complex, and time-constrained modernization and recapitalization effort in coordination with DoD. DOE/NNSA must make concerted investments now to make available the necessary capabilities and infrastructure to execute modernization programs to meet DoD timelines. If adjustments need to be made in future years, DOE/NNSA will work with DoD to consider and adjust schedule and/or scope to major activities, including potential effects to warhead modernization programs and infrastructure projects.

8.10.1 Estimate of Weapons Activities Program Costs

Since the FY 2022 budget request does not include program-based defense budget levels beyond the budget year, the Weapons Activities budget projections are not available. The policy judgments reflected in the Administration's upcoming Nuclear Posture Review and National Defense Strategy will inform the out-year budget estimates. Once policy judgments are completed, the projected out-year budget estimates will be updated in the following SSMP.

[26] In the FY 2021 SSMP, the "low" estimate represented the 85th percentile and the "high" estimate included additional SRT&E facility proposals as well as additional recapitalization costs for production facilities.
[27] See Chapter 6, Section 6.2.2.

Chapter 9
Conclusion

This Department of Energy's National Nuclear Security Administration (DOE/NNSA) *Fiscal Year (FY) 2022 Stockpile Stewardship and Management Plan* (SSMP), together with its classified annex, is a key planning document for the nuclear security enterprise. This SSMP is the culmination of planning efforts from across numerous DOE/NNSA programs and organizations and documents the 25-year plan for ensuring the safety, security, and effectiveness of the U.S. nuclear stockpile. The FY 2022 SSMP also details efforts to maintain the scientific and engineering tools, capabilities, and infrastructure that underpin the current and future nuclear deterrent. The SSMP was prepared by the DOE/NNSA Federal workforce in collaboration with DOE/NNSA's management and operating partners and coordinated with the Department of Defense (DoD) through the Nuclear Weapons Council.

The global threat environment continues to rapidly evolve and grow increasingly dangerous, complex, and uncertain. In response to this changing environment, the United States must have a modern, resilient, and flexible nuclear security enterprise in order to respond to these challenges by providing DoD with appropriate capabilities so that it can continue to execute its nuclear deterrent mission. Together with support from Congress, DOE/NNSA will ensure that our workforce has the resources and the responsive, agile infrastructure needed to steward the systems that comprise our deterrent today while preparing for the cutting-edge research and development that will inform the future national security mission solutions of tomorrow.

Appendix A Requirements Mapping

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

The *Fiscal Year 2022 Stockpile Stewardship and Management Plan* (FY 2022 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 2022 SSMP.

A.2 50 U.S. Code § 2523

50 U.S. Code § 2523	*FY 2021 Response*	*FY 2022 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
(b) Submissions to Congress		
(1) In accordance with subsection (c), not later than March 15 of each even-numbered year, the Administrator shall submit to the congressional defense committees a summary of the plan developed under subsection (a).	*Unclassified* All Chapters *Classified Annex*	*N/A*
(2) In accordance with subsection (d), not later than March 15 of each odd-numbered year, the Administrator shall submit to the congressional defense committees a detailed report on the plan developed under subsection (a).	*N/A*	*Unclassified* All Chapters
(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.	*Unclassified* Chapter 1, Section 1.2 *Classified Annex*	*N/A*

50 U.S. Code § 2523	*FY 2021 Response*	*FY 2022 Response*
(2) A summary of the status, plans, budgets, and schedules for warhead life extension programs and any other programs to modify, update, or replace warhead types.	*Unclassified* Chapter 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	*N/A*
(3) A summary of the methods and information used to determine that the nuclear weapons stockpile is safe and reliable, as well as the relationship of science-based tools to the collection and interpretation of such information.	*Unclassified* Chapter 2, Sections 2.1.1, 2.1.2; Chapter 3, Sections 3.5–3.8	*N/A*
(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.	*Unclassified* Chapter 1, Section 1.4; Chapter 4, Sections 4.1–4.2; Chapter 5, Sections 5.1–5.7	*N/A*
(5) A summary of the status, plans, and budgets for carrying out the stockpile responsiveness program under section 2538b of this title.	*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	*N/A*
(6) A summary of the plan regarding the research and development, deployment, and lifecycle sustainment of technologies described in subsection (d) (7).		
(7) A summary of the assessment under subsection (d)(8) regarding the execution of programs with current and projected budgets and any associated risks.		
(8) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*Unclassified* Chapter 1, Section 1 text box; Chapter 5, Section 5.1.1	*N/A*
(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—		
(A) 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 1.4; Chapter 2, Sections 2.1, 2.2

50 U.S. Code § 2523	*FY 2021 Response*	*FY 2022 Response*
(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;	*N/A*	*Unclassified* Chapter 8, Section 8.4, 8.9
(C) 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 2, Sections 2.2, 2.4; Chapter 8, Section 8.4
(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;	*N/A*	*Unclassified* Chapter 2, Section 2.1; Chapter 3, Section 3.5; Chapter 4, Section 4.3
(E) a description of the process used in recertifying the safety, security, and reliability of each warhead type in the nuclear weapons stockpile;	*N/A*	*Unclassified* Chapter 2, Section 2.1; Chapter 4, Sections 4.2.2, 4.3
(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);	*N/A*	*Unclassified* Chapter 2, Section 2.1; Chapter 3, Sections 3.3.2, 3.4.2; Chapter 4, Sections 4.2, 4.3
(G) mechanisms to provide for the manufacture, maintenance, and modernization of each warhead type in the nuclear weapons stockpile, as needed;	*N/A*	*Unclassified* Chapter 2, Sections 2.1, 2.2, 2.4; Chapter 3, Sections 3.2–3.5; Chapter 4, Section 4.3
(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;	*N/A*	*Unclassified* Chapter 2, Sections 2.1.1, 2.4; Chapter 3, Section 3.5; Chapter 4, Section 4.3
(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;	*N/A*	*Unclassified* Chapter 1, Section 1.3; Chapter 4, Section 4.2.2; Chapter 7; Appendix E

50 U.S. Code § 2523	*FY 2021 Response*	*FY 2022 Response*
(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;	*N/A*	*Unclassified* Chapter 2, Section 2.1.2
(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	*N/A*	*Unclassified* Chapter 8, Sections 8.3–8.6, 8.9
(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;	*N/A*	*Unclassified* Chapter 8, Section 8.3
(M) the status, plans, activities, budgets, and schedules for carrying out the stockpile responsiveness program under section 2538b of this title;	*N/A*	*Unclassified* Chapter 4, Section 4.3; Chapter 8, Section 8.4–8.6; Appendix D
(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	*N/A*	*Unclassified* Chapter 8, Section 8.4–8.6; Appendix D
(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;	*N/A*	*Unclassified* Chapter 2, Section 2.1; Chapter 4, Sections 4.2.2, 4.3
(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	*N/A*	*Unclassified* Chapter 4, Section 4.3
(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;	*N/A*	*Unclassified* Chapter 4, Sections 4.2, 4.3
(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;	*N/A*	*Unclassified* Chapter 2, Section 2.1.2; Chapter 4, Section 4.3; Appendix E

50 U.S. Code § 2523	*FY 2021 Response*	*FY 2022 Response*
(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	*N/A*	*Unclassified* Chapter 2, Section 2.1.2; Chapter 4, Section 4.2; Appendix E
(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—	*N/A*	*Unclassified* Chapter 7, Sections 7.1, 7.3; Appendix E
(i) the number of scientists, engineers, and technicians, by discipline, required to maintain such competencies; and	*N/A*	*Unclassified* Chapter 7, Sections 7.2, 7.3; Appendix E
(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.	*N/A*	*Unclassified* Chapter 7, Section 7.4; Appendix E
(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—	*N/A*	*Unclassified* Chapter 6, Sections 6.3, 6.4
(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;	*N/A*	*Unclassified* Chapter 6, Sections 6.3, 6.4
(ii) the most recent quadrennial defense review if such strategy has not been submitted as of the date of the plan; and	*N/A*	*Unclassified* Chapter 6, Sections 6.3, 6.4
(iii) the most recent Nuclear Posture Review as of the date of the plan;	*N/A*	*Unclassified* Chapter 6, Sections 6.3, 6.4
(B) a schedule for implementing the measures described under subparagraph (A) during the 10-year period following the date of the plan;	*N/A*	*Unclassified* Chapter 6, Sections 6.3.1, 6.3.2
(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	*N/A*	*Unclassified* Chapter 8, Sections 8.7.1, 8.9.3
(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.	*N/A*	*Unclassified* Chapter 8, Section 8.7.4

50 U.S. Code § 2523	*FY 2021 Response*	*FY 2022 Response*
(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;	*N/A*	*Unclassified* Chapter 4, Section 4.4
(B) a description of the level of test readiness that the Administrator, in consultation with the Secretary of Defense, determines to be appropriate;	*N/A*	*Unclassified* Chapter 4, Section 4.4
(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;	*N/A*	*Unclassified* Chapter 4, Section 4.4
(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	*N/A*	*Unclassified* Chapter 4, Section 4.4
(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).	*N/A*	*Unclassified* Chapter 4, Section 4.4
(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.	*N/A*	*Unclassified* Chapter 4, Sections 4.3.1, 4.3.2
(B) An assessment of scientific and testing instrumentation for plutonium at elemental and bulk conditions.	*N/A*	*Unclassified* Chapter 4, Sections 4.3.1, 4.3.2
(C) An assessment of manufacturing and handling technology for plutonium and plutonium components.	*N/A*	*Unclassified* Chapter 3, Section 3.2.1; Appendix E, Sections E.2.2, E.3.3
(D) An assessment of computational models of plutonium performance under static and dynamic loading, including manufactured and nonmanufactured conditions.	*N/A*	*Unclassified* Chapter 4, Sections 4.2.2, 4.3.1–4.3.4
(E) An identification of any capability gaps with respect to the assessments described in subparagraphs (A) through (D).	*N/A*	*Unclassified* Chapter 4, Sections 4.3.1–4.3.4
(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.	*N/A*	*Unclassified* Chapter 8, Section 8.5.1, 8.6.1
(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.	*N/A*	*Unclassified* Chapter 8, Section 8.5.1, 8.6.1
(H) Such other items as the Administrator considers important for the integrated management of plutonium for stockpile and stockpile stewardship needs.	*N/A*	*Unclassified* Chapter 3, Section 3.2.1

50 U.S. Code § 2523	*FY 2021 Response*	*FY 2022 Response*
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—	*N/A*	*Unclassified* Chapter 5
(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;	*N/A*	*Unclassified* Chapter 5
(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	*N/A*	*Unclassified* Chapter 5, Sections 5.3, 5.4
(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.	*N/A*	*Unclassified* Chapter 8, Sections 8.8.3, 8.8.4
(8) An assessment of whether the programs described by the report can be executed with current and projected budgets and any associated risks.	*N/A*	*Unclassified* Chapter 8, Sections 8.9, 8.10
(9) 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 8
(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 2021 Response***	***FY 2022 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.		

A.3 H.R. 116-449

H.R. 116-449 – *ENERGY AND WATER DEVELOPMENT AND RELATED AGENCIES APPROPRIATIONS BILL, 2021, July 15, 2020, pp 141-142*	***FY 2021 Response***	***FY 2022 Response***
Stockpile Responsiveness Program The NNSA shall submit to the Committee an annual report with the budget request that includes a detailed accounting and status of each program, project, and activity within the program. The Committee expects to receive timely updates on the status of any new and existing taskings, studies, and assessments.	*N/A*	*Unclassified* Appendix D

A.4 H.R. 244

H.R.244 – Consolidated Appropriations Act, 2017, P.L. 115-31	***FY 2021 Response***	***FY 2022 Response***
SEC. 4. EXPLANATORY STATEMENT. The explanatory statement regarding this Act, printed in the House section of the Congressional Record on or about May 2, 2017, and submitted by the Chairman of the Committee on Appropriations of the House, shall have the same effect with respect to the allocation of funds and implementation of divisions A through L of this Act as if it were a joint explanatory statement of a committee of conference.		
Congressional Record – House, Vol 163, No 76—Book II, page H3753, May 3, 2017 (Explanatory Statement to Accompany the FY 17 Omnibus Appropriations [P.L. 115-31]]		
Life Extension Reporting. – The NNSA is directed to provide to the Committees on Appropriations of both Houses of Congress a classified summary of each ongoing life extension and major refurbishment program that includes explanatory information on the progress and planning for each program beginning with the award of the phase 6.3 milestone and annually thereafter until completion of the program.	*Classified Annex*	*Classified Annex*

A.5 Related Legislation: 50 U.S. Code § 2521

50 U.S. Code § 2521
§ 2521. Stockpile stewardship program (a) Establishment The Secretary of Energy, acting through the Administrator for Nuclear Security, shall establish a stewardship program to ensure – (1) the preservation of the core intellectual and technical competencies of the United States in nuclear weapons, including weapons design, system integration, manufacturing, security, use control, reliability assessment, and certification; and (2) that the nuclear weapons stockpile is safe, secure, and reliable without the use of underground nuclear weapons testing.
(b) Program elements The program shall include the following:
1) An increased level of effort for advanced computational capabilities to enhance the simulation and modeling capabilities of the United States with respect to the performance over time of nuclear weapons.
(2) An increased level of effort for above-ground experimental programs, such as hydrotesting, high-energy lasers, inertial confinement fusion, plasma physics, and materials research.
(3) Support for new facilities construction projects that contribute to the experimental capabilities of the United States, such as an advanced hydrodynamics facility, the National Ignition Facility, and other facilities for above-ground experiments to assess nuclear weapons effects.
(4) Support for the use of, and experiments facilitated by, the advanced experimental facilities of the United States, including - (A) the National Ignition Facility at Lawrence Livermore National Laboratory; (B) the Dual Axis Radiographic Hydrodynamic Testing facility at Los Alamos National Laboratory; (C) the Z Machine at Sandia National Laboratories; and (D) the experimental facilities at the Nevada National Security Site.
(5) Support for the sustainment and modernization of facilities with production and manufacturing capabilities that are necessary to ensure the safety, security, and reliability of the nuclear weapons stockpile, including - (A) the nuclear weapons production facilities; and (B) production and manufacturing capabilities resident in the national security laboratories.
(1) With respect to exascale computing—
(a) PLAN REQUIRED.—The Administrator for Nuclear Security shall develop and carry out a plan to develop exascale computing and incorporate such computing into the stockpile stewardship program under section 4201 of the Atomic 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.

A.6 Related Legislation: 50 U.S. Code § 2522

50 U.S. Code § 2522
§ 2522. Stockpile stewardship criteria
(a) Requirement for criteria The Secretary of Energy shall develop clear and specific criteria for judging whether the science-based tools being used by the Department of Energy for determining the safety and reliability of the nuclear weapons stockpile are performing in a manner that will provide an adequate degree of certainty that the stockpile is safe and reliable.
(b) Coordination with Secretary of Defense The Secretary of Energy, in developing the criteria required by subsection (a), shall coordinate with the Secretary of Defense.

A.7 Related Legislation: 50 U.S. Code § 2524

50 U.S. Code § 2524
§ 2524. Stockpile management program
(a) Program required The Secretary of Energy, acting through the Administrator for Nuclear Security and in consultation with the Secretary of Defense, shall carry out a program, in support of the stockpile stewardship program, to provide for the effective management of the weapons in the nuclear weapons stockpile, including the extension of the effective life of such weapons. The program shall have the following objectives:
(1) To increase the reliability, safety, and security of the nuclear weapons stockpile of the United States.
(2) To further reduce the likelihood of the resumption of underground nuclear weapons testing.
(3) To achieve reductions in the future size of the nuclear weapons stockpile.
(4) To reduce the risk of an accidental detonation of an element of the stockpile.
(5) To reduce the risk of an element of the stockpile being used by a person or entity hostile to the United States, its vital interests, or its allies.
(b) Program limitations In carrying out the stockpile management program under subsection (a), the Secretary of Energy shall ensure that—
(1) any changes made to the stockpile shall be made to achieve the objectives identified in subsection (a); and
(2) any such changes made to the stockpile shall— (A) remain consistent with basic design parameters by including, to the maximum extent feasible, components that are well understood or are certifiable without the need to resume underground nuclear weapons testing; and (B) use the design, certification, and production expertise resident in the nuclear security enterprise to fulfill current mission requirements of the existing stockpile.
(c) Program budget In accordance with the requirements under section 2529 of this title, for each budget submitted by the President to Congress under section 1105 of title 31, the amounts requested for the program under this section shall be clearly identified in the budget justification materials submitted to Congress in support of that budget.

A.8 Related Legislation: 50 U.S. Code § 2538b

50 U.S. Code § 2538b
§ 2538b. Stockpile responsiveness program (a) Statement of policy It is the policy of the United States to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive.
(b) Program required The Secretary of Energy, acting through the Administrator and in consultation with the Secretary of Defense, shall carry out a stockpile responsiveness program, along with the stockpile stewardship program under section 2521 of this title and the stockpile management program under section 2524 of this title, to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons.
(c) Objectives The program under subsection (b) shall have the following objectives: (1) Identify, sustain, enhance, integrate, and continually exercise all of the capabilities, infrastructure, tools, and technologies across the science, engineering, design, certification, and manufacturing cycle required to carry out all phases of the joint nuclear weapons life cycle process, with respect to both the nuclear security enterprise and relevant elements of the Department of Defense. (2) Identify, enhance, and transfer knowledge, skills, and direct experience with respect to all phases of the joint nuclear weapons life cycle process from one generation of nuclear weapon designers and engineers to the following generation. (3) Periodically demonstrate stockpile responsiveness throughout the range of capabilities required, including prototypes, flight testing, and development of plans for certification without the need for nuclear explosive testing. (4) Shorten design, certification, and manufacturing cycles and timelines to minimize the amount of time and costs leading to an engineering prototype and production. (5) Continually exercise processes for the integration and coordination of all relevant elements and processes of the Administration and the Department of Defense required to ensure stockpile responsiveness. (6) The retention of the ability, in consultation with the Director of National Intelligence, to assess and develop prototype nuclear weapons of foreign countries and, if necessary, to conduct no-yield testing of those prototypes.
(d) Joint nuclear weapons life cycle process defined In this section, the term “joint nuclear weapons life cycle process” means the process developed and maintained by the Secretary of Defense and the Secretary of Energy for the development, production, maintenance, and retirement of nuclear weapons.

Appendix B
Weapons Activities Capabilities

This appendix describes the breadth of capabilities maintained by Weapons Activities programs in the Department of Energy's National Nuclear Security Administration (DOE/NNSA) nuclear security enterprise to execute the stockpile mission. These capabilities should not be viewed in isolation or as mutually exclusive, as many overlap and are complementary. They represent the underlying disciplines, activities, and specialized skills required to meet DOE/NNSA missions. In this document, the capabilities are presented as facets of seven interdependent portfolios, each containing a suite of capabilities that together address a particular aspect of Weapons Activities. In part, this appendix supports the legislative requirements listed in Appendix A.

B.1 Weapon Material Processing and Manufacturing

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.

Capability	***Definition***
Special Nuclear Materials (SNM)[1] Handling, Packaging, and Processing (Plutonium and Uranium)	Components that contain SNM (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.
Tritium Production, Handling, and Processing	Tritium has a 12-year half-life and must be periodically replenished in gas transfer systems. Tritium is produced by irradiating tritium-producing burnable absorber rods (TPBARs) in Tennessee Valley Authority's Watts Bar nuclear reactors. Handling and processing of tritium includes transporting the TPBARs to Savannah River Site and extraction of tritium from the TPBARS, as well as purifying, storing and loading the tritium into gas transfer system reservoirs and inspection of the reservoirs. Tritium is also recovered from returned gas transfer systems.
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.
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.

[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.

B.2 Weapon Component Production

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

Capability	*Definition*
Non-Nuclear Component Production	Non-nuclear weapon components and assembly processes require special manufacturing, assembly, and inspection protocols. The components include, but are not limited to, cable assemblies; electronic assemblies; microelectronics packaging; gas transfer systems; arming, fuzing, and firing assemblies; lightning arrestor connectors; environmental sensing devices; radars; neutron generators; and power sources.
Weapon Component and Material Process Development	Process development of weapon components involves small-lot production, precise controls, and a deep understanding of the hazards of working with SNM and other exotic materials. Component process development is needed whenever process changes are made to reduce cost or production time.
Weapon Component and System Prototyping	Development, qualification, and manufacture of high-fidelity, full-scale prototype weapon components and systems reduce the cost and life cycle time to develop and qualify new designs and technologies. This capability includes the ability to design, manufacture, and employ mockups with sensors to support laboratory and flight tests that provide evidence that components can function with Department of Defense delivery systems in realistic environments.
Advanced Manufacturing	Advanced manufacturing uses innovative techniques from industry, academia, or internal research and development to reduce costs, reduce component development and production time, improve safety and performance, and control waste streams. Examples include additive manufacturing, use of microreactors, microwave casting, and electrorefining.

B.3 Weapon Simulation and Computing

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.

Capability	*Definition*
High Performance Computing	High performance computing (HPC) encompasses software, hardware, and facilities of sufficient power to achieve the dimensionality, resolution, and complexity in simulation codes to accurately model the performance of weapon systems and components and the fundamental physical processes that are critical to nuclear operation. This capability includes research and development in computer, information, and mathematical sciences to support developing and operating HPC.

Capability	Definition
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.

B.4 Weapon Design and Integration

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.

Capability	Definition
Weapons Physics Design and Analysis	Design and analysis of the nuclear explosive package is required to maintain existing U.S. nuclear weapons; modernize the stockpile; evaluate possible proliferant nuclear weapons; and respond to emerging threats, unanticipated events, and technological innovation. Elements of design capability include concept exploration; conceptual design; requirements satisfaction; detailed design and development; production; process development; certification; and qualification. Weapons physics analysis includes evaluation of weapons effects.
Weapons Engineering Design, Analysis, and Integration	Elements of weapons engineering include the following life cycle phases: concept exploration; requirements satisfaction; conceptual design; detailed design and development; production; certification; and qualification. This capability also encompasses systems integration, which includes understanding and developing the interfaces among the non-nuclear subsystems, between the non-nuclear components and the nuclear explosives package and between DOE/NNSA and Department of Defense systems.
Environmental Effects Analysis, Testing, and Engineering Sciences	Environmental effects analysis, testing, and engineering sciences use an array of test equipment, tools, and techniques to create stockpile-to-target sequence conditions and measure the ensuing response of materials, components, and systems. Examples of environmental testing (normal, hostile, and abnormal) include shock, vibration, radiation, acceleration, temperature, electrostatics, and pressure conditions. The engineering sciences that support this analysis include thermal and fluid sciences, structural mechanics, dynamics, aerodynamics, and electromagnetics.
Weapons Surety Design, Testing, Analysis, and Manufacturing	Weapons surety design, analysis, integration, and manufacturing employ a variety of safety and use control systems to prevent accidental nuclear detonation and unauthorized use of nuclear weapons to ensure a safe and secure stockpile. This knowledge, infrastructure, and equipment requires strict classification control and secure facilities.
Radiation-Hardened Microelectronics Design and Manufacturing	Research, design, production, and testing of radiation-hardened microelectronics is required for nuclear weapons to function properly in hostile environments. This capability requires a secure, trusted supply chain, including quality control of the materials used in the process and products.

B.5 Weapon Science and Engineering

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.

Capability	*Definition*
Nuclear Physics and Engineering	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.
Radiochemistry	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.
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.
High Energy Density Physics	High energy density (HED) 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 HED states producing data exploring the physical processes that occur in plasma states to validate computational models.
Laser and Optical Science, Technology, and Engineering	Lasers are coherent light sources delivering intense beams of energy to localized regions to generate and probe HED 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, and 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.
Accelerator and Pulsed Power Science, Technology, and Engineering	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 produce data that are critical to understanding physical phenomena, qualifying nuclear weapon components, and improving performance assessments.
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.

Capability	*Definition*
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 (HE) and contain SNM that never achieves a critical configuration and does not create nuclear yield. Both types of experiments provide data that are essential to validating models within multi-physics design codes and predicting nuclear weapon performance.
Chemistry and Chemical Engineering	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.
High Explosives and Energetics Science and Engineering	HE 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 HE and other energetic materials and components for specific applications. Understanding these materials is necessary to understand nuclear weapon performance.
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).

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

After weapon components are produced, each requires assembly into complete warheads and temporary storage before delivery to the Department of Defense. Some of these warheads are removed from the stockpile on an annual basis for surveillance to provide data to evaluate the health of the stockpile. These surveillance activities (such as inspections, laboratory and flight tests, nondestructive tests, and component and material evaluations) provide data over time to predict, detect, assess, and resolve aging trends and any observed anomalies. This process requires disassembly and sometimes reassembly. At their end of life or for other reasons, nuclear weapons undergo disposition. The Weapon Assembly, Storage, Testing, and Disposition portfolio covers all of these capabilities.

Capability	*Definition*
Weapon Assembly, Storage, and Disposition	This capability includes assembly and disassembly of all warheads, including components and subsystems contained within a device. This encompasses the breadth of national security enterprise capabilities requiring special conduct of operations, equipment, facilities, and quality control. Disassembly, inspection, and disposition of the warhead, components, and subsystems requires similar special conduct of operations, equipment, and facilities. Storage of weapons and sub-systems requires special safety and security processes and protocols.
Testing Equipment Design and Fabrication	Design and fabrication of special test equipment to simulate environmental and functional conditions ensure that products meet specifications. Data from test equipment provide evidence for qualification, certification, reliability, surety, and surveillance.

Capability	Definition
Weapon Component and System Surveillance and Assessment	Surveillance enhances integration across test regimes to demonstrate performance requirements for stockpile systems by inspections, laboratory and flight tests, nondestructive tests, and component and material evaluations. Comparing data over time provides the ability to predict, detect, assess, and resolve aging trends and anomalous changes in the stockpile and address or mitigate issues or concerns. Assessment is the analysis, largely through modeling and simulation, of data gathered during surveillance to evaluate the safety, performance, and reliability of weapon systems and the effect of aging on performance, uncertainties, and margins.

B.7 Transportation and Security

The Transportation and Security 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.

Capability	Definition
Secure Transportation	Protection and movement of nuclear weapons, weapon components, and SNM between facilities includes design and fabrication or modification of vehicles, design and fabrication of special communication systems, and training of Federal agents.
Physical Security	Physical security protects the Nation's nuclear materials, infrastructure assets, and 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.
Information Technology and Cybersecurity	Information technology and cybersecurity provides infrastructure and protection for both classified and unclassified computing networks, secure communications, applications, systems, and logical environments. It ensures electronic information and information assets are operating nominally and are protected from unauthorized access and malicious acts that would adversely affect national and economic security.

Appendix C
Exascale Computing

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 fields, but could also eventually rise in science, national defense, energy innovation, and the commercial computing market.

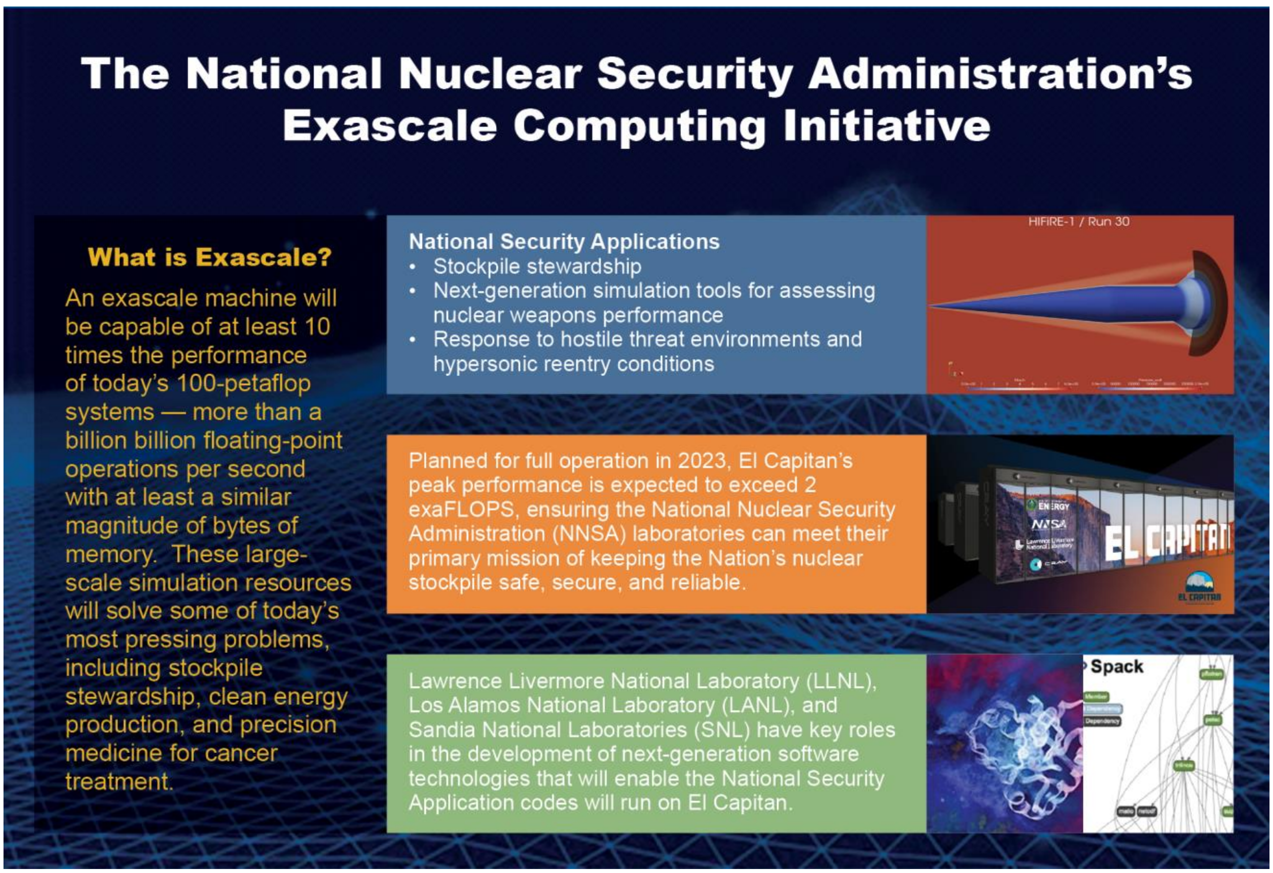

Figure C–1. Overview of the DOE/NNSA Exascale Computing Project

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, the U.S. Department of Energy

(DOE), represented by a partnership between the DOE Office of Science and the National Nuclear Security Administration (NNSA), has the lead responsibility for focusing and implementing the joint Exascale Computing Initiative (ECI). This initiative focuses on advanced simulation that continues exploiting MOSFET[1] technology to emphasize sustained HPC to advance DOE/Office of Science and 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.

C.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)
- 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 two decades
- Advancing the Advanced Simulation and Computing (ASC)-funded laboratory and open-source software stack to run efficiently on the new advanced architectures and to support emerging workflows
- Developing prototype systems to assess the viability of alternate HPC architecture paths for the ASC
- Improving remote computing infrastructure to facilitate access across the DOE/NNSA complex to exascale and other leading-edge platforms wherever each may be sited
- Modernizing NNSA computing facilities to prepare them for siting future petascale and exascale platforms through increasing structural integrity, power, and cooling capabilities

C.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 ECI, 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 greatly supports the two organizations as they leverage each other’s critical non-recurring engineering development costs and jointly manage the technical progress of the two exascale system projects.

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[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.

The FY 2022 spend plan for Exascale Computing Initiative elements is delineated in **Table C–1**. In FY 2022, the NNSA portion of the Exascale Computing Initiative spans across all of six ASC program elements: Advanced Technology Development and Mitigation (ATDM), Integrated Codes, Physics and Engineering Models, and Verification and Validation, which fund the next-generation simulation technologies for the weapons mission; Computational Systems and Software Environment (CSSE) subprogram that procures the El Capitan system; and Facility Operation and User Support that funds the site installation work for the power-up of El Capitan. Future exascale investments will include improvements to remote tri-lab computing infrastructure.

Table C–1. NNSA Exascale Computing Initiative funding schedule for FY 2022

Exascale Computing Initiative Elements	*FY 2022 Request (dollars in millions)*
Advanced Technology Development and Mitigation	40
Defense Applications and Modeling	18
Computational Systems and Software Environment	20
Facility Modifications	1
El Capitan Procurement	125
Total, NNSA Exascale Initiative	204

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 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 stockpile, 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 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 the stockpile simulation code development over the next few years.
- *ATDM/ECP Software Technology*: 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 two projects at the national security laboratories to work on the DOE/Office of Science-NNSA-National Cancer Institute Collaboration.

Defense Application and Modeling – Next-Generation Application Development

In FY 2021, NNSA began transitioning the viable and validated ATDM next-generation code and associated capabilities into its Integrated Codes, Physics and Engineering Modeling, and Verification and Validation subprograms to support the annual assessment activities.

Computational Systems and Software Environment – Next-Generation Computing Technologies

In FY 2021, NNSA started the process of transitioning 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.

Facility Modifications

NNSA will continue its investment in upgrading the structural, mechanical, and electrical capacities at Lawrence Livermore National Laboratory to prepare for the powering up and operation of El Capitan.

Computational Systems and Software Environment – El Capitan Procurement

NNSA is embarking on a multi-year collaboration with the selected system vendor and its subcontractors to work on non-recurring engineering and system integration to deliver El Capitan. The collaboration focuses on system engineering efforts and software technologies to assure the 2023 exascale system will be a capable and productive computing resource for the Stockpile Stewardship Program.

C.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 C–2**. 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.

C.4 Milestones

DOE/NNSA has five milestones for FY 2022:

- Continue engagement with the El Capitan system vendor on non-recurring engineering activities
- Begin transition of selected NNSA ATDM application codes to the ASC Defense Applications and Modeling portfolio to support annual certification and assessment mission
- Begin transition of selected NNSA ATDM computing technologies to its CSSE portfolio
- Deploy El Capitan early access system-3 (EAS-3) nodes at LLNL
- Port ATDM application codes to EAS-3 nodes to analyze potential performance issues

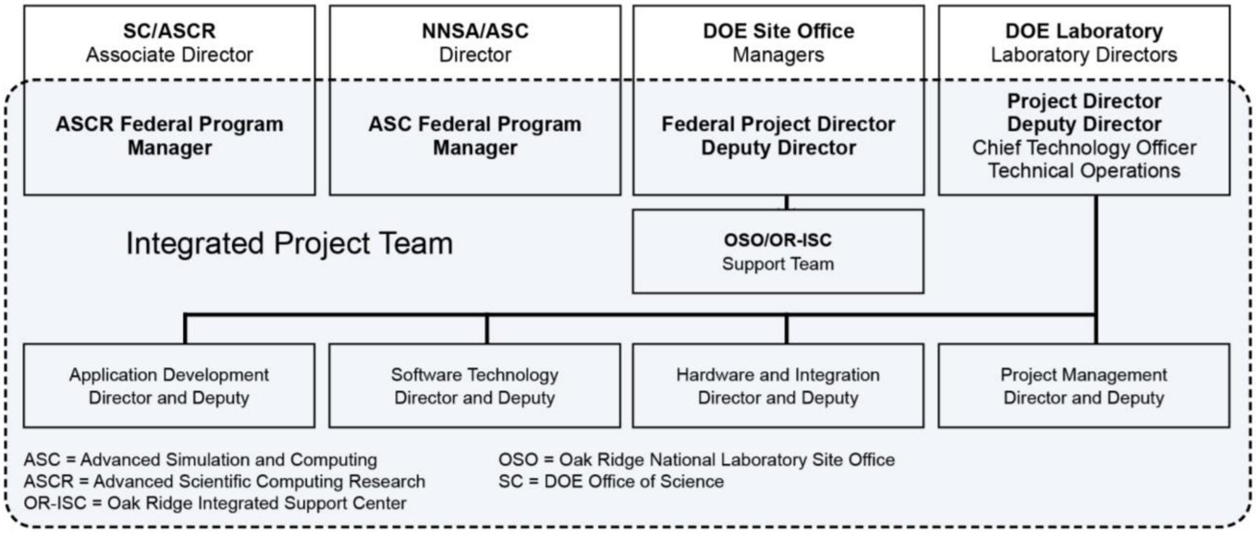


Figure C–2. Exascale Computing Project integrated project team

C.5 Conclusion

DOE/NNSA, through the ASC exascale computing effort, is investing in products and approaches that will respond directly to anticipated disruptive changes in the HPC ecosystem. Activities include 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. Collaboration projects with computer vendors has also led to significant advances in HPC software and hardware technologies. These activities have provided valuable lessons learned and delivered numerous software development tools and libraries that many ASC applications now rely on. To complete this effort, more intensive research, development, and engineering effort is needed for DOE/NNSA to achieve the goal of deploying and fully utilize an exascale capability in 2023.

Appendix D
Stockpile Responsiveness Program

This appendix is provided pursuant to 50 U.S. Code § 2523, which requires inclusion of plans for the Stockpile Responsiveness Program in the Stockpile Stewardship and Management Plan. This appendix also addresses the request in House Report 116-449 – Energy And Water Development And Related Agencies Appropriations Bill, 2021: "The NNSA shall submit to the Committee an annual report with the budget request that includes a detailed accounting and status of each program, project, and activity within the [Stockpile Responsiveness] program."

D.1 Program Establishment, Purpose, and Early Execution

The Stockpile Responsiveness Program was created by Congress in Section 3112 of the *National Defense Authorization Act for Fiscal Year 2016* (NDAA), which states, "It is the policy of the United States to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive."

The Act directs that the program be carried out by the Secretary of Energy, in consultation with the Secretary of Defense. The five objectives for the program are:

1. Identify, sustain, enhance, integrate, and continually exercise all of the capabilities, infrastructure, tools, and technologies … required to carry out all phases of the joint nuclear weapons life cycle process.
2. Transfer knowledge to the next generation of scientists and engineers.
3. Demonstrate responsiveness including prototypes, flight testing, and development of plans for certification without the need for nuclear explosive testing.
4. Shorten design, certification, and manufacturing cycles and timelines to minimize the amount of time and costs leading to an engineering prototype and production.
5. Exercise relevant elements and processes with the Department of Defense (DoD) to ensure stockpile responsiveness.

Accompanying report language emphasized that the program was intended to respond to future threats to our nuclear deterrent through science and technology. Report language reiterated a key constraint that the acquisition of new or modified systems for the U.S. stockpile requires explicit congressional line item appropriations.

In February 2018, NNSA provided a report on the Stockpile Responsiveness Program, as requested in Senate Report 114-255, which requested identification of gaps in the ability of NNSA programs to meet these five objectives and plans for addressing those gaps. The principal identified gap was the lack of experience in exercising integrated design capabilities against new requirements, which would be filled by exercising integrated system design capabilities through "Challenge Problems" (CPs) directed at future threats or new technological opportunities.

Section 3118 of the *National Defense Authorization Act for Fiscal Year 2018* (FY 2018 NDAA) provided additional guidance on design and prototyping activities and directed NNSA "to exercise the full set of design skills necessary for an effective nuclear deterrent, [by] develop[ing] and conduct[ing] the first in what the committee envisions to be a series of design competitions that integrate the full end-to-end process from novel design conception through engineering, building, and non-nuclear testing of a prototype." NNSA informed Congress that it would meet the requirements of this section of legislation through the Stockpile Responsiveness Program.

In FY 2017, the Stockpile Responsiveness Program received a limited appropriation of $2 million, which enabled the program to engage with the U.S. Strategic Command (USSTRATCOM) Global Strike Division (J87) to address options for future needs for hard and deeply buried target defeat. In mid-FY 2018, the program received an appropriation of $30 million, which constituted the true execution start of the Stockpile Responsiveness Program. In FY 2019, the appropriation was increased to $34 million. At this funding level, NNSA initially focused on filling the highest-priority gap through activities implemented with the three nuclear weapons laboratories.

In early FY 2020, Congress increased the funding to $70 million and NNSA immediately broadened its scope to the establishment of national security laboratory/production plant collaborations focused on accelerating the production process.

D.2 Planned Budget

To accomplish the goal of improving enterprise responsiveness, DOE/NNSA programs the Stockpile Responsiveness Program budget by site. This allows substantial participation of each of the relevant sites and encourages development of national security laboratory/production plant partnerships to accelerate design, production, and qualification of future nuclear weapons systems. To this end, substantial participation of each of the relevant sites is important.

Site	FY 2021 Enacted	FY 2022 Request
Pantex Plant	3,975,000	3,975,000
Y-12 National Security Complex	3,625,000	3,625,000
Kansas City National Security Campus	5,397,600	5,498,000
Los Alamos National Laboratory*	19,500,000	19,233,000
Lawrence Livermore National Laboratory	18,000,000	17,733,000
Sandia National Laboratories	18,000,000	17,733,000
Headquarters	1,502,400	2,203,000
Total	**70,000,000**	**70,000,000**

** LANL's budget includes $1.5 million for the separate production agency Technical Area 55 to examine ways to enhance the responsiveness of pit production, especially through examining issues involving the rapid execution of a subcritical experiment based on the Stockpile Responsiveness Program's created design chosen to accelerate pit production issues.*

D.3 Governance and Priorities

From the outset, NNSA has collaborated closely with the Office of the Secretary of Defense, Deputy Assistant Secretary of Defense for Nuclear Matters on Stockpile Responsiveness Program execution. NNSA and the Nuclear Weapons Council agreed that the Nuclear Weapons Council Standing and Safety Committee would receive annual briefings on program accomplishments, and the Nuclear Weapons Council would approve plans for the upcoming year, including authorization of joint NNSA/DoD activities to execute the program. Additionally, the Nuclear Weapons Council would annually review and update the "Stockpile Responsiveness Capabilities Development Guidance," which establishes priorities for the Stockpile Responsiveness Program. A joint Stockpile Responsiveness Program conference is held annually to communicate accomplishments, issues, and opportunities among NNSA participants and relevant DoD elements.

The Nuclear Weapons Council's FY 2020 guidance, which remains effective for FY 2021, established that the overarching priority for DoD was to demonstrate methods to reduce the time and cost of producing and qualifying nuclear weapons components and systems. This is consistent with the views expressed on page 309 of the House Armed Services Committee Report 116–442, *William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021*, which "encourages the Secretary of Defense and the Administrator of the National Nuclear Security Administration to focus some resources and effort toward reducing cost, risk, and difficulty of manufacturing and producing nuclear weapons."

The Nuclear Weapons Council guidance directed the Stockpile Responsiveness Program to pursue this overarching priority in the context of two key issues: hard and deeply buried target defeat and Defended Target defeat. Section 3118 of the 2018 NDAA also directed the NNSA to execute a design competition to look at the challenge of holding defended targets at risk.

D.4 Approach to Responsiveness, Risk Management, Safety, and Security

Modernization is a radical departure from stewardship activities focused on maintaining the aging stockpile systems that are currently deployed. The past priority and focus has been to maintain confidence in the safety and reliability of the current deterrent. Modernization brings a new dimension to the task of stewardship. It requires new technologies in new systems to meet new military requirements to address emerging threats. The ability to maintain old technologies and materials is no longer practical or feasible. Surmounting the risk inherent in modernization requires accepting the existence of technical risk and the inevitability of failed experiments and demonstrations. In addition, successful new system development requires radically shortening the design-build-test cycle from years to a month or less to validate new technologies and materials for nuclear applications.

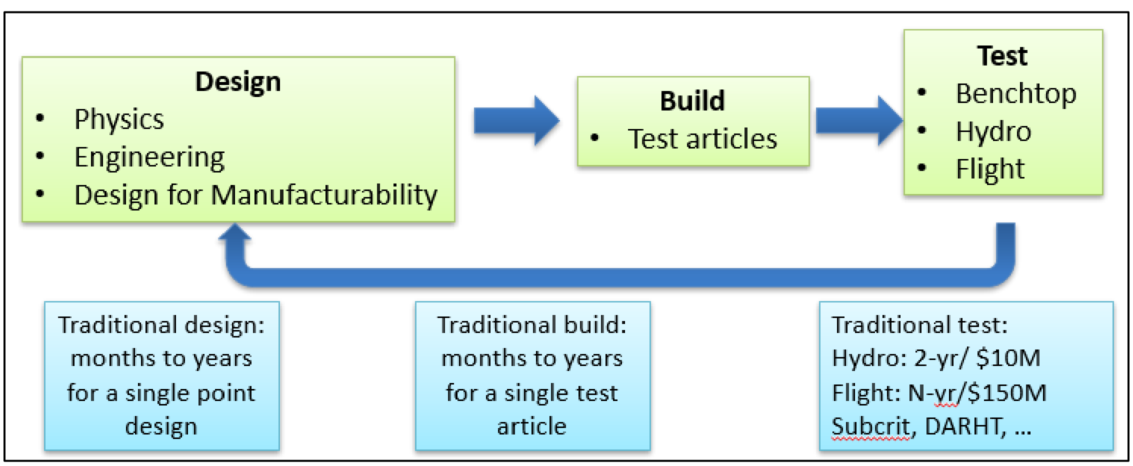


Figure D–1. The traditional design-build-test cycle for weapon system development

Historically, the ability to progress expeditiously through the design-build-test cycle has been key to the successful development of complex technological systems, such as the development of the SR-71 at Lockheed Martin's Skunkworks; new launch technologies of SpaceX; or original development of the strategic systems in the U.S. nuclear weapons arsenal. DOE/NNSA's life extension programs (LEPs) and modernization programs today do not embody the rapid development principles in any of these examples.

The system concepts that are being explored under the Stockpile Responsiveness Program CPs are vital to setting the context for exercising and accelerating the design-build-test cycle in NNSA. They provide the opportunity to take a fresh approach, using modern technological capabilities, that is independent of the constraints of present or proposed LEPs. LEP execution prioritizes conformance to rigorous requirements with a high premium on cost and schedule certainty, with little tolerance for technical risk. For example, if a Stockpile Responsiveness Program activity were to interfere or conflict with an LEP activity, or if it produced an anomalous result that impacted confidence in a presently deployed system, it would attract increased scrutiny and oversight. Such reactions are in direct conflict with the rapid execution principles of the design-build-test cycle and the goal of accepting technical risk to provide learning opportunities.

Per the legislation establishing the Stockpile Responsiveness Program, the intended product is *responsiveness*: not to produce a new system, but to accelerate the process by which new systems, when authorized, will be designed and built. In demonstrating opportunities to sharply reduce timelines and costs associated with producing nuclear weapons, the Stockpile Responsiveness Program is focusing on what can be done through accelerated technical activities while identifying administrative and process control burdens as technical programs are pursued.

The Stockpile Responsiveness Program will not compromise personnel, facility, or nuclear safety or security requirements. But the Stockpile Responsiveness Program will in many cases seek to make these issues irrelevant by developing unclassified surrogates or using material surrogates that eliminate safety issues. This will maximize the rate at which information can be gained from testing, as well as maximize the extent to which the next generation of scientists and engineers can gain experience.

D.5 Execution of the Technical Program

NNSA has organized the program according to four major technical efforts (MTEs) aligned with the stated objectives of the Stockpile Responsiveness Program. All technical efforts rely upon seasoned mentors to transfer knowledge to less experienced technical staff, from threat assessments to system design to testing activities to development of individual technologies. Technology development teams provide leadership opportunities for early-career staff members. DoD connections are exercised throughout the Stockpile Responsiveness Program, from coordination with the Nuclear Weapons Council to technical exchanges with relevant Air Force and Navy material elements.

Table D–1 describes the approximate distribution of effort across the MTEs.

Table D–1. Distribution of the Stockpile Responsiveness Program budget across major technical efforts

MTE	*Subject*	*Budget Fraction*
1	Future threats, technology trends and opportunities	10%
2	Challenge Problems – Integrated system designs to address future threats	20%
3	Prototyping, testing and flight testing	30%
4	Technologies for production responsiveness	40%

MTE = major technical efforts.

Exercising nuclear design capabilities, which is critical to developing stockpile responsiveness, is one part of the overall technical program to develop a responsive posture. The bulk of the technical effort is on other aspects of testing and production.

D.5.1 Major Technical Effort 1: Future Threats, Technology Trends, and Opportunities

Because the focus of the Stockpile Responsiveness Program is on improving the capability of the nuclear enterprise to respond to future threats, it is essential that the program participate in identification of those threats. Under this MTE, national security laboratory technical capabilities are applied to understanding and anticipating future challenges to the nuclear deterrent arising from foreign trends, evolving U.S. operational needs and employment doctrine, and emerging technology trends. The national security laboratories provide analytic capability in collaboration with field intelligence elements, the Intelligence Community more generally, and the military combatant commands, in particular U.S. Strategic Command.

One component of this is the Design for Effects" effort at The Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (SNL) (tri-laboratory). This effort uses the advanced analysis tools, especially computational tools and resources developed for stockpile stewardship to support the planning needs of the combatant commanders. For instance, high-fidelity three-dimensional geophysics models are providing improved understanding of the offensive and defensive aspects of weapons effects. Specific analyses have included:

- Analysis of identified targets supporting NNSA and Defense Intelligence Agency/DRI-5 (Physical Vulnerability division)
- Specific Analyses of Pill Sources versus High-Fidelity Sources Survey (LLNL, LANL, SNL)
- Cratering/Ground Shock Fluid/Structure coupling to finite element method/discrete element method code (LANL)
- Machine Learning approach for translating computer-aided design files to usable numerical model (LLNL)
- Development of higher resolution grids in TOPANGA E3 code for ionospheric-communication modeling (LLNL)
- Shock Fluid/Structure interaction for tree models – Non-Ideal Air Blast (SNL)
- Non-Ideal Air Blast analyses of four test problems (LANL, LLNL, SNL)
- Weaponeering Options for Contingencies (LANL)

D.5.2 Major Technical Effort 2: Challenge Problems

CPs are established by a joint agreement between DoD and NNSA and are posed as a method to exercise integrated system design capability against possible future threats. CPs enable the national security laboratories to rebuild/rediscover the skills needed to design integrated systems with new delivery vehicles, environments, and performance requirements. The CPs do not just exercise nuclear design capabilities, they also exercise the range of engineering and systems design capabilities required to integrate new technologies on new delivery platforms, while accelerating the weapons life cycle from manufacturing to certification and qualification.

CP teams include staff members of various skill and experience levels across multiple disciplines and professions, including design physicists, engineers, weapon effects scientists, diagnostic and testing specialists, and those who will have to prototype or produce the system. The major focus areas are training the next generation of technical staff, building multidisciplinary teams, and developing a responsive culture. Close collaborations with the production plants have been established so that the manufacturing and qualification impacts of design choices are understood by designers and become a factor in system optimization.

Challenge Problem 1

CP1 is focused on hard target defeat, an objective identified in Nuclear Weapons Council taskings. Discussions among the tri-laboratory physics and engineering staff and DoD partners, especially USSTRATCOM and Navy Strategic Systems Programs, were held to understand needs. Concepts were developed with a range of performance, development, and manufacturing complexity. Some concepts were based on traditional approaches to the problem, while others proposed more innovative and technically challenging solutions. One specific concept, which revolved around a high level of responsive manufacturability, was down-selected based on strong interest from the military services and production plants. This down-selected hard target defeat concept has led to prototyping and testing activities reported in MTE 3.

The work performed for the CP1 Design Exercise during the past year includes:

- Low-fidelity system concepts expected to be effective (LANL, LLNL, SNL)
- Evaluation of the set of concepts for technical feasibility, production feasibility, delivery platform compatibility, and relative time to deployment (LANL, LLNL, SNL)
- Preliminary weapons effectiveness assessment (Task 2 under Threats) (LANL, LLNL, SNL)
- A summary of concept assessments delivered to the Nuclear Weapons Council (LANL, LLNL, SNL)
- Technical gap analysis to identify the leading concept-spanning technical challenges (LANL, LLNL, SNL)
- Plans for hardware prototype development and testing activities for the leading technical challenges (LANL, LLNL, SNL)

Challenge Problem 2

CP2 was developed pursuant to the 2018 NDAA language to execute a design competition to address target defenses that could arise in the 2030s. The national security laboratories have executed this challenge by creating clean-sheet designs, unconstrained by existing LEPs, to deliver new capabilities if required by the Nuclear Weapons Council and authorized by Congress. CP2 emphasizes analysis of existing and emerging threats and development of designs that mitigate those threats in system-level models.

The LANL approach to CP2 was to down-select quickly to a specific option and then concentrate on refining the design and taking it to prototyping, ground testing, and flight testing to gain early experience exercising the entire design-build test cycle. This design was used to demonstrate acceleration of hydrotesting, and LANL is pursuing options for rapid flight testing of engineering prototypes.

LLNL has focused on developing a process to design and assess design packages by developing a diverse portfolio of multi-purpose, modular, and flexible options. The designs in this portfolio can fly in multiple carriers, and LLNL is concentrating on those that can defeat prospective targets with a range of weights, yields, and other traits and are all designed with ease of manufacturing in mind. Each option can field interchangeable parts or materials, including component reuse to simplify mitigation options. "Proof-of-principle" work has been completed on this portfolio, and designs can be fine-tuned against a range of emerging contingencies. In collaboration with other NNSA agencies, LLNL will prototype a down-selected option.

D.5.3 Major Technical Effort 3: Prototyping, Testing, and Flight Testing

The ability to rapidly produce and test prototypes is integral to accelerating the nuclear weapons life cycle for new capabilities. In executing this statutory objective of the Stockpile Responsiveness Program, NNSA relies on the prototyping definition provided under the now eliminated 50 U.S. Code § 2660, *Design and use of prototypes of nuclear weapons for intelligence purposes,* which authorized within section (b)(2):

> **(A)** Design and system engineering activities of full-scale engineering prototypes (using surrogate special nuclear materials), including weaponization features as required
>
> **(B)** Design, system engineering, and experimental testing (using surrogate special nuclear materials) of above-ground experiment test hardware
>
> **(C)** Design and system engineering of scaled or subcomponent experimental test articles (using special nuclear materials) for conducting experiments at the Nevada National Security Site

This prototyping authority is consistent with the prototyping direction of Section 3118 of the 2018 NDAA, which prohibits experiments that could produce a nuclear yield.

The context established by CP1 inspired an ambitious prototyping and testing program executed through collaborations between LANL, LLNL, SNL, and the Kansas City National Security Campus (KCNSC). SNL has fielded several experiments on the Davis Gun at White Sands Missile Range to examine ground penetration issues and shock mitigation techniques to validate codes in this harsh environment.

Small, focused tests have been performed at LLNL and other external facilities. These will culminate in a hyper-velocity sled-track test at Holloman High Speed Test Track at Holloman Air Force Base. During FY 2020, LLNL added a target development test to an already established experiment for the Weapon Survivability subprogram. The data from this test led to a redesign of embedded wire diagnostics in a high explosives (HE) test. Equation-of-state data obtained from rapidly prototyped samples then led to a redesign of targets to be fielded in FY 2021. Lessons learned in each phase directly contributed to the successes of the following phase at a pace that would not have been possible if each test were designed to be "perfect." Technical staff have gained experience in the realities of field testing where lack of immediate resources forces compromises to complete experiments satisfactorily in a constrained availability window.

CP2 is driving rapid prototyping capabilities to demonstrate innovative technologies and processes. LANL is pursuing an effort to greatly decrease the time required to execute hydrotests. An initial demonstration was completed in 10 months, less than half the normal time. Ultimately, both LANL and LLNL are pursuing efforts to drive hydrotesting times down to a few months. It is also driving the development of new capabilities such as flash X-ray radiography on a centrifuge to measure displacements and deformations of an accelerated object in situ. In these demonstration activities, the Stockpile Responsiveness Program is accepting risk by fielding previously unproven diagnostics, technologies, fabrication methods, and assembly techniques in its hydrotesting program. LANL is pursuing commercially-provided flight services as platforms to enable rapid prototyping and testing of near full-scale engineering prototypes. This will bring systems and technologies to maturity for future consideration in acquisition programs.

The KCNSC Technology Integration Demonstrator uses digital engineering to design, simulate, fabricate, and test new components on a time frame of months rather than years. KCNSC then subjects payloads containing these new components to real-world testing environments on sounding rockets. This fast cycle allows new materials to be developed and tested in real-world conditions and is generating data to improve simulation models.

SNL prototyping and testing efforts include:

- Re-establishing an aeroshell prototyping capability
- Advanced radar antenna prototyping and testing
- Prototyping and testing a next-generation fuze design
- Establish new ground test capability at the SNL Superfuge centrifuge facility to better encompass future mixed environments through the full stockpile-to-target sequence

D.5.4 Major Technical Effort 4: Technologies for Production Responsiveness

MTE 4 encompasses efforts specifically important to furthering production. This includes design for manufacturability, digital engineering techniques, novel approaches to materials production, advanced manufacturing processes, development of architectures that accelerate production and enhance maintainability, and efforts to accelerate qualification and acceptance of components and systems.

Digital Engineering. Stockpile Responsiveness Program prototyping activities use digital engineering capabilities to transfer data and design information across the nuclear security enterprise to the maximum extent possible. Model-based systems engineering and machine learning are also being adopted to accelerate design for manufacturability.

Materials production technologies are pursued to provide new materials or materials production processes for critical and hard-to-produce products:

- **HE production.** LLNL and LANL have developed HE formulations with improved energy delivery that could replace conventional HE (CHE) in future systems. The national security laboratories are working to accelerate scale-up of synthesis, formulation, and qualification of candidate insensitive HE (IHEs) to reduce the reliance on CHEs in future system designs. LLNL is accelerating the development of LX-22 as a new main charge formulation and LANL is working to scale up synthesis of the IHE DAAF [Diaminoazoxyfurazan] and formulate it into a new IHE, PBX 9701.
- **Continuous flow process to support HE synthesis and production**. In addition to working on component-level HE manufacturing technologies, LLNL is working on advanced synthesis and formulation methodologies to optimize control over the feedstock material, which also increases quality control and production yields and reduces costs and schedule risks.
- **Additive manufacturing of polymers**. Additive manufacturing of polymers and polymer-based composite materials has been maturing quickly in the past few years. Under the Stockpile Responsiveness Program, LLNL is leveraging these advances and using these technologies to rapidly produce bespoke components on a regular basis to accelerate testing.
- **Uranium alloys production.** Electron Beam Cold Hearth Melting is a technology that significantly reduces waste and accelerates timelines in the alloying and recycling of uranium alloys, and LLNL is working to design and commission a system.

Advanced manufacturing technologies

- **Uranium component manufacture**. Additive manufacturing of uranium components is being developed to enable rapid prototyping and production of parts for hydrotesting at the national security laboratory level, as well as production of some components at the production plants. This effort is a collaboration between LLNL and Y-12 National Security Complex.
- **Additive manufacture of HE main charge**. The manufacture and qualification of HE represents a significant fraction of the development and production effort. DOE/NNSA is developing and demonstrating new additive manufacturing technologies that will enable control of the properties of energetic material components. This will increase product quality control, increasing yield and reducing production schedules. This effort is a collaboration between LLNL and Pantex Plant.
- **Digital Twins to accelerate production**. Digital Twins are virtual representations of production machines that mimic the specific behavior of a piece of equipment. They can simulate new toolpath programming without risking equipment damage, explore tool capabilities, train new personnel, and explore the impact of programming on the product quality. The Stockpile Responsiveness Program is developing Digital Twin technology for additively manufactured polymers and HE.

Ameliorating the qualification burden. The Stockpile Responsiveness Program joined with the Advanced Certification and Qualification program on an initiative to reduce the burden of qualification while maintaining confidence in the deterrent. An NNSA/national security laboratory/production plant workshop held in April 2020 explored issues and opportunities, and the Stockpile Responsiveness Program has started several technical initiatives within this MTE.

Rapid qualification with in-situ inspections. Qualification of materials and components is time-intensive at the production plants and can actually consume more resources than component manufacturing itself. On-machine inspections allow characterization of the material, parts, and components during manufacture. DOE/NNSA is developing and deploying optical- and spectroscopy-based on-machine inspection techniques for parts manufacturing. If all properties can be tested during manufacturing, a part or component would be “born qualified” and allow characterization of components that are too complex to be inspected in their completed configuration. These efforts are collaborations between LLNL, Pantex Plant (for additively manufactured HE), and KCNSC (for additively manufactured metals).

Appendix E
Workforce and Site-Specific Information

As detailed in Chapter 1, the Department of Energy's National Nuclear Security Administration (DOE/NNSA) has eight nuclear security enterprise sites, spread across the Nation, that possess the expert workforce and advanced capabilities to maintain the Nation's nuclear deterrent. These eight sites include three national security laboratories (Lawrence Livermore National Laboratory [LLNL], Los Alamos National Laboratory [LANL], and Sandia National Laboratories [SNL]), four nuclear weapons production facilities (Kansas City National Security Complex [KCNSC], Pantex Plant [Pantex], Savannah River Site [SRS], and Y-12 National Security Complex [Y-12]), and the Nevada National Security Site (NNSS). Specific information is included in this appendix to elaborate on each site's mission, weapon activities capabilities, the fiscal year (FY) 2022 budget request, recent accomplishments, and workforce data.

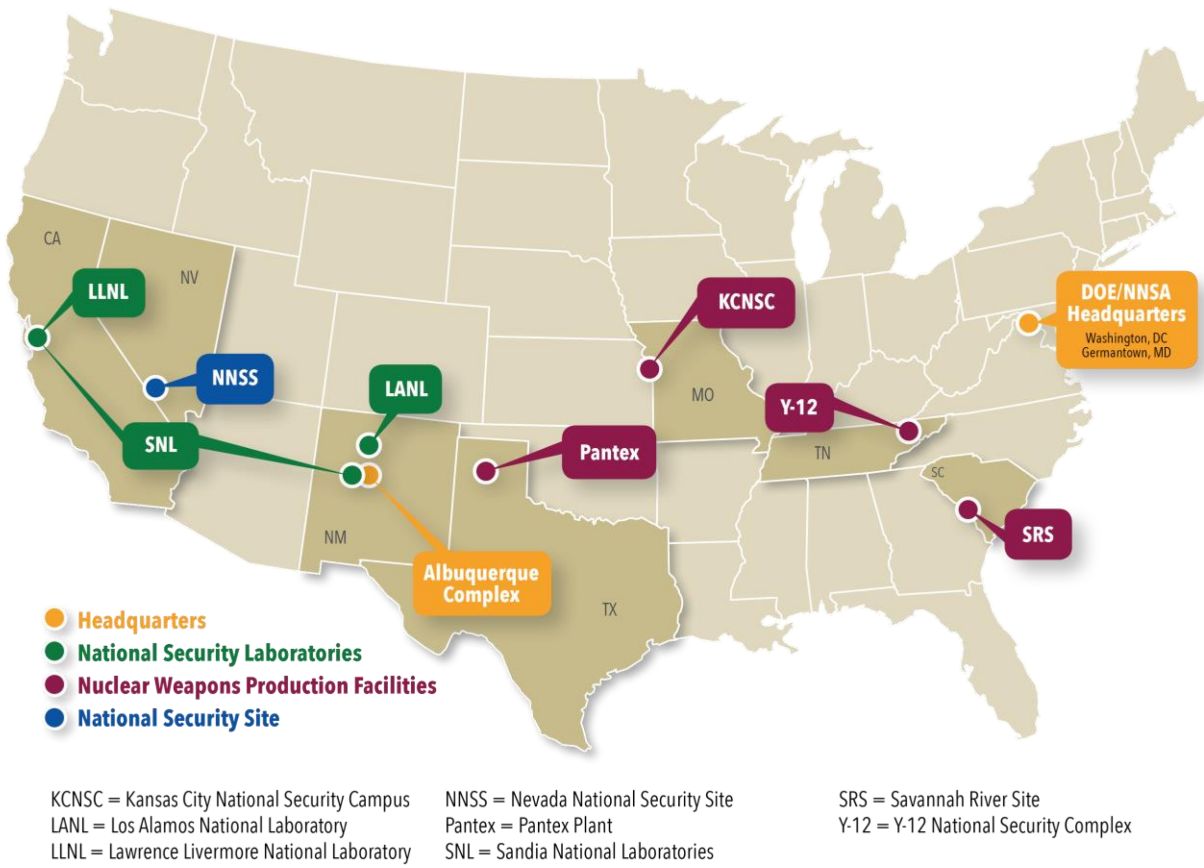


Figure E–1. The DOE/NNSA nuclear security enterprise

Critical Importance of Investing in Advanced Capabilities, Infrastructure, and the Workforce

Planning and investing in advanced capabilities, infrastructure, and, most importantly, the workforce are at the heart of achieving U.S. nuclear security objectives. These aspects are also interrelated.

- The nuclear deterrent must provide decision-makers with capabilities that are modern, robust, flexible, resilient, ready, and appropriately tailored to deter 21st century threats. DOE/NNSA's capabilities for weapons activities enable these characteristics. Advanced capabilities help meet evolving deterrence needs.
- Modern stockpile stewardship, including major modernization programs, requires specialized technologies and processes, as demonstrated by the capabilities that DOE/NNSA requires for mission success (see Appendix B, "Weapons Activities Capabilities"). These technologies and processes include but are not limited to, areas such as advanced manufacturing, processes that can produce and handle hazardous materials, materials science, and computer science.
- These special capabilities, technologies, and processes require specialized facilities that can successfully contain the necessary work, such as processing lithium or conducting experiments on plutonium. These facilities must ensure that the work can be done safely and on schedule.
- To successfully accomplish the mission, DOE/NNSA must attract, train, and retain a skilled and experienced workforce. The workforce provides the specialized knowledge, skills, and abilities to operate specialized equipment, design and manufacture components, and understand how specialized materials interact, among other areas of knowledge. Without a safe and appropriate infrastructure, the ability to attract and grow the workforce would be limited.

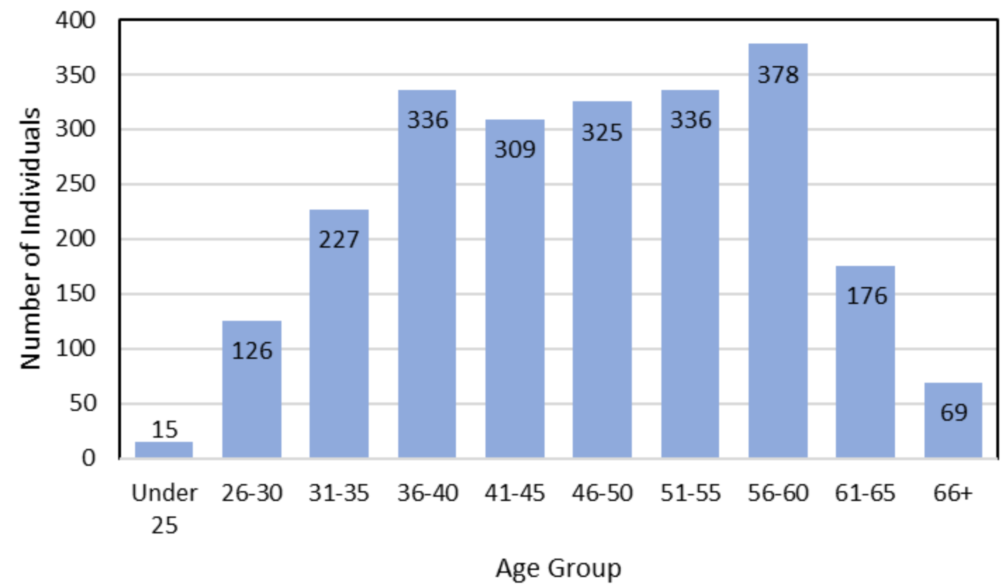
E.1 National Nuclear Security Administration

E.1.1 Federal Workforce

The Federal workforce plans, manages, and oversees the nuclear security enterprise and is accountable to the President, Congress, and the public. NNSA's Federal workforce handles program and project management for DOE/NNSA's major missions of maintaining the nuclear weapons stockpile, naval nuclear propulsion, and nuclear threat reduction through counterterrorism and nonproliferation. In addition to these functions, Federal employees also perform important missions in areas such as physical security, cyber security, management and human resources, logistics, infrastructure planning and budgeting, and strategic communications and public affairs. The Federal workforce operates out of Headquarters facilities in Washington, DC; Germantown, Maryland; and Albuquerque, New Mexico. Federal staff are dispersed throughout field offices located at each of the sites. These field offices employ subject matter experts in a wide variety of disciplines to provide oversight for each site's diverse national security missions. NNSA's Federal workforce, like its contracted management and operating (M&O) partners and other non-M&O contractors, is composed of dedicated professionals working to promote the nuclear security mission.

DOE/NNSA has launched a workforce strategy group to attract and retain the best talent to sustain current and future nuclear security missions. DOE/NNSA recognizes the need for effective leadership; performance measures; management consistency; an increased focus on training at the entry, middle, and executive levels; and increased flexibility and adaptability in the current staff; as well as the need for aggressive knowledge transfer programs. NNSA has implemented foundational competencies and began developing occupational competencies and career paths. These talent management initiatives will promote DOE/NNSA as an employer of choice, build the bench of talent needed at all levels, and foster sustained mission excellence. During FY 2020, DOE/NNSA enhanced current programs, products, and services, and developed additional new programs. Notably, DOE/NNSA focused on developing career paths for mission critical occupations. The career paths and competency models will strengthen employees' levels of knowledge, skills, abilities, and behaviors.

At the end of FY 2020, NNSA had a Federal headcount of 2,297, which includes the Office of Secure Transportation and omits support service contractors and Office of Naval Reactors personnel. The average age of Federal employees is about 48 years; about 16 percent are retirement-eligible. The average years of service for Federal employees is about 15, and most Federal employees have between 0 and 15 years of service. This is a reflection of aggressive hiring efforts now and in the past few years. Most separations from the Federal workforce were retirements or voluntary separations, with retirements higher among experienced workers and voluntary separations higher among those with fewer years of service. The number of voluntary separations among those with 0-5 years of service is particularly noticeable and an enterprise-wide trend. For more detailed information on NNSA's Federal workforce, refer to Chapter 7, **Figures E–2** through **E–5**, and the accompanying notes.



Notes:

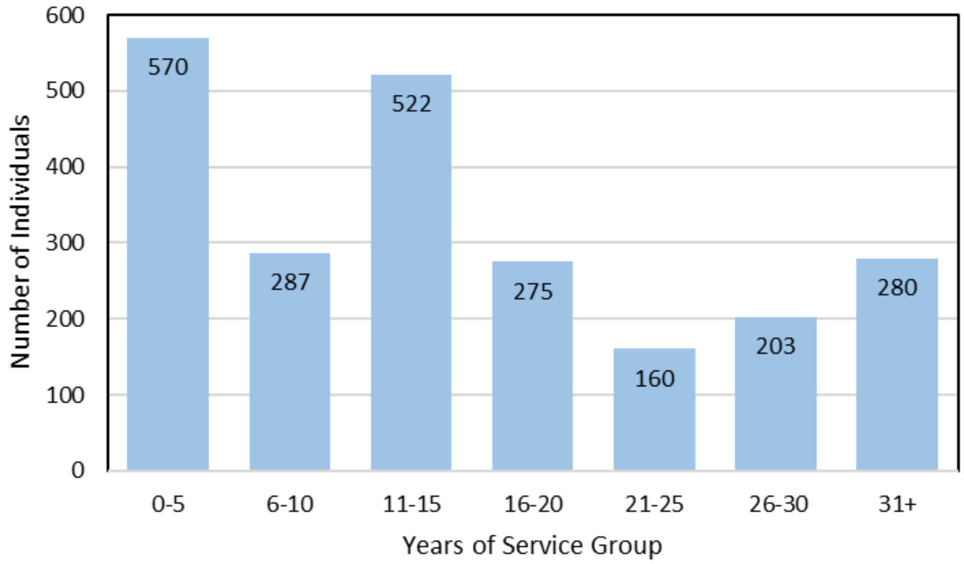
The data set includes approximately 319 nuclear materials couriers who are, on average, younger than the rest of the workforce. 76 percent of the courier workforce is 20 to 45 years of age so those age categories are skewed slightly by that workforce. Many of the challenges associated with an aging workforce have been identified and are addressed in the same manner as with years of service challenges.

In partnership with the sites, DOE/NNSA has also conducted focused recruiting events at Georgia Tech, Texas A&M University, Purdue University, the University of California Merced, University of Toledo, Case Western University, and University of Michigan.

Equally important to the DOE/NNSA staffing plan is succession planning. A projected 41 percent of the current DOE/NNSA Federal Salaries and Expense account (non- Office of Secure Transportation) workforce will be eligible to retire by FY 2025. Due to the unique nature of the nuclear security mission, NNSA has undertaken an aggressive talent management approach that includes employee development and knowledge transfer.

Working with Office of Personnel Management experts, DOE/NNSA conducted a succession planning training session for all Senior Executive Service members in key roles to outline an approach to identify a leadership talent pool and develop a pipeline of successors whose strengths fit agency needs. A second, more extensive, 2-day training was held with Learning and Career Management and Human Resources personnel to concentrate resources on addressing talent management gaps to yield a greater return on the DOE/NNSA employee developmental investment.

Figure E–2. Federal workforce distributed by age group (as of September 30, 2020)

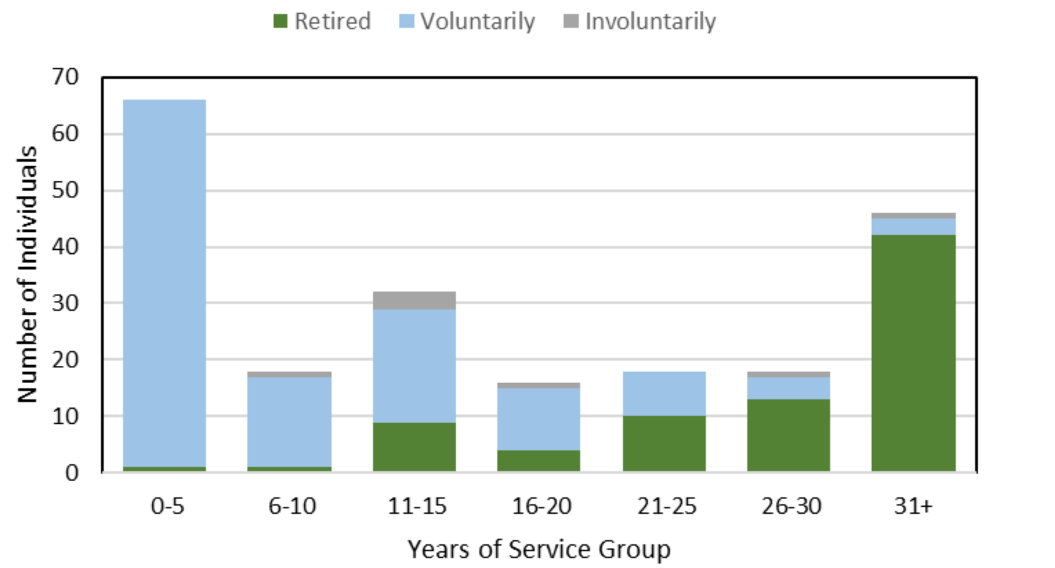


Notes:

DOE/NNSA hiring efforts over the last 2 fiscal years are evident in the higher numbers of full-time equivalents (FTEs) on the left side of the years of service graph. DOE/NNSA continues to have a somewhat bi-modal distribution, which can indicate some risk due to an "experience gap" in the valley between the two peaks. However, there are a significant number of experienced employees on the left side of the bi-modal distribution (809 employees with 6-15 years of service), which represents an opportunity to manage the risk. To address these demographic challenges, during FY 2020, senior leadership funded $3.4 million of organizational training and travel costs/needs identified via the Annual Training Assessment to empower employees to refine skills and prepare for new DOE/NNSA mission growth in anticipation of the expanded DOE/NNSA mission. DOE/NNSA has also focused on shifting age, years of service and retirement demographics by hiring more entry-level employees. Avenues used in this regard include increased use of the NNSA Graduate Fellowship Program, the Pathways Program, and the Minority Serving Institute Partnership Program.

DOE/NNSA recognizes the need for effective leadership; performance measures; management consistency; increased focus on training at the entry, middle, and executive levels; and increased flexibility and adaptability in the current staff; as well as the need for aggressive knowledge transfer programs. DOE/NNSA has implemented foundational competencies and began developing occupational competencies and career paths. These talent management initiatives will promote DOE/NNSA as an employer of choice, build the bench of talent needed at all levels, and foster sustained mission excellence. During FY 2020, DOE/NNSA's Office of Learning and Career Management (LCM) enhanced current programs, products, and services, and developed additional new programs. Notably, LCM focused on developing career paths for mission critical occupations. The career paths and competency models will strengthen employees' levels of knowledge, skills, abilities, and behaviors.

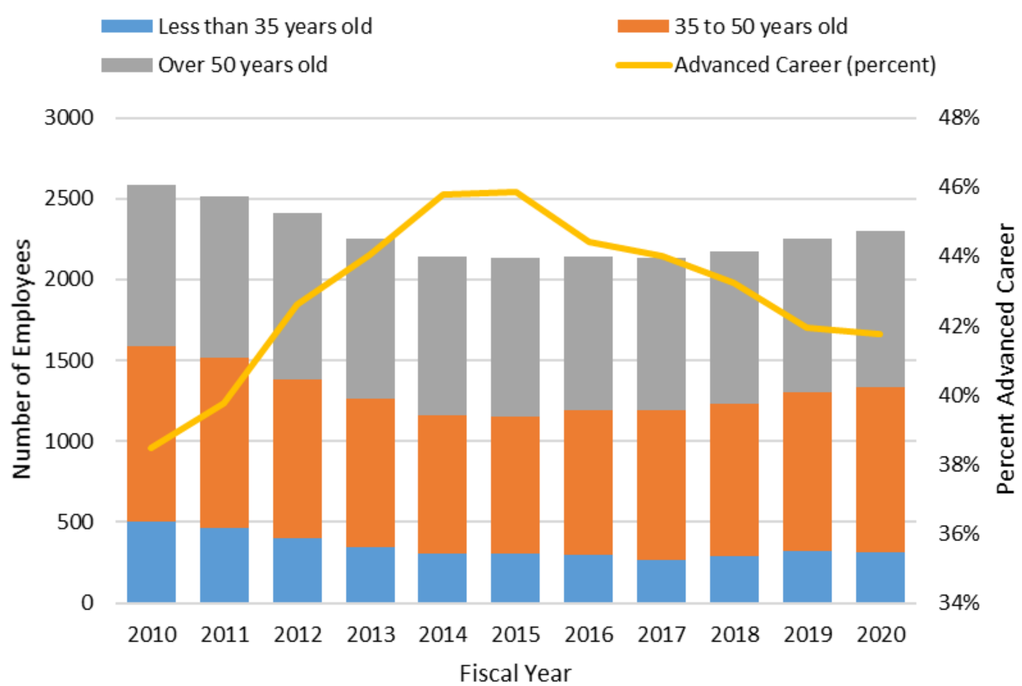
Figure E–3. Federal workforce distributed by years of service group (as of September 30, 2020)



Notes:

Retirements have represented a little over 60 percent of separations in the non-Office of Secure Transportation workforce in the last few years. This presents a unique opportunity to reshape the workforce with more diverse people who are trained and positioned to address nuclear security challenges with new talent and new technologies.

Figure E–4. Federal employee separation by years of service group (as of September 30, 2020)



Notes:

In FY 2015-FY 2018, NNSA focused on shifting retirement eligibility demographics by using the excepted service authority to hire over 20 entry-level employees each year.

Figure E–5. Federal workforce participation trends by age category and percent advanced career (as of September 30, 2020)

E.2 National Security Laboratories

E.2.1 Lawrence Livermore National Laboratory

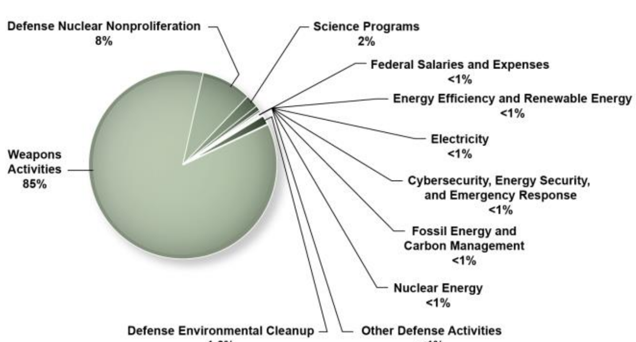
E.2.1.1 Mission Overview

DOE/NNSA sponsors the Lawrence Livermore National Laboratory (LLNL) in Livermore, California. As a Federally Funded Research and Development Center (FFRDC), LLNL is uniquely positioned to guide challenging research and development (R&D) and deliver results on behalf of DOE/NNSA mission needs. This is accomplished by providing research, development, test and evaluation (RDT&E) capabilities for the stockpile, as well as a broad range of national security needs integral to the mission and operation of DOE and other Federal agencies. LLNL is managed by Lawrence Livermore National Security, LLC.

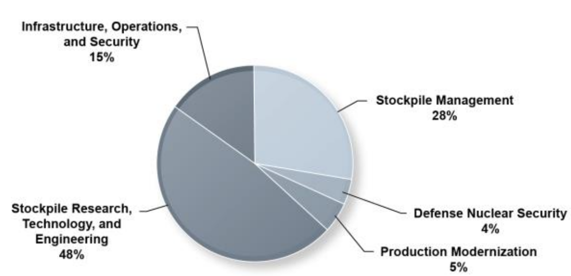
- Locations: Main site, Livermore, California (Site 200); Experimental Test Site, Tracy, California (Site 300)
- Total Employees: 7,274 (as of the end of FY 2020)
- Type: Multi-program national security laboratory
- Website: www.llnl.gov
- Contract Operator: Lawrence Livermore National Security, LLC, a corporate subsidiary of Bechtel National; University of California; BWX Technologies, Inc.; the Washington Division of URS Corporation; and Battelle
- Responsible Field Office: Livermore Field Office

E.2.1.2 Funding

FY 2022 request – site funding by source
(total LLNL FY 2022 request = $2,233 million)



LLNL split for the FY 2022 Weapons Activities President's Budget Request *($1,913 million)*



E.2.1.3 Site Capabilities

LLNL is a DOE/NNSA Center of Excellence for Nuclear Design and Engineering, with core competencies in high explosives (HE), high energy density (HED) physics, high performance computing (HPC), nuclear physics, materials science and engineering, and additive manufacturing. LLNL is the lead design agency for the W80-4 (the Air Force's cruise missile warhead) life extension program (LEP) and the W87-1 Modification Program. LLNL has primary assessment responsibility for the W80-1, W87-0, B83, and W84, as well as review responsibility for other systems.

LLNL operates key DOE/NNSA flagship stockpile stewardship facilities such as the National Ignition Facility, Livermore High Performance Computing Center and Sierra – advanced technology computing system, High Explosives Applications Facility, Contained Firing Facility, Flash X-Ray, and Plutonium Superblock. LLNL also sustains and advances the physical infrastructure and capabilities supporting R&D, science, and technology missions in weapons engineering, design, performance physics, advanced materials, HPC, and HED physics.

LLNL capabilities related to design, development, and sustainment of stockpile systems with their associated challenges and strategies are described in **Table E–1**.

Table E–1. Lawrence Livermore National Laboratory capabilities

Weapons Physics Design and Analysis		
LLNL scientists, engineers, and technical staff design and assess the performance of the nuclear explosive package through implementing and advancing the capability to certify the stockpile without nuclear testing. LLNL characterizes primary and secondary performance, HE, and material performance via physics design and analysis and maintains critical capabilities such as advanced diagnostics and sensors; laser, pulsed power, and accelerator technology; hydrodynamic and subcritical experiments; and weapons surety design, analysis, integration, and manufacturing.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Improvements in key capabilities are required for LEPs, including operational risk reduction activities for dynamic radiography, increased experimental workloads, and investment in advanced diagnostics for nuclear explosive package performance certification.	DOE/NNSA is investing in infrastructure support and recapitalization to modernize Site 300 capabilities, including firing sites at the Flash X-Ray and Contained Firing Facility, and in plutonium infrastructure and advanced diagnostics development to support weapons certification. Production enclave investment ensures RDT&E for new materials that support the stockpile.	
Weapons Engineering Design, Analysis, and Integration		
LLNL is responsible for weaponizing the physics package to ensure performance through the warhead stockpile-to-target sequence, and to support production engineering. Engineering design and analysis supplement the fundamental capability to certify the stockpile without nuclear testing through destructive and nondestructive surveillance evaluations as well as reliability and condition assessments. This capability is also used to fabricate complex special nuclear material target assemblies to enable focused tests and experiments.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
LLNL will need continuous modernization of warhead test and evaluation capabilities and needs investment in and evaluation of disruptive manufacturing technologies such as advanced manufacturing.	DOE/NNSA is making multi-year sustainment investments in weapons engineering capabilities, including fabrication and inspection, nondestructive evaluation, environmental testing, plutonium science, and radioactive material processing.	Continue multi-year investments, including those focused on specialized Advanced Manufacturing Laboratory space and equipment

High Explosives Science and Engineering		
LLNL's HE RDT&E capabilities support stockpile stewardship, nuclear nonproliferation, and nuclear counterterrorism efforts via a multidisciplinary approach to synthesis, formulation, characterization, processing, and testing of energetic materials, components, and warhead subassemblies. LLNL characterizes HE performance and safety at device and laboratory scales. Modernization activities support LEP and warhead assessments in facilities and equipment for HE large charge pressing, plot-scale synthesis, and formulation systems. LLNL has demonstrated the first-known capability to additively manufacture three-dimensional (3D) HE structures and has demonstrated their ability to detonate. LLNL holds three Records of Invention in HE additive manufacturing technology.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
LLNL is responsible for qualifying insensitive high explosives (IHE) for assigned U.S. stockpile systems. HE processing capabilities require modernization for LLNL to meet programmatic demands for additional prototyping of warhead HE systems and support RDT&E capacities and throughputs. Infrastructure supporting HE pressing and machining capabilities needs continued condition assessment and recapitalization.	DOE/NNSA is investing in the High Explosives Applications Facility and Site 300 infrastructure through a 5-year program that addresses short- and long-term facility recapitalization for mission objectives. LLNL is currently implementing capability-based investments and minor construction project investments in scaled HE synthesis and large charge pressing capabilities.	Establishment of a Production Enclave focused on joint material development and handling with production agencies to deliver increased lot acceptance and improved first principles modeling with the goal of enhancing performance and safety predictions with less experimental verification.

High Performance Computing		
LLNL drives the Nation's ability to field premier computing platforms. Multi-laboratory collaborations have been developed to achieve exascale-class computing. LLNL HPC support includes operating systems, architecture, and code development.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
LLNL must anticipate, develop, and deploy new computing architectures to support integrated design codes and weapons design and certification needs.	Planning for the exascale paradigm includes architecture, code-developing environments, operating systems, and physical infrastructure. DOE/NNSA plans to focus investment on the utility backbone of the laboratory, including electrical and water systems. Investment in computing facilities will support deployment of the first U.S. exascale-class computing platform.	Partner with industry and academia to develop new hardware technologies.

High Energy Density Physics		
LLNL designs and executes experiments to advance fundamental understanding of HED regimes, the state of matter a weapon is in when the majority of yield is produced. These experiments advance and validate computational tools implemented to design and certify the stockpile. HED experiments at the National Ignition Facility produce data on high-Z material properties, burn physics, radiation transport, radiation hydrodynamics, and a mix of other topics.		
Challenges	*Strategies*	
	Current Strategy Being Implemented	***Future Strategies Needed***
Experimental infrastructure is aging and is subject to increased usage and increased operational tempo. Although the United States has pioneered HED physics, nations around the world are advancing their own experimental capabilities that may soon be competitive with the previously unique capabilities of the United States.	LLNL has developed a 3-year investment plan to consolidate target fabrication equipment for efficiency while supporting more than 400 shots per year at the National Ignition Facility. Infrastructure recapitalization and modernization are essential to realizing this plan.	LLNL must develop an enduring infrastructure capability base in target fabrication and be prepared to manage increased facility usage.

<table>
<tr><th colspan="3">Additive Manufacturing</th></tr>
<tr><td colspan="3">LLNL must anticipate and develop appropriate materials and manufacturing processes to provide responsive options to meet design and production requirements. We have sought to drive advancements in manufacturing through fundamental understanding of the underlying science, leading to improvement of these processes and invention and development of new processes. We have sought to drive advancements in manufacturing to rapidly create and qualify novel materials, structures, and advanced manufacturing methods to meet the current and future needs for the stockpile and national security. Underlying this priority is the need to predictively understand materials processing, structure, property, and performance relationships using a combination of computational and experimental tools. Our efforts extend, build on, and integrate foundational capabilities at LLNL for validated predictive simulations, tailored materials synthesis, characterization and testing, design optimization, and precision and additive manufacturing.</td></tr>
<tr><th rowspan="2">Challenges</th><th colspan="2">Strategies</th></tr>
<tr><th>Current Strategy Being Implemented</th><th>Future Strategies Needed</th></tr>
<tr><td>LLNL manufacturing facilities and infrastructure are dispersed and aging. Maturation of additive and advanced manufacturing technologies requires collaboration between the design, engineering, materials, and production communities.

Success also requires effective integration of capabilities in feedstocks, design, characterization and testing, and predictive simulations and performance modeling.</td><td>Exploit industry/academic/laboratory collaborations at the Advanced Manufacturing Laboratory.

Execute existing infrastructure investment plans, including the following:
– Complete and exploit capabilities housed in the Applied Materials Engineering Facilities.
– Complete construction and make operational the Polymer Production Enclave.
– Complete renovations to the LLNL Manufacturing Complex, Non-Destructive Evaluation facilities, and Mechanics of Materials facilities.</td><td>Realize infrastructure investments to build on existing capabilities, including facilities that integrate new feedstocks and manufacturing processes with automated processes, in-situ characterization, and advanced data analytics approaches. Such investments include the Stockpile Materials Development Foundry and the Next Generation LEP R&D Component Fabrication Facility. In addition, deepen the collaborative innovation approaches demonstrated in the Polymer Production Enclave by successfully launching additional collaborative Production Enclaves as they are identified and prioritized.</td></tr>
</table>

HE = high explosives
HPC = high performance computing
RDT&E = research, development, test and evaluation

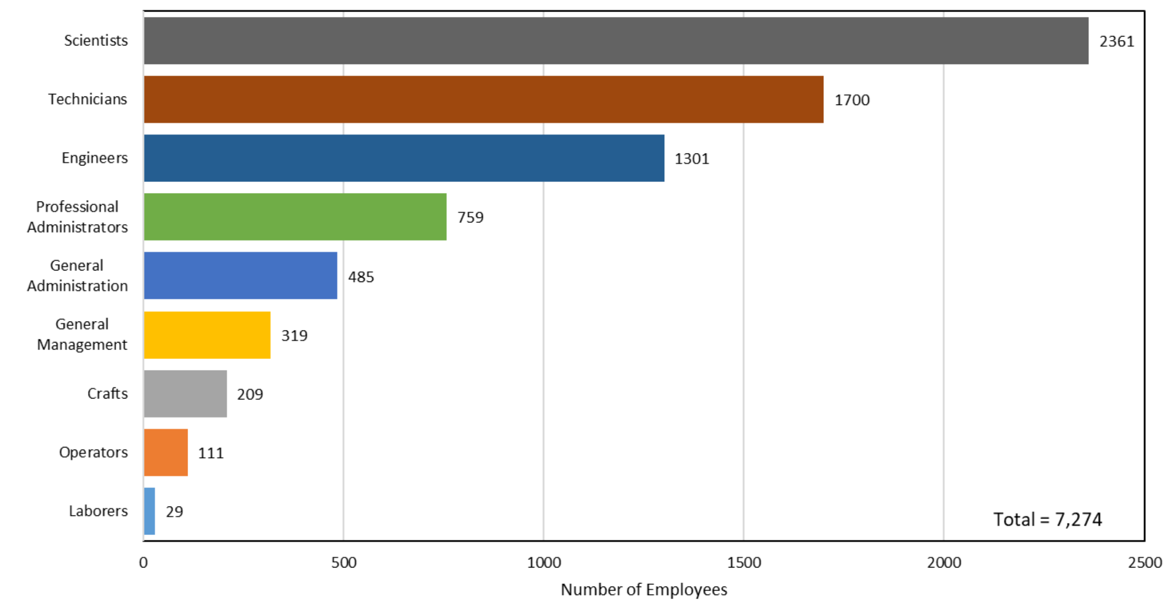
E.2.1.4 Accomplishments

- LLNL completed all deliverables for Cycle 25 of the Annual Assessment Review, including extensive peer review, as part of the Independent Nuclear Weapon Assessment Process. The laboratory also met the requirements for sustaining the W80, B83, W84, and W87 systems.
- LLNL's Hydrodynamic and Subcritical Experiments program delivered data to support certification and assessment activities for LLNL's systems. Specifically, LLNL successfully conducted six hydrodynamic tests in support of stockpile systems, including four experiments for the W80-4 and one each for the B83 and W87.
- LLNL is fully engaged in the W80-4 LEP and the W87-1 Modification Program, working with the plants to bring modern, cost-efficient manufacturing processes into the NNSA complex. Both efforts are on schedule. The W80-4 LEP is about halfway through Phase 6.3 and the W87-1 team is maturing design options in Phase 6.2.
- The Sierra supercomputer brought unprecedented capabilities to NNSA and is providing vital support to stockpile modernization efforts. With the extensive preparatory work done adapting codes to Sierra's revolutionary architecture, the machine has made 3D simulations routine: one 3D inertial confinement fusion simulation was completed in 60 hours rather than 30 days on Sequoia. Preparations are under way for El Capitan, NNSA's first exascale supercomputer.

- The National Ignition Facility performed the highest-pressure plutonium X-ray diffraction experiment to date. Experiments also supported SNL scientists with a series of code-validation tests; tested an important new diagnostic platform and a new hohlraum design; and progressed in identifying and understanding performance limitations to achieving ignition.
- To meet national security and broader national needs, LLNL made significant progress in advanced manufacturing capabilities to develop specialized materials together with processes and systems for product manufacturing and qualification. In FY 2020, LLNL researchers achieved important successes in improving printing speed and product quality. The newly opened Advanced Manufacturing Laboratory at LLNL is working with industry to expand NNSA's capabilities.
- LLNL has combined artificial intelligence and machine learning with HPC for many innovative applications: perfecting 3D printing at the nanoscale; identifying microscopic changes in aging materials; better diagnosing and treating diseases; designing and synthesizing new materials for special applications; detecting early signs of nuclear proliferation; and combining simulations with experimental data to expedite progress in inertial confinement fusion research.
- LLNL applied HPC to accelerate scientific discovery related to the COVID-19 virus; developed rapid, accurate diagnostic technologies; and supported rapid discovery of potential medical countermeasures. Notable successes include early February release of predicted structures of a key COVID-19 viral protein; identification of an initial set of therapeutic antibody sequences; prototype development of a simple ventilator for easy assembly; and update of Lawrence Livermore Microbial Detection Array to detect the virus.
- LLNL completed the Expand Electrical Distribution System line-item project on time and under budget. The upgraded infrastructure has eliminated single points of failure at LLNL and SNL's California site. The expansion now supplies power on the laboratory's east side, adds capability to the Livermore Computing Center, and contributes to increased serviceability and safety of the LLNL high-voltage system.
- LLNL completed construction on the first two of four new buildings that are part of the Applied Materials and Engineering Area Plan. A 100-person office building and a polymers laboratory were completed in FY 2020 to replace capabilities currently housed in an aged facility with seismic risks, high deferred maintenance, and sustained contamination. The Applied Materials and Engineering facilities support the core weapons engineering capabilities required to execute LEPs, stockpile modernization, and annual assessments.

E.2.1.5 Lawrence Livermore National Laboratory Workforce

LLNL has 7,274 employees, with an average age of 47 years and an average of 12 years of service. Approximately 31 percent of LLNL's employees are eligible to retire. Since the end of FY 2018, LLNL hired 1,664 employees and experienced 812 separations, resulting in a net gain of 852. Retirement separations are dispersed throughout many "years of service" groups. Non-retirement voluntary separations were most pronounced among employees with 5 years of service or less. Over the last 10 years, LLNL new hires increased representation of the early-career workforce in the laboratory population. Over the same period, the advanced career population has remained consistent and the mid-career population has slightly increased. LLNL anticipates continued growth over the Future Years Nuclear Security Program (FYNSP) period, especially as the work scope increases for W80-4 LEP and W87-1 Modification Program activities. Workforce demographics are illustrated and discussed in **Figures E–6** through **E–14**.



Notes:

Scientist and engineer Common Occupational Classification System (COCS) counts differ from previously reported numbers due to recategorization.

Figure E–6. LLNL total workforce by Common Occupational Classification System (as of September 30, 2020)

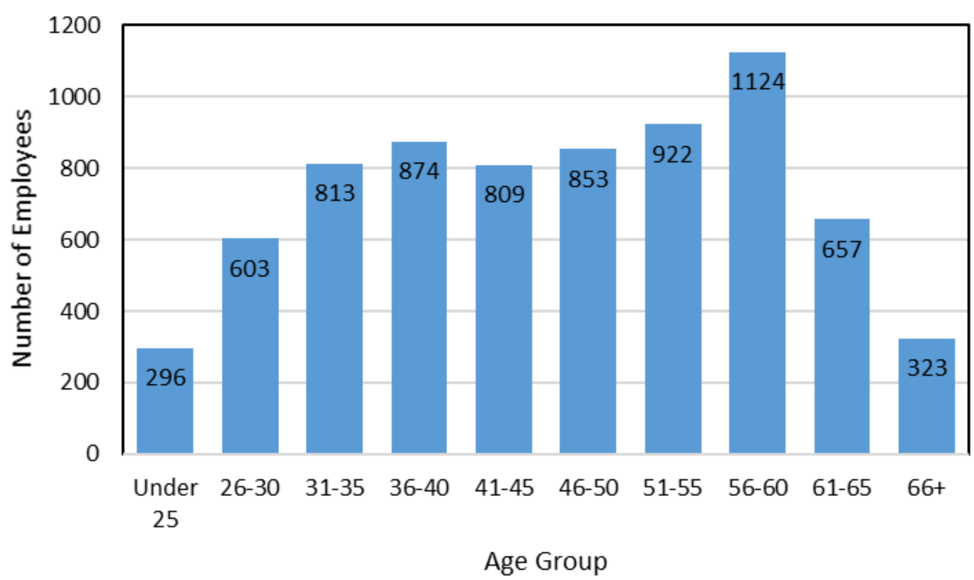
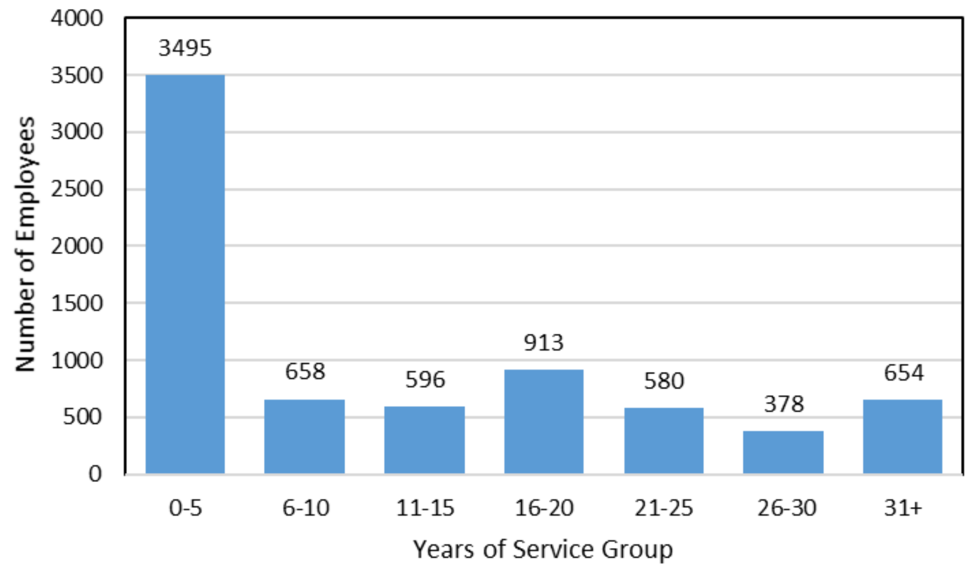


Figure E–7. LLNL workforce distributed by age group (as of September 30, 2020)



Notes:

This graphic demonstrates the continuing pattern of retirements and new hires. In FY 2020, 43 percent of employees had 5 years of service or less, an increase from 38 percent in FY 2019. Additionally, the average years of services was 11.4 in FY 2020, down from 12.2 in FY 2019.

Figure E–8. LLNL workforce distributed by years of service group (as of September 30, 2020)

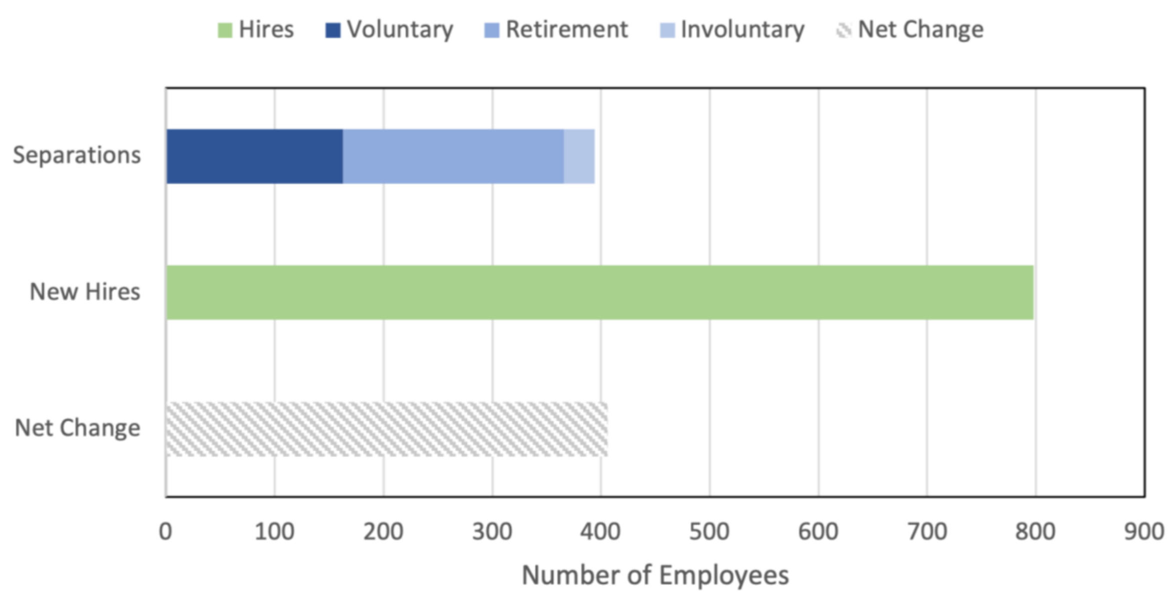


Figure E–9. LLNL net change for fiscal year (as of September 30, 2020)

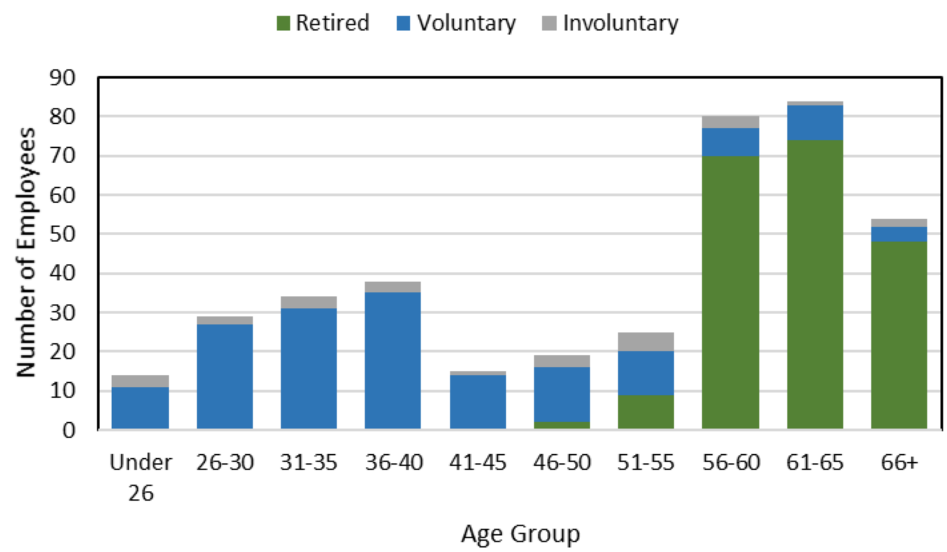
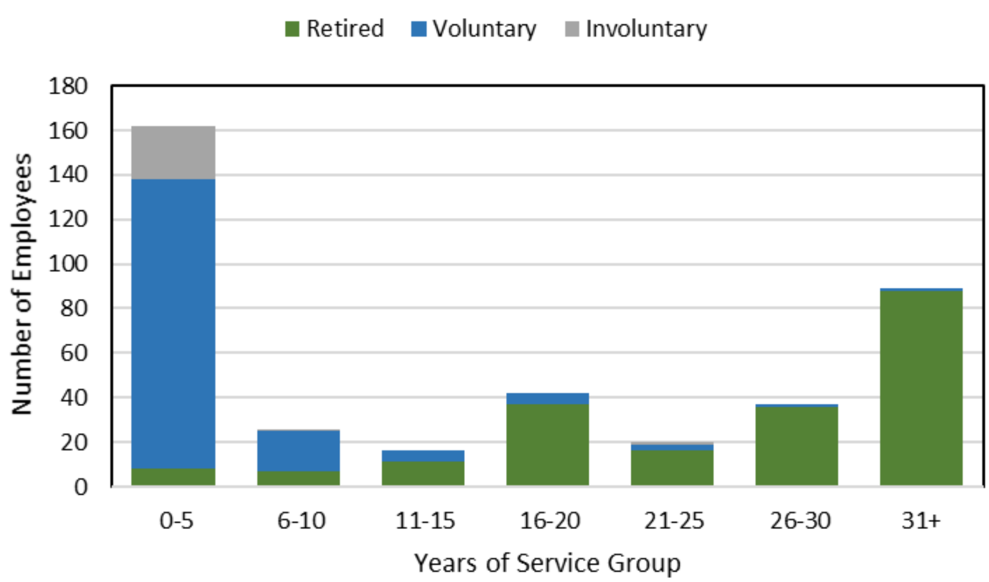


Figure E–10. LLNL employee separations by age group (as of September 30, 2020)

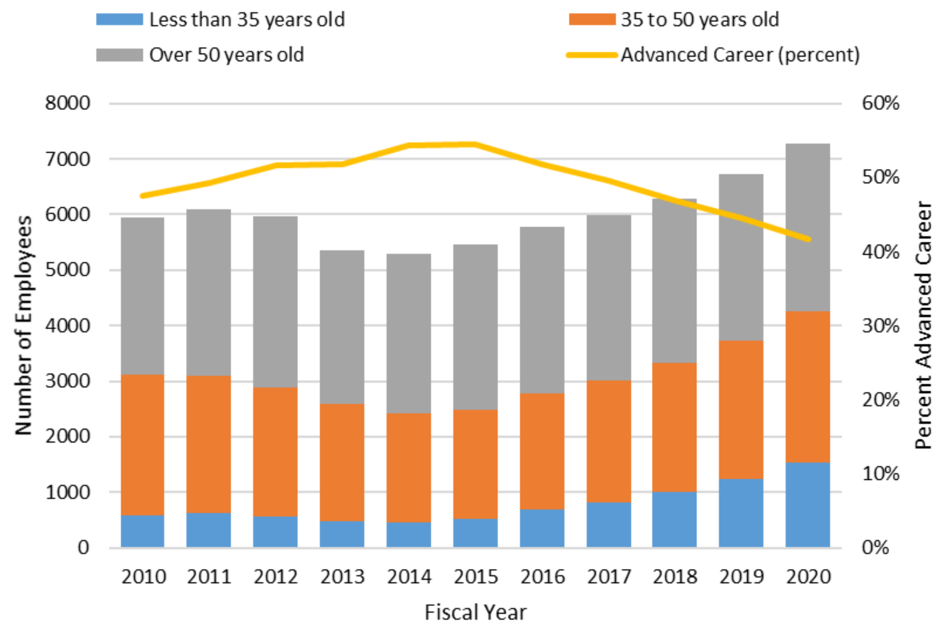


Notes:

LLNL retirements are distributed across all years of service ranges, but retirement is the driving separation cause for employees with greater than 10 years of service. Voluntary separation is the primary driver for employees with 0-10 years of service at LLNL. By far, the largest number of separations occurred among employees with 0-5 years of service. These separations, however, were not exclusive to early-career employees, but were distributed across multiple age ranges.

As discussed in Chapter 7, high rates of turnover among employees in lower years of service ranges is a challenge for developing and honing the skills and knowledge base necessary to execute LLNL's mission. These separations are spread out across a wide range of ages, suggesting that this trend is not entirely driven by generational changes in employment preferences.

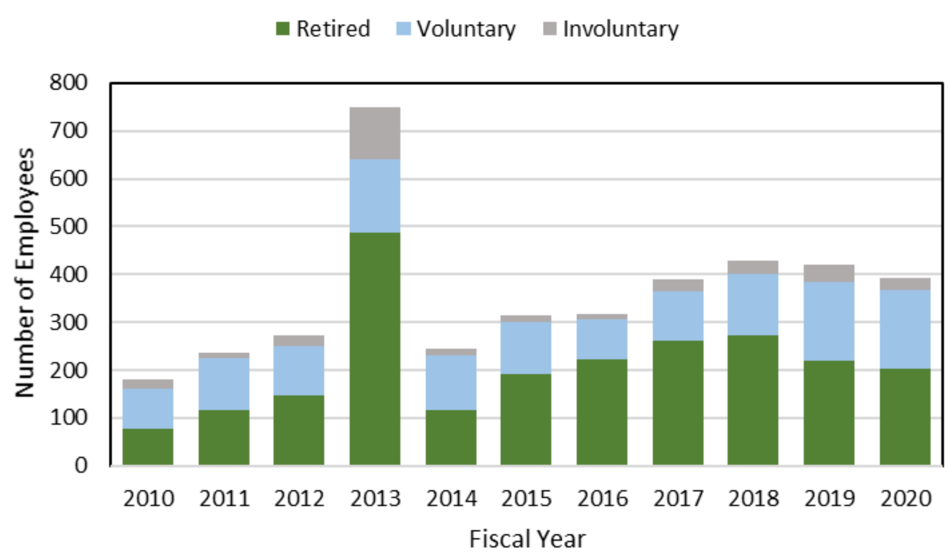
Figure E–11. LLNL employee separation by years of service group (as of September 30, 2020)



Notes:

Recent hiring combined with consistent numbers of retirements have led to increasing proportions of early-participation (less than 35 years old) and mid-participation (35-40 years old) employees among the laboratory population.

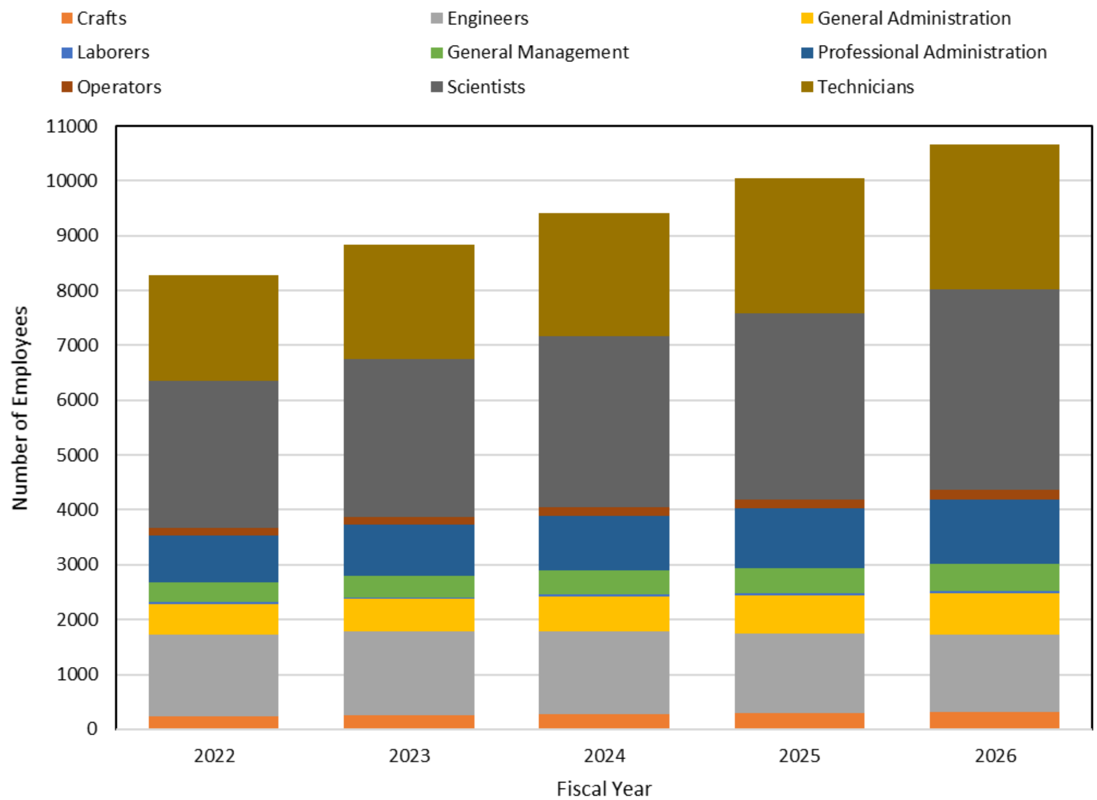
Figure E–12. LLNL workforce participation trends by age category and percent advanced career (as of September 30, 2020)



Notes:

The peak in FY 2013 represents a laboratory budget reduction that resulted in a significant number of early retirements and some layoffs, which are defined as involuntary separations in the chart. In more recent years, involuntary separations have remained low and retirements have decreased. However voluntary separations have increased every year since FY 2016.

Figure E–13. LLNL employee separation trends



Notes:

FY 2022 to FY 2025 numbers are different from previously reported numbers due to a recategorization of scientist and engineer COCS codes. The change considers unconstrained planning headcounts. An increase of engineers in FY 2022 to FY 2024 will be needed to meet modernization program requirements.

Figure E–14. LLNL workforce projection needs by Common Occupational Classification System

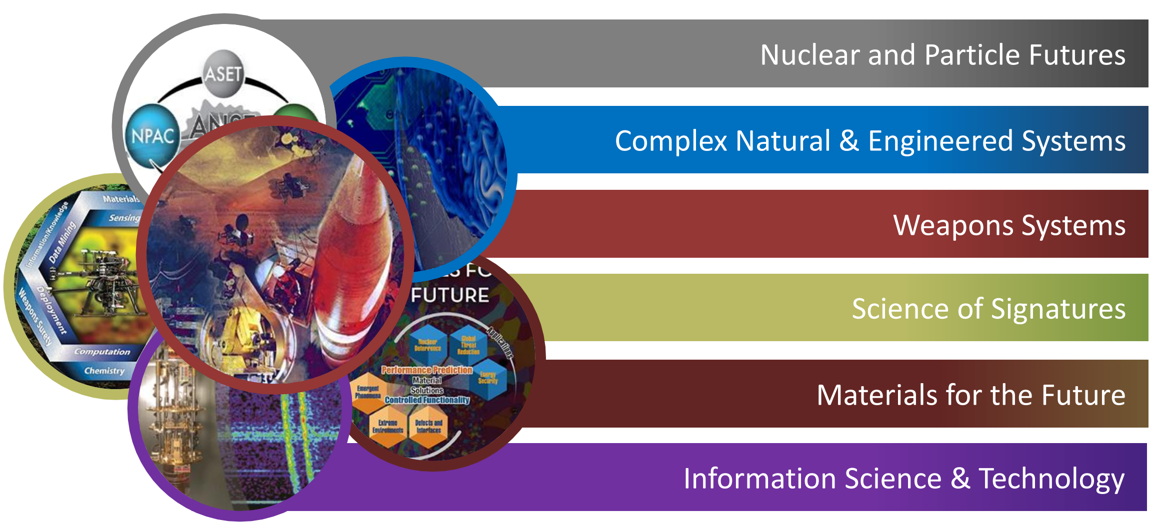
E.2.2 Los Alamos National Laboratory

E.2.2.1 Mission Overview

Los Alamos National Laboratory (LANL), initially known as Project Y, was organized in April 1943 during World War II for the design of nuclear weapons as part of the Manhattan Project. After nearly 80 years, LANL continues its service to the Nation through applications of scientific and engineering solutions to solve national and global security challenges. The laboratory relies on its skilled workforce, a complex portfolio of facilities, specialized equipment, and disciplined business practices to meet its missions and deliver solutions. These capabilities are exercised through four strategic objectives: nuclear security; science, technology and engineering; mission operations; and community relations.

LANL's Weapons Activities represent foundational elements of the DOE/NNSA Stockpile Stewardship and Management Plan (SSMP). LANL designed five of the seven types of nuclear warheads in the deployed stockpile and is currently responsible for the continued safety, security, and effectiveness of the B61 gravity bomb, the W76 and W88 submarine-launched intercontinental ballistic missile warheads, and the W78 intercontinental ballistic missile warhead. LANL is leading the B61-12 LEP and the W88 Alteration (Alt) 370 Program. LANL's production agency responsibility includes the manufacturing of pits, detonators, detonator cables and radioisotope thermoelectric generators (RTGs). LANL weapons programs provide design expertise, production expertise, and tools including: advanced experimental capabilities; modeling and simulation; processing, prototyping and testing of weapons materials; and components and warheads assemblies (without nuclear materials).

LANL's national security mission requires a multidisciplinary approach to solve some of the Nation's toughest science and engineering challenges. In addition to direct stockpile stewardship activities, the laboratory contributes to overcoming national security and economic challenges, including nuclear nonproliferation and counterterrorism, medicine and health sciences, energy, and advanced computation. LANL is also involved in strategic partnership and collaborations with other agencies. Science, technology, and engineering (ST&E) capabilities consist of a diverse portfolio and execute laboratory missions through six scientific pillars.



Los Alamos science, technology, and engineering capability pillars

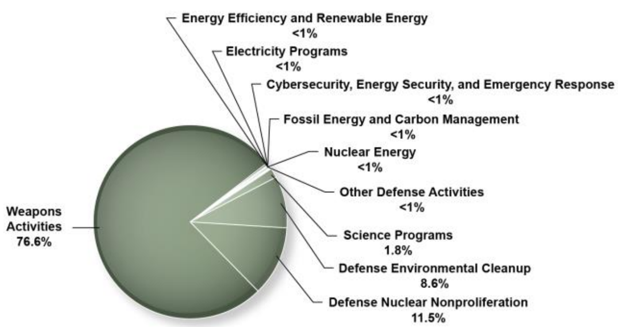
LANL's leadership assembles a broad spectrum of operational expertise, resources, and processes to enable the readiness and excellence of the stockpile stewardship and ST&E missions. These operational functions address LANL's broad capabilities in integration planning and execution, safety, security, efficiency, accountability, waste, business practices, workforce management/development, and community relations and service.

LANL operates a complex portfolio of nuclear, HE, and specialized facilities and physical infrastructure. Additional descriptions of laboratory assets and capabilities, and their current state are presented below.

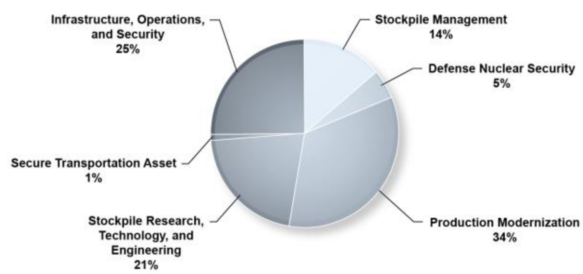
- Location: Los Alamos, New Mexico
- Total Employees: 9,109 (as of the end of FY 2020)
- Type: Multi-program national security laboratory
- Website: www.lanl.gov
- Contract Operator: Triad National Security, LLC, (Triad) is made up of three members: Battelle Memorial Institute, Texas A&M University, and the University of California
- Responsible Field Office: Los Alamos Field Office

E.2.2.2 Funding

FY 2022 request – site funding by source
(total LANL FY 2022 request = $3,386 million)



LANL split for the FY 2022 Weapons Activities President's Budget Request *($2,976 million)*

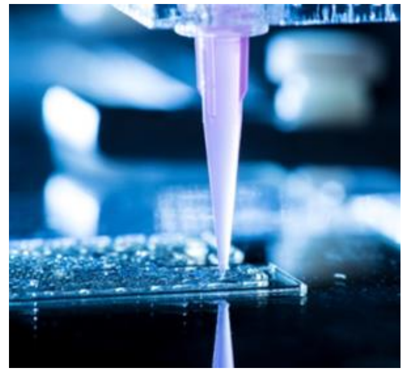


E.2.2.3 Site Capabilities

Dual-Axis Radiographic Hydrodynamic Test Facility Hydrodynamic experiment device in confinement vessel.

LANL is the lead design agency for the B61, W76, W78, and W88 systems and is also the production agency for pit, detonator, detonator cable, and RTGs. LANL contributes to nuclear design and physics capabilities in the nuclear security enterprise and is the Nation's Plutonium Center of Excellence for Research and Development. Core competencies at LANL include weapons physics design and analysis; weapons engineering and energetics, design, analysis, testing, and integration; stockpile component production and surveillance for pits, detonators, and RTGs; HED physics; materials science and engineering; and HPC.

LANL operates a complex set of HE, radiological, nuclear, and other specialized scientific facilities. Several weapons mission critical facilities include: the Nicholas Metropolis Center for Modeling and Simulation, the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT), the National Explosives and Engineering Weapons Campus, the Uranium R&D facility (Sigma), and Waste Handling Facilities. LANL operates several DOE/NNSA flagship user facilities, including the Los Alamos Neutron Science Center (LANSCE), Center for Integrated Nanotechnologies, and the National High Magnetic Field Laboratory.



Additive Manufacturing approach to advance stockpile production.

LANL's core capabilities and their associated challenges and strategies are described in **Table E–2**. Additional information on Plutonium capability and LANL 30 pits per year (ppy) plan is also presented below.

Table E–2. Los Alamos National Laboratory capabilities

Weapons Physics Design and Analysis		
LANL performs integrated experiments and simulations to enable design and assessment of the nuclear explosives package for both enduring and future weapons systems. Design and assessment capabilities encompass hydrodynamic and subcritical experiments; proton radiography, materials, and nuclear science experiments; HPC; HE RDT&E; weapons engineering, surety, radiography, and assembly; and accelerator technology.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Aging in weapons materials and components; an aging workforce with specialized weapons knowledge and experiments capabilities, lack of programmatic needs to transition to the next generation of designers and engineers; and degrading design and certification infrastructure.	Current warhead modernization activities provide a near-term opportunity to reinvest in current capabilities and exercise the workforce. LANL is coordinating with DOE/NNSA to address aging enduring physical infrastructure and modernize specialized capabilities such as DARHT, LANSCE, Sigma, HPC, HE, and weapons engineering facilities.	Continue coordination with DOE/NNSA. Several mission-critical facilities will need replacement, with planning required in advance. See Chapter 7 for enterprise workforce strategies.
Plutonium (Special Nuclear Materials Handling, Packaging, and Processing)		
The plutonium core capability consists of plutonium production and process R&D, manufacturing, and radioactive waste disposition. LANL provides the only fully functioning plutonium facility for R&D and the only pit manufacturing capability within the nuclear security enterprise. LANL is a consolidated Center of Excellence for plutonium R&D and manufacturing activities.		
Challenges	***Strategies***	
Plutonium operations require increased capacity and modernized infrastructure.	***Current Strategy Being Implemented***	***Future Strategies Needed***
	LANL's plutonium strategy has been adopted by DOE/NNSA and endorsed by the Nuclear Weapons Council. The Chemistry and Metallurgy Research facility is continuing a small set of operations, with the goal of ceasing all programmatic work in anticipation of transferring these capabilities to the Radiological Laboratory Utility Office Building and the Plutonium Facility. Continued investments are being planned through the LAP4 line item project.	Continue implementation of current plutonium strategy.

High Performance Computing (HPC)		
The HPC core capability provides the supercomputers, facilities, and computer science that enable simulations of weapons performance for all aspects of stockpile stewardship. HPC enables scientists to routinely use multi-dimensional simulations to increase understanding of complex physics, as well as improve confidence in the predictive capability for stockpile stewardship for LEPs and significant finding investigations (SFIs). The Advanced Simulation and Computing Program (ASC) leverages both the Advanced Technology System (ATS) and Commodity Technology System for this work.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Near-term challenges, approximately 2026, include physical infrastructure modernization to accommodate the next-generation supercomputer (ATS-5) at LANL.	Planning is ongoing for both the near-term and long-term HPC infrastructure. Trinity (ATS-1) will be replaced in FY 2022 by Crossroads, a next-generation supercomputer to be sited at LANL (ATS-3).	Insertion of ATS-5 and the supporting electrical and cooling infrastructure.

Weapons Engineering and Energetics		
Weapons engineering and HE capabilities provide the materials, components, and assemblies for weapons work. This capability includes the experimental testing required to assess the current state of the stockpile; surveil the current stockpile and address SFIs; and provide qualified materials and HE for LEP and new options. Additional functions include modeling weapon performance, safety, engineering, and aging responses throughout their operating conditions and life cycle.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
The primary challenge is aging physical infrastructure. A large number of the facilities were built in the 1950s and were optimized for the fabrication and engineering testing capabilities and processes of that time.	Several line item investments for consolidation and replacement of facilities are proposed over the next decade, with the highest priority being the Energetic Materials Characterization. Continued recapitalization investments will ensure the long-term viability of enduring facilities.	Continue coordination with DOE/NNSA. Several mission-critical facilities will need replacement, and planning will be required in advance.

Hydrodynamic and Subcritical Experiments		
Hydrodynamic and subcritical experimental capabilities supply data to weapon physicists and engineers to inform the annual assessment process and certification decisions, advance nuclear weapon science, refine weapon computational models, develop emergency response tools, assess foreign and terrorist designs, gauge technological surprise, and develop the skills and experience of weapon designers and engineers.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
The hydrodynamic facilities and infrastructure are aging. Another challenge is the lack of ability to study late-implosion dynamics of subcritical experiments with penetrating radiography and reactivity measurements. Finally, procurement of the confinement vessels used in both types of experiments has struggled to meet experimental needs.	The Enhanced Capabilities for Subcritical Experiments project will deliver additional advanced diagnostics both at LANL and the Nevada National Security Site in the mid-2020s. Strategic investments are being planned and implemented to recapitalize DARHT, procure additional vessels, and modernize DARHT Axis I and II.	Continued coordination required with DOE/NNSA. Partnerships with laboratories and universities to reinforce development of future capabilities.

Neutron Science – Los Alamos Neutron Science Center (LANSCE)		
The protons and neutrons produced by the LANSCE accelerator deliver essential material science, nuclear physics, and dynamic radiography data needed for assessment of the current stockpile, qualification of advanced manufacturing techniques, certification of the future stockpile, and threat reduction. LANSCE data are used for SFI resolution, support of LEP, ALT, and MOD certification, and the continued development of advanced material models used to advance our predictive capabilities.		
Challenges	***Strategies***	
The LANSCE accelerator was commissioned in 1972, and some components are starting to experience end-of-life failures. Deferred maintenance has reduced the reliability of other components.	***Current Strategy Being Implemented***	***Future Strategies Needed***
	A modernization initiative, including the LANSCE Modernization Project (LAMP) line-item capital acquisition, is being considered. LAMP would replace obsolete elements at the front of the LANSCE accelerator. Continued recapitalization through Infrastructure and Operations investments are addressing facility condition issues in a risk-based manner.	Next generation facilities, infrastructure, and equipment will be required.

Uranium, Beryllium, Organics, and Inorganics		
Outside of plutonium, high explosives, and tritium capabilities, the Sigma capability provides the rest of the materials and production science expertise for the weapons nuclear explosive package. These include facilities, equipment, and expertise to work with uranium, beryllium, and most of the organic and inorganic materials in the stockpile. The work provides low- to mid-TRL research, development, and manufacturing processes that can subsequently be turned over to the production agencies, as well as the capability to produce test hardware for qualification and certification. These capabilities further provide both a test bed for new materials and emerging technologies, as well as an understanding of the materials' properties and their aging and performance behaviors. Additional capabilities include surveillance activity for legacy weapons systems and manufacturing science and production support at Y-12 and Kansas City plants.		
Challenges	***Strategies***	
The Sigma complex, including its facilities, infrastructure and materials processing equipment, is aging. The late 1950's facility and much of the equipment which dates back to the 1950s (or earlier) is reaching an age where facility/equipment downtime is an ongoing struggle and is negatively impacting Sigma's ability to meet many milestones and related deliverables because of the frequency of equipment and facility down-time.	***Current Strategy Being Implemented***	***Future Strategies Needed***
	Investments that include facility revitalization and materials processing equipment are proposed within the next 5-10 years to decrease risk to high-impact, high-visibility deliverables and delivery of hardware needed for the LANL Annual Certification Program. Continued recapitalization investments will further reduce the risk to these programs.	Replacement facility for Sigma complex will be needed.

Alt = alteration
HPC = high performance computing
RDT&E = research, development, test and evaluation
TRL = technology readiness level

DARHT = Dual-Axis Radiographic Hydrodynamic Test
LANSCE = Los Alamos Neutron Science Center
Sigma = Uranium R&D Facility
LAP4 = Los Alamos Plutonium Pit Production Project

Plutonium Capability and 30 ppy Plan – In the next 5 years, LANL has a primary responsibility to modernize the Plutonium Center of Excellence and to deliver a 30 ppy capacity. Implementation of that plan has started. LANL has an experienced and skilled workforce, high-hazard nuclear facilities and associated infrastructure, and unique plutonium processing, fabrication, and experimental capabilities.

In May 2018, DOE/NNSA directed LANL to deliver a minimum of 30 War Reserve ppy at an annual confidence level of 90 percent by 2026 to support the broader goal of meeting the military requirement to produce no fewer than 80 War Reserve ppy. Expanding pit production to this level will require significant resources. The plutonium missions at LANL will be integrated to successfully execute this expansion while still delivering on the other missions. To achieve national goals, LANL's Plutonium Center of Excellence will recruit, hire, train, and retain a workforce to:

- Produce plutonium pits for the nuclear weapons stockpile
- Produce RTGs for the nuclear weapons stockpile
- Produce plutonium-238 heat sources for use by NASA in space exploration
- Evaluate pits returned from the nuclear weapons stockpile to support annual assessments and inform future pit designs
- Produce plutonium components for assembly into devices used in subcritical experiments
- Perform fundamental science on plutonium aging and material properties
- Process plutonium into forms suitable for disposition to support nonproliferation goals
- Recover americium for the DOE Office of Science
- Maintain nuclear and hazardous facilities and the associated utilities and infrastructure
- Manage environmental protection, safety, quality, and security programs and requirements
- Manage the disposition of waste onsite and its shipment off site
- Provide business, IT, and other support services to achieve the required plutonium mission

LANL performed a series of staffing analyses in FY 2019 that identified the staffing required for plutonium missions. The program staff at LANL will need to increase by approximately 1,700 FTEs (full-time equivalent positions) in the next 4-5 years to enable all plutonium missions to be successful and to deliver a minimum of 30 ppy starting in 2026. Indirect-funded staffing may increase by an additional 1,300 FTEs. Indirect-funded functions include human resources, information technology (IT), business services, emergency management, procurement, legal counsel, finance, and accounting. Increases in indirect-funded FTEs are driven by site-wide increases in staffing, facility footprint, and scope for the plutonium enterprise.

More than half of the planned pit production related staffing is required to support reliable facility operations, maintenance, waste operations, and support functions. These functions must be reliably staffed to operate and maintain LANL's plutonium enterprise and to execute the program of record associated with all plutonium missions. LANL is pivoting to 24/7 operations for PF-4 to deconflict maintenance, construction, and other facility support functions from plutonium missions' operations. Facility operations, maintenance, waste operations, and support functions must be reliably staffed to support all plutonium missions regardless of increases in scope for any one mission.

LANL will need to hire a large interim workforce to complete the many infrastructure investments to support the plutonium enterprise. As planning for infrastructure investments is refined, the associated staffing will be estimated using an integrated resource-loaded schedule.

E.2.2.4 Accomplishments

Notable FY 2020 achievements include:

Stockpile Assessments, Design and Development

- LANL met all statutorily required deliverables for the annual assessment reporting process. Specifically:
  - Annual assessment reports for the B61, W76, W78, and W88 were distributed in July 2020.
  - The Director's Red Team and LLNL's Independent Nuclear Weapons Assessment Teams delivered briefings in August 2020.
  - The Director's annual assessment letter was signed out on September 17, 2020.
- LANL supported the B61-12 limited life component (LLC) exchanges and weapon and component deliveries to the Department of Defense (DoD) and ensured an adequate active stockpile by dispositioning several unsatisfactory reports. Following on the successful FY 2019 effort to design and certify the W76-2, the system has completed production; all three W76 modifications are in the maintenance phase. The W78 is also in the maintenance phase. Rebuild and maintenance activities for the W76-0, W76-1, W76-2, and the W78 were fully supported throughout FY 2020.
- The Weapons Program continues successful execution of the W88 Alt 370 Program, with first production unit achieved in the fourth quarter of FY 2021. Delays in the W88 Alt 370 caused by issues with base metal electrode capacitors impacted the logistics for LLC exchanges for the W88 Program. New LANL LLC product definition changes were developed and implemented in 3 months to maintain the active stockpile numbers.
- LANL is managing additional scope in support of the W88 Alt 940.
- LANL completed support activities for the W80-4 LEP and the W87-1 Modification Program.
- The Weapons Program contributed to trade studies for the W93.
- LANL completed the first 3D, end-to-end simulation of a warhead encountering radiation and blast hostile environments.
- LANL conducted a joint centrifuge test to evaluate a new Stockpile Responsiveness Program design and new surety technologies at high-g loadings. This was the first developmental test of its kind and included radiographic imaging and the successful performance of new surety technologies under these environments.
- Material properties were measured for newly cast, 10 year, and 30 year naturally aged plutonium. These data are informing assessments of the effects of plutonium aging on weapons performance.
- LANL executed two series of experiments to support the qualification of the direct cast depleted uranium manufacturing process for the future stockpile.
- LANL executed three hubcap experiments to support qualification of the direct-cast manufacturing method for depleted uranium and the related FY 2021 Stewardship Capability Delivery Schedule L1 milestone. These experiments compare newly manufactured material with historic material.
- LANL analyzed static Neutron-Diagnosed Subcritical Experiment (NDSE) tests with special nuclear material (SNM) at the Nevada National Security Site to show that the subcriticality of a system can be extracted with only a ~0.3 percent uncertainty.

- LANL provided performance qualification data on PBX 9502 lots supporting the B61-12 LEP, as well as PBX 9012 and PBX 9701, to inform HE reactive burn models for the current and future stockpile.
- LANL completed design, prototype assembly and alignment of Variable Field of View DARHT downstream transport regions of the accelerator and final assembly of the entire Variable Field of View system on the DARHT firing point, as part of the post-Weather Enclosure DARHT restoration.
- LANL completed 41 transuranic waste shipments to the Waste Isolation Pilot Plant, containing 1,233 waste containers; as of August 2020, the overall Triad transuranic inventory is below 1,500 containers (a multi-year low). Triad also moved 1,390 containers out of Technical Area (TA-55) to exceed the milestone for FY 2020.
- Construction of the Exascale Class Computer Cooling Equipment (EC3E) Project was completed ahead of schedule and under budget. EC3E will support the next generation of supercomputing at the laboratory for the Stockpile Stewardship Program, including Crossroads and other HPC platforms.
- LANL completed two DOE/NNSA recapitalization projects: the DARHT facility weather enclosure and the Explosive Crystal Laboratory.
- As part of its knowledge transfer effort, LANL provided a range of services and tools for the workforce. The New Employee Training Program has implemented an in-depth onboarding program for new employees to increase retention and reduce time to job readiness. The National Security Research Center completed six new digitizing laboratories to speed up digitization of vast collections of weapons program material, including microfilm, microfiche, motion picture film and other at-risk media types.

Weapons Production

- LANL completed three pit builds; matured development activities as part of Process Prove-In; significantly increased the rate and yield of metal production and castings; and added a second shift in Plutonium Facility (PF-4) to enable continued execution of 24 construction and equipment-installation projects despite COVID-19 operational challenges.
- LANL partnered with LLNL to produce a new baseline for pit production first production units, resulting in a schedule where Qualification Evaluation Release will be completed at the end of FY 2022, allowing a full 12 months to build and diamond stamp the first production unit pit. This schedule optimizes engineering evaluations and mitigates risks to successful completion of final certification tests.
- In partnership with KCNSC, LANL improved the production yield of the 1E40 detonator cable assembly and helped with production of numerous W88 Alt 940 components.
- LANL delivered the Electronic Module Sub-Assembly components and all 12 development cables and five different types of cables to SNL; four of the cable types were fully manufactured at LANL.
- LANL partnered with SRS to support the 50 ppy planning effort and expertise to implement NNSA's pit production plan.
- LANL completed a pilot training/education program for weapons production in FY 2020. Key elements of this program include:

- Launching the New Employee Training Academy to provide orientation and training for Glovebox/Fissionable Material Handlers. The first 30-person pilot cohort and the majority of a second cohort have successfully advanced through this comprehensive program. The third cohort started and will be expanded to Savannah River National Laboratory operators.
- Securing a Memorandum of Agreement with Savannah River National Laboratory and SRS NNSA Capital Projects on July 22, 2020, to strengthen R&D capabilities and establish collaborative interactions for engineering staff between LANL Plutonium and SRS programs.
- Establishing and expanding training and classroom spaces for new pit production operators and engineers. These include refurbishing the TA-35 Trident facility, renovating and repurposing 30,000 square feet of leased space in Los Alamos County.
- Developing a new certificate and Associate Degree program with the University of New Mexico-Los Alamos. The program received accreditation by the State Higher Education Department and will provide science, operations, and business education on all aspects of working in modern nuclear materials handling and processing facilities.

Science, Technology and Engineering

- The Alliance for Computing at Extreme Scale, a partnership between LANL and SNL, announced the contract award to deliver Crossroads.
- LANL was chosen to serve as a lead partner in the Quantum Science Center and will lead one of three DOE major research thrusts to develop quantum technologies as part of the $115 million Quantum Science Center.
- A new fast-forward simulation algorithm was developed for current and near-term future quantum computers, opening the way for applications to run past strict time limits that restrict many quantum calculations.
- LANL designed several scientific instruments, electronic components, and the radioisotope fuel pellets for NASA's Perseverance Mars rover.
- LANL successfully applied unique multi-variable modeling approaches to develop national and global COVID-19 models. A number of these models have been developed and delivered to local, state, and Federal entities to inform strategic decision making. For example, LANL provided weekly updates to the Office of the Governor of New Mexico. In addition, LANL provided the Air Force Air Combat Command with pandemic statistics for almost 30 specific geographic areas that impact its mission. Finally, a number of quick response modeling efforts were completed to support the Defense Threat Reduction Agency and other national security agencies.

Operations and Community Relations

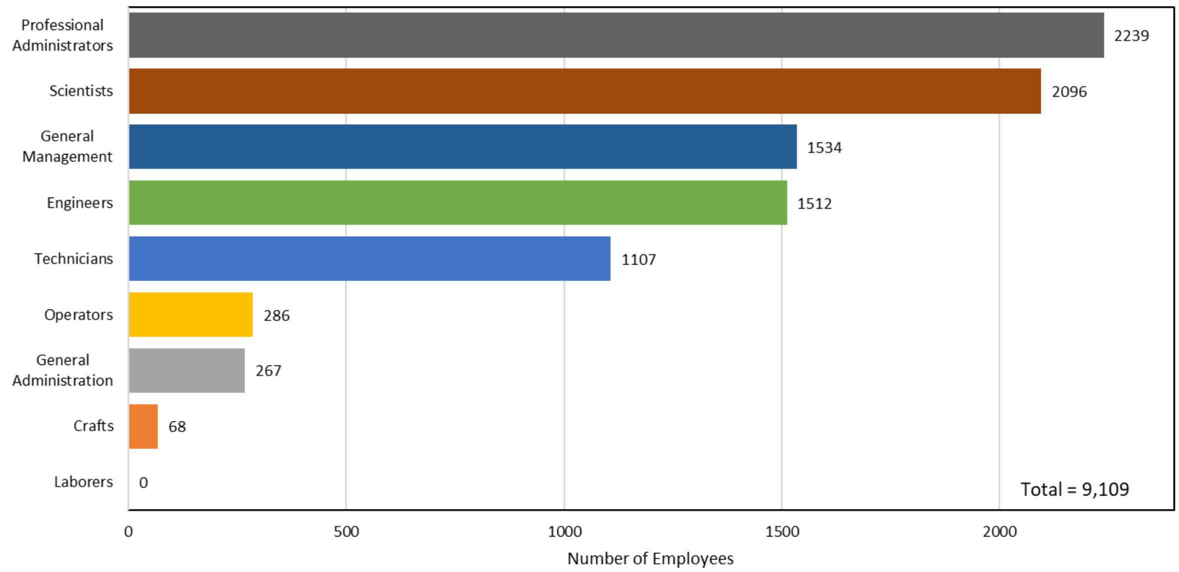
- LANL collaborated closely with the community and local stakeholders to establish broker pipeline programs with local institutions to provide the local training programs and workforce pipeline initiatives for machinists, engineering, and craft trades. TA-55 has benefited from a successful radiological control technician (RCT) training program to significantly mitigate the RCT shortage and enable smooth operation in PF-4. Triad has enacted additional workforce pipeline initiatives to meet the workforce needs for the 30-ppy deliverable and other mission needs.
- In response to COVID-19 challenges, LANL's Continuity of Operations program strengthened the emergency response function (already in place) and established regular accountability drills. LANL leveraged a task force and infectious disease capabilities to create protocols for safe operations; redirected some of its R&D capabilities to help understand the virus and its mutations,

treatments, and vaccine development; and used its biological expertise to stand up testing for the workforce. The Laboratory applied lessons learned from the crisis to reinforce aspects of culture change. Other responses include adding the back shift at PF-4, implementing a new approach to telework, and modifying requirements (where essential mission needed) to improve operational flexibility.

- LANL successfully created a COVID-19 testing capability for employees and new modeling capabilities that the State of New Mexico relies on for forecasting. This partnership also enabled LANL to broker pipeline programs with local institutions.
- Triad initiated a telework pilot to explore possible benefit to the government of long-term telework. This pilot will also examine the potential of evolving LANL's infrastructure to support turnaround or hub spaces. This effort has already provided much-needed space for high-priority mission activities and is considering establishing a footprint off the laboratory via an active Request for Information. To date, the pilot has already enabled transfer of certain office buildings to Weapons Production, immediately providing the program with space for an additional 285 workstations.
- Triad continued progress addressing the RCT shortage, hiring 57 new RCTs in FY 2020. Several candidates came from multiple established pipelines, including – LANL Human Resources targeting military candidates, the Northern New Mexico College program, and outreach to other Associate of Applied Science programs. In addition, new RCT retention strategies are paying off, decreasing projected attrition rates from 30 percent to less than 15 percent.
- LANL Human Resources successfully completed several initiatives, including its 2-year compensation project, which updated all job descriptions, matched them to market and internal alignment, and updated the salary bands for those unaligned positions, enabling better recruitment and retention of employees; a new talent acquisition strategy proactively addressing strategic needs in scientific areas; an offsite onboarding process allowing new hires to integrate more quickly to the Laboratory; a cloud-based Learning Management System that provides enhanced data security and is fully compliant with Federal Risk and Authorization Management Program requirements, improving cost predictability and reducing risk and liability; and introduction of multiple online training courses.

E.2.2.5 Los Alamos National Laboratory Workforce

LANL had 9,109 employees at the end of FY 2020, with an average age of 45 years and an average of 11 years of service. Approximately 40 percent of LANL's employees are eligible to retire. Since the end of FY 2018, LANL has hired 2,358 employees and experienced 1,204 separations, resulting in a net gain of 1,154 employees. More than half of LANL's employee separations came through retirements, while the remainder were mostly voluntary separations among those with 15 years of service or less. The number of early-career employees has been growing steadily the past few years, and mid-career employees have experienced a recent uptick after years of decline. Staffing planning for NNSA programmatic drivers indicates that, over the next 5 years, hiring is expected to accommodate workforce growth (e.g., for pit production) and anticipated attrition. Workforce demographics are illustrated and discussed in **Figures E–15** through **E–23**.

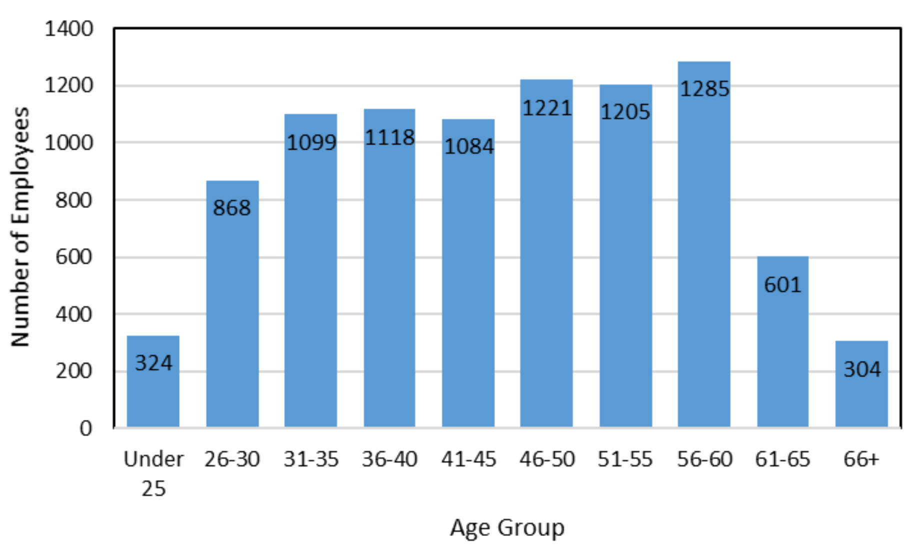


Notes:

LANL continues to see growth in the total headcount to meet mission demands. Overall, LANL's FY 2020 employee site count increased by 7.5 percent from FY 2019. Growth was seen in most categories, but the largest increases were in engineers, general management, and technicians.

Data includes only regular employees. LANL's Common Occupational Classification System-coded laborers and most of its craft persons are Union Craft employees who are not considered "permanent career employees," and so were not included in this data. There are over 1,000 craft persons on site.

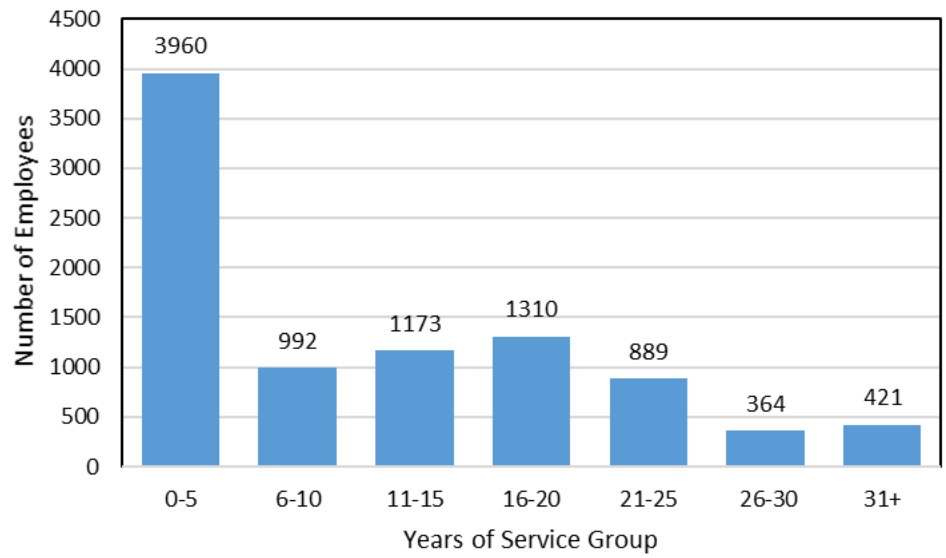
Figure E–15. LANL total workforce by Common Occupational Classification System (as of September 30, 2020)



Notes:

LANL continues to concentrate on attracting and retaining young, new talent to fill the pipeline for retiring individuals. Consequently, the average age has continued to drop as has the percent eligible to retire decreases.

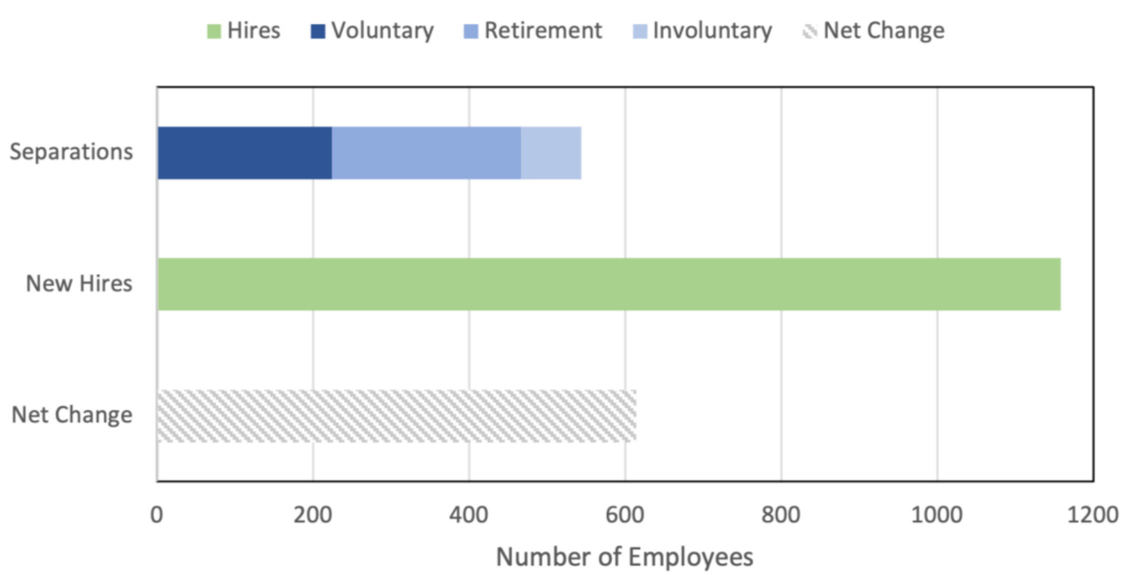
Figure E–16. LANL workforce distributed by age group (as of September 30, 2020)



Notes:

This graphic demonstrates the continuing pattern of retirements and new hires. In FY 2020, 43 percent of employees had 5 years of service or less, an increase from 38 percent in FY 2019. Additionally, the average years of service was 11.4 in FY 2020, down from 12.2 in FY 2019.

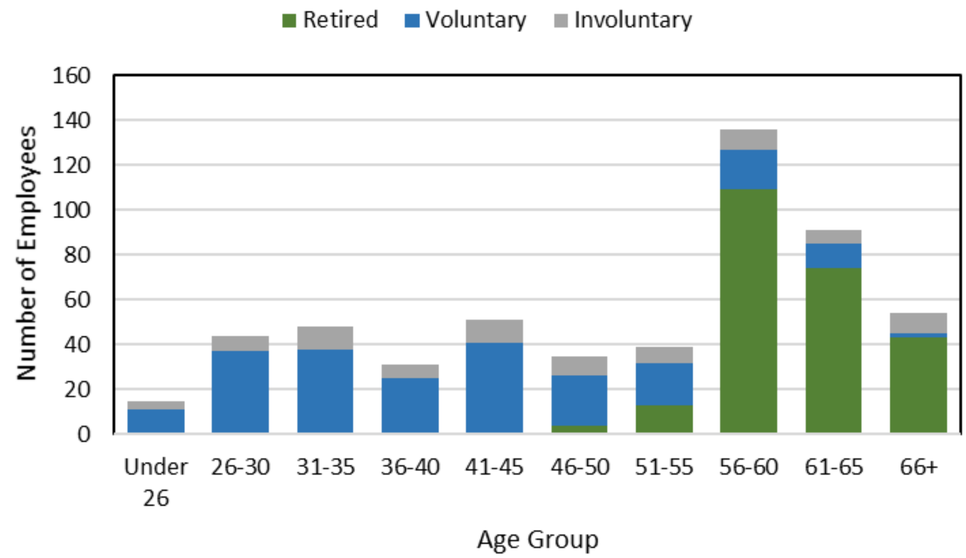
Figure E–17. LANL workforce distributed by years of service group (as of September 30, 2020)



Notes:

LANL saw a decrease in separations this past year due to decreases in both retirements and voluntary terminations. In FY 2020, there were 544 separations, down from 660 in FY 2019. The overall decrease in separations is suspected to be attributable in part to COVID-19 impacts.

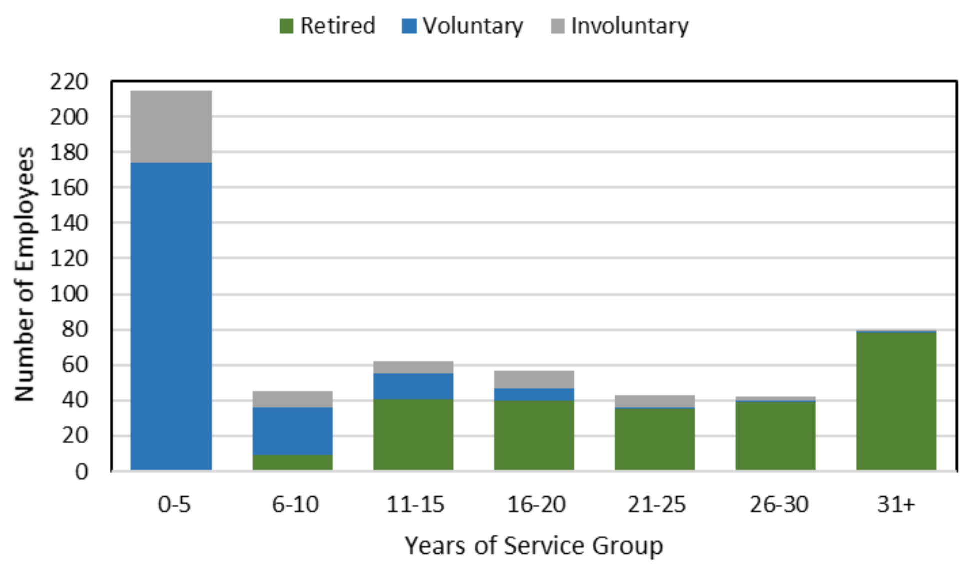
Figure E–18. LANL net change for fiscal year (as of September 30, 2020)



Notes:

A large proportion of workforce attrition is due to retirements in the 56-65 age range. Voluntary attrition rates are highest for individuals in the 26-30 and 41-45 age ranges.

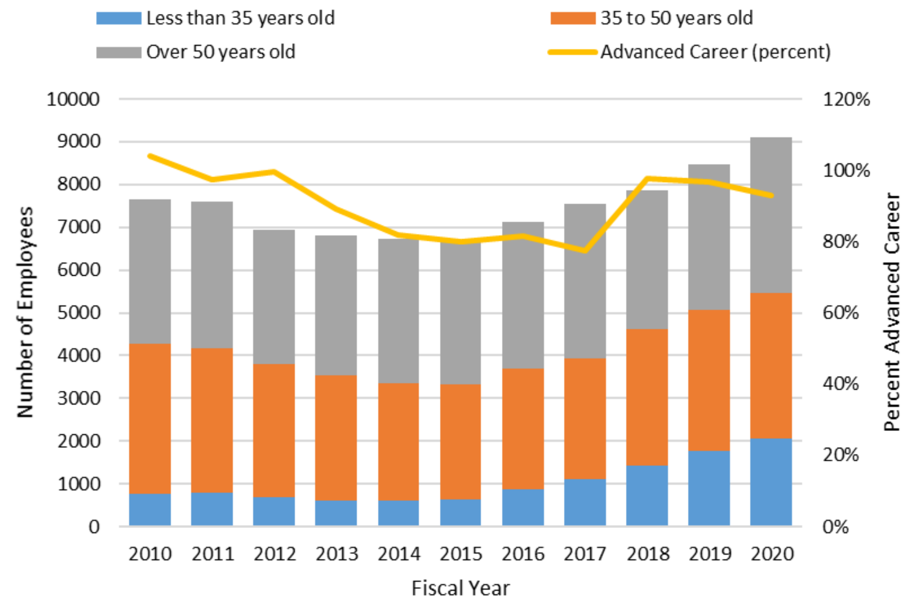
Figure E–19. LANL employee separations by age group (as of September 30, 2020)



Notes:

Overall, attrition rates are highest for those with 36 to 45 years of service due to retirements. However, voluntary attrition rates are highest for new hires. Employees with less than 6 years of service separated at an attrition rate of 4.37 percent which was 1.6 times higher than the rate for employees with 6-10 years of service. Additionally, the higher number of terminations among those with less than 6 years of service is largely due to the growing population of that service band.

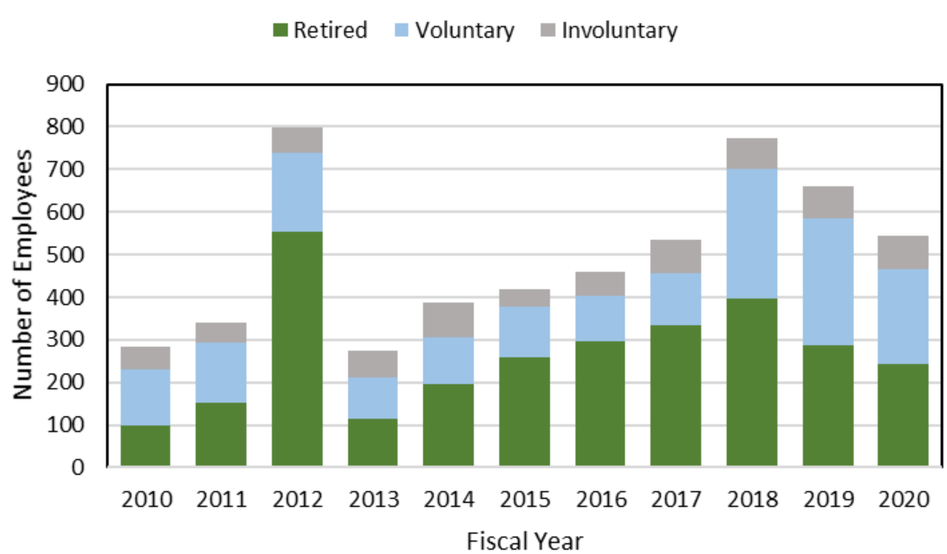
Figure E–20. LANL employee separation by years of service group (as of September 30, 2020)



Notes:

LANL has been hiring in all age categories; however, the largest proportion of new hires is the less-than-35-years-old workforce participation group. The proportion of less-than-35-year-old-employees continued to grow in FY 2020, increasing by approximately 1.5 percent from FY 2019. Over the past decade, this participation group has doubled. Inversely, the proportion of 35-years-old-and-over participation groups has decreased over the years. The proportion of workforce participation over 50 years old for this fiscal year has remained similar to last fiscal year.

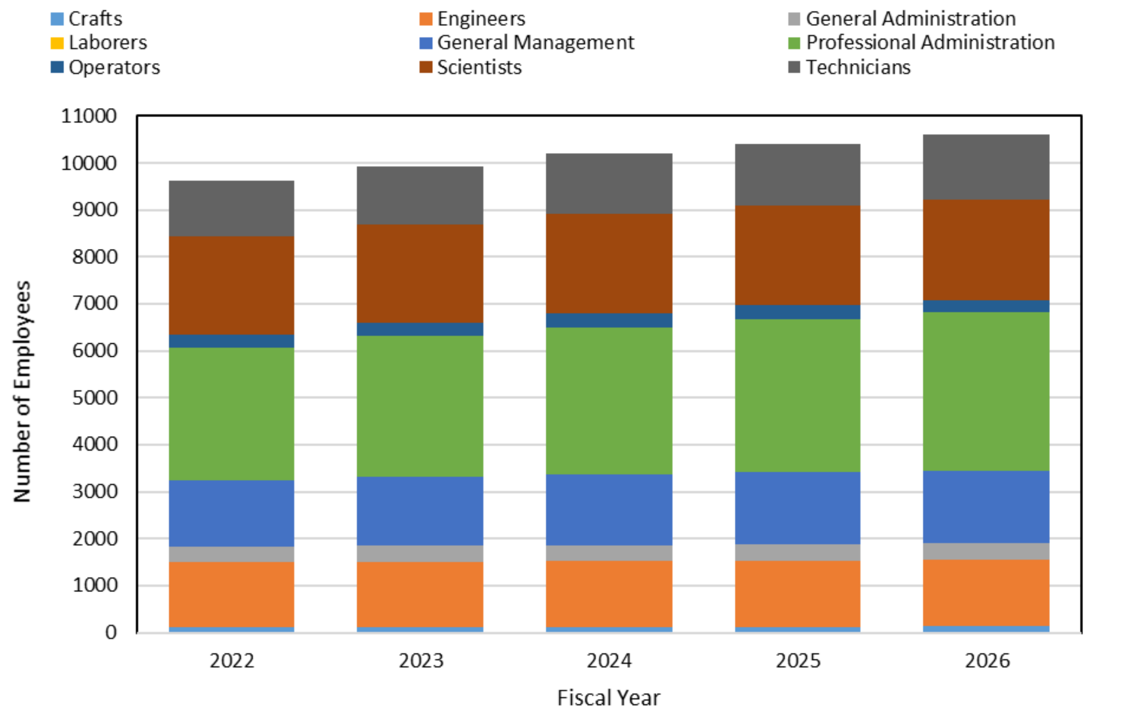
Figure E–21. LANL workforce participation trends by age category and percent advanced career (as of September 30, 2020)



Notes:

Retirements and voluntary separations have decreased for the second year in a row. The decrease from FY 2018 to FY 2019 was primarily due to the contract transition to Triad. The decrease from FY 2019 to FY 2020 is suspected to be attributable in part to COVID-19 impacts.

Figure E–22. LANL employee separation trends



Notes:

The increase in headcount projections is attributable to the LANL pit production mission. Technician and Professional Administration categories are expected to be required and, thus, grow in the next years.

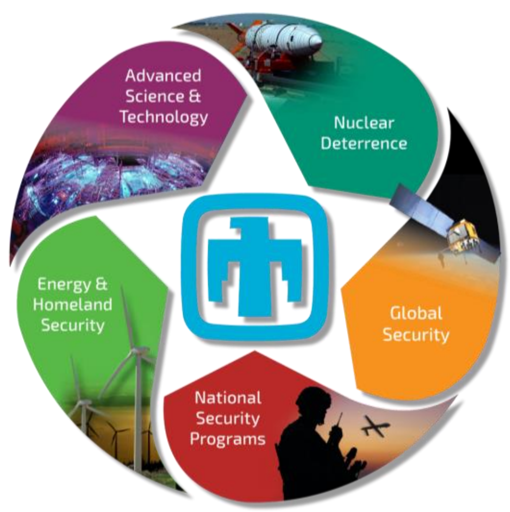
Figure E–23. LANL workforce projection needs by Common Occupational Classification System

E.2.3 Sandia National Laboratories

E.2.3.1 Mission Overview

For over 70 years, Sandia National Laboratories (SNL) has delivered essential engineering, science, and technology to resolve the Nation's most challenging security issues. SNL began in 1945 as Z Division, the ordnance design, testing, and assembly arm of Project Y, which after World War II became Los Alamos Scientific Laboratory. Z Division was renamed Sandia Laboratory in 1948 and, in 1949, Sandia Corporation was established as an AT&T, Inc., subsidiary to manage the laboratory through a no-fee contract. In 1956, a second site was opened in California's Livermore Valley. In 1979, Congress designated Sandia Laboratory as a DOE national laboratory. Since May 2017, SNL has been operated and managed by National Technology and Engineering Solutions of Sandia, LLC. As a multi-mission national security laboratory and Federally Funded Research and Development Center (FFRDC), SNL serves as an objective, independent, and trusted advisor, drawing upon a ST&E foundation to anticipate, innovate, create, and inform policy discussions for a broad range of decision-makers. SNL's core purpose is to develop advanced technologies to ensure global peace.

The nuclear deterrence mission exists at SNL within a framework of five interdependent portfolios that represent multiple missions. Most of these have a direct and symbiotic relationship with nuclear weapons work, and all strengthen SNL's capability-based science and engineering foundation.



Together, these programs provide the Nation the best possible return on its national security investments. SNL's activities for other Federal agencies and for non-Federal entities leverage, sustain, and strengthen the unique capabilities, facilities, and essential skills that support both the Defense Programs mission and broader national security needs. SNL's national security work currently includes the following programs' portfolios:

- Nuclear Deterrence
- Global Security
- National Security Programs
- Energy and Homeland Security
- Advanced Science and Technology

SNL's traditional, long-term nuclear deterrence mission includes nuclear weapons R&D, design, qualification, testing, certification, and systems integration of all components, subsystems and systems, to arm, fuze, and fire a weapon to military specifications and ensure safety and security. The integration role is evident in three key areas:

- Integration of all non-nuclear components, systems, and subsystems
- Integration between a weapon's non-nuclear portion and its nuclear explosives package
- Integration of a weapon with its military delivery platform

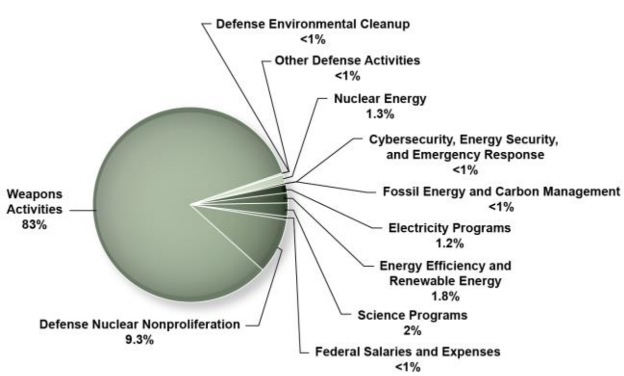
The current warhead modernization activities constitute SNL's largest, most complex design, development, and qualification work scope in the last 30 years. SNL is involved in all stockpile modernization programs currently underway (the B61-12 LEP, W88 Alteration (Alt) 370 Program, W80-4 LEP, W87-1 Modification Program, W93, and Mk21 Fuze), and is responsible for designing the life extension of the Safeguards Transporter and its replacement design (the Mobile Guardian Transporter [MGT]) for secure transport of nuclear weapon materials and components to DOE/NNSA partner sites and DoD customer sites. SNL also has production agency responsibilities for some weapon non-nuclear components (e.g., power sources, neutron generators and trusted, strategic radiation-hardened microsystems).

Continuity in warhead modernization and rebalancing priorities in response to the global security environment and uncertain future threats are top priorities. The United States must maintain the range of flexible, responsive, and tailored nuclear capabilities to protect ourselves and our allies against nuclear or non-nuclear aggression. This strategy translates to the need to sustain SNL's capability-based science and engineering foundation to prepare for this uncertain future. As an FFRDC, part of this service to the Nation is to scan the horizon for emerging national security issues and articulate the challenges anticipated for the country.

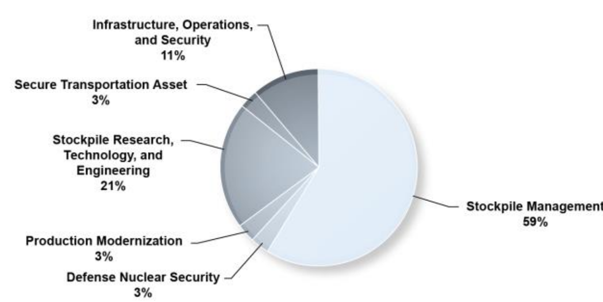
- Primary Sites: Albuquerque, New Mexico; Livermore, California; Tonopah Test Range, Nevada; Kauai, Hawaii
- Total Employees: 13,013 (as of the end of FY 2020)
- Type: Multi-mission national security laboratory
- Web site: www.sandia.gov
- Contract Operator: National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc.
- Responsible NNSA Field Office: Sandia Field Office

E.2.3.2 Funding

FY 2022 request – site funding by source
(total SNL FY 2022 request = $2,911 million)



SNL split for the FY 2022 Weapons Activities President's Budget Request *($2,419 million)*



E.2.3.3 Site Capabilities

SNL develops advanced technologies to ensure global peace and is responsible for developing and sustaining the science and engineering capabilities that provide the foundation of the Nation's nuclear deterrent portfolio. A strong capability-based science and engineering foundation can serve as a deterrent, guard against technological surprise, and enable a rapid response to an evolving set of mission requirements.

SNL stewards a broad set of capabilities supporting national security needs. Both Defense Programs and other national security missions will require a pool of engineers and scientists with advanced degrees in specialized disciplines of electrical engineering, computer science, computer engineering, materials science and other disciplines to provide expertise for diverse applications such as hypersonics, electromagnetics, radiofrequency design, and exascale computing. These and other emerging technical fields will be essential to keep pace with evolving threat environments and avoid technological surprise. To enhance the recruiting pipeline in these areas, SNL is initiating targeted university partnerships and other innovative approaches to provide skill sets to support national security missions.

Weapon Activities capabilities support an evolving set of mission requirements, are interdependent, and contribute across the entire weapons life cycle. **Table E–3** describes and highlights a few select SNL capabilities related to DOE/NNSA weapons activities, with associated challenges and strategies.

Table E–3. Sandia National Laboratories capabilities

<table>
<tr><th colspan="3">Agile Component and Systems Design, Engineering, Production, Surveillance and Integration</th></tr>
<tr><td colspan="3">Systems integration, engineering, and surveillance are the core capabilities of SNL's nuclear weapons program. SNL designs, develops, qualifies, and assesses arming, fuzing, and firing systems, neutron generators, gas transfer systems, power sources, energetic components, and weapon surety and nuclear safety and security systems for Alts, Mods, and LEPs. This capability also includes production responsibility for several non-nuclear components and robust prototyping that is enabled by model-based design and advanced manufacturing technologies. SNL partakes in surveillance evaluations and stockpile maintenance to assess nuclear weapon systems and detect or anticipate potential problems.</td></tr>
<tr><th rowspan="2">Challenges</th><th colspan="2">Strategies</th></tr>
<tr><th>Current Strategy Being Implemented</th><th>Future Strategies Needed</th></tr>
<tr><td>The capabilities, programs, people, and equipment are scattered around the SNL New Mexico site in aging Cold War-era facilities. Housing these people and programs needs increased priority to continue meeting mission needs. SNL must also maintain R&D, production, and surveillance capabilities.</td><td>Proactively engage with NNSA to ensure an integrated approach that collocates related capability assets to improve efficiency and effectiveness, recapitalizes aging and inadequate facilities, and maintains facilities fit for mission use. Execute the Power Sources Capability line item.</td><td>Recapitalization or replacement of equipment and facilities will be needed to sustain long-term health.</td></tr>
<tr><td>Threats by adversaries are evolving rapidly and unpredictably. Traditional weapon product lifecycles (design, development, and production) are too long, impeding the ability to respond in a timely manner to emerging threats.</td><td>Seek ways to accelerate and more efficiently integrate the nuclear security enterprise-wide product realization process through improvement to technical, process, and cultural factors. Intentionally focus on improving the digital engineering ecosystem to include common tools and standards, and advancing prototyping capabilities to more quickly respond to emerging threats; participate in the Stockpile Responsiveness Program.</td><td>Continue coordination with DOE/NNSA to define longer-term strategies and investments.</td></tr>
</table>

Increasing supply chain risk to meet stringent non-nuclear component production requirements.	Seek opportunities to maintain current and develop new trusted supplier partnerships. Improve our sourcing methods to engage our suppliers more strategically.	Continue current efforts and assess opportunities for new technologies.
Manage the workforce as multiple LEPs and Alts transition from development to production.	SNL has developed and implemented a planning tool to estimate and project staffing needs and attrition.	Continue current efforts.
Competition is high for electrical engineers and computer scientists.	Leverage the existing recruiting program and initiate innovative on-campus research partnership, internships, and other creative mechanisms to develop a pipeline of future-generation warhead engineers.	See Chapter 7, Section 7.4.1, for enterprise recruitment and hiring challenges and strategies.
Major life extension activities have focused laboratory attention and resources on near-term deliveries, making maturation of new technologies and components difficult.	Seek opportunities to advance technology development in a broad range of program venues, including the Strategic Partnership Projects, Laboratory-Directed Research and Development, and DOE/NNSA programs such as the Stockpile Responsiveness Program	Continue coordination with DOE/NNSA to define longer-term strategies and investments.
Microsystems R&D and Manufacturing		
Trusted, strategic, radiation-hardened advanced microsystems (i.e., nanoscale and microscale system ST&E.		
Challenges	***Strategies***	
Trusted microsystems fabrication facilities are aging and past their design lives.	***Current Strategy Being Implemented***	***Future Strategies Needed***
	Work with NNSA in extended life planning to maintain the R&D capability and ensure an uninterrupted ability to produce trusted, strategic radiation-hardened microsystems.	Explore potential for line item construction, given continued risk with current investments.
Materials Science and Engineering and Advanced Manufacturing		
Virtually all classes of non-nuclear materials, including metals, polymers, glasses, ceramics, and electronic and optical materials and their interfaces and interactions with their environments, are critical to the safety, security, and effectiveness of the U.S. nuclear weapon stockpile. This capability at SNL includes (1) evaluation of materials for aging, compatibility, and model validation to resolve stockpile and production issues rapidly and (2) innovation to replace legacy materials and evaluate new materials for insertion into the stockpile.		
Challenges	***Strategies***	
SNL must support evaluating materials aging, compatibility, and model development/validation and sustain the innovation necessary to replace legacy materials and evaluate new materials for insertion into the stockpile.	***Current Strategy Being Implemented***	***Future Strategies Needed***
	SNL must advance material science R&D for response to evolving threats and future needs. This includes creating new measurement and analytical capabilities and conducting R&D to enhance our understanding of the structure and processing of materials to evaluate their behavior; capturing the phenomenology driving this behavior; defining and predicting performance in current and future stockpiles; and enabling applications in additive manufacturing with a science basis for qualification.	Expand/continue engagement with DOE/NNSA.

The material science and engineering facility at SNL California does not meet modern seismic and other building code standards. SNL Albuquerque facility operations exceed the design intent and increased heating, ventilation, and air conditioning capacity needed to enable mission-driven chemical operations.	Proactively engage with DOE/NNSA to ensure an integrated approach to resolving facility challenges. Develop an Integrated Facilities and Infrastructure Plan to capture infrastructure needs and define priorities. Commission studies to establish conditions and alternatives to best mitigate risk to the mission.	Continue coordination with DOE/NNSA.
The current generation of materials scientists is approaching the end of their careers. The number of students seeking advanced degrees in material disciplines who choose to enter and work within the nuclear security enterprise may not be sufficient to meet future workforce needs. Competition is high for scientists and engineers who are qualified in these disciplines.	Leverage existing recruiting programs and initiate innovative on-campus research partnerships, internships, and other creative mechanisms to develop a pipeline of a future generation of materials science specialists for SNL's unique needs.	See Chapter 7, Section 7.4.1, for enterprise recruitment and hiring challenges and strategies.
Engineering Sciences and Testing, Radiation Effects and High Energy Density Sciences, and Advanced Experimental Diagnostics and Sensors		
These capabilities include evaluation of the effects of operational and abnormal environments on nuclear weapon systems and components using an array of engineering science test equipment (e.g., the Annular Core Research Reactor, Z, Saturn, and HERMES), diagnostic tools, and techniques, as well as research and testing to support design, qualification, and surveillance.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
The workload imposed by concurrent LEPs is stressing the capacity and capability of aging facilities and equipment and accelerating replacement needs. Experimental test capabilities to validate data models require more and higher-fidelity data to enable stronger coupling with integrated design codes (IDCs).	Select facility and equipment investments to ensure continuity of the engineering sciences capability. Support enhancement of the predictive capability by tightening the coupling and integration of modelers and the data necessary for model validation. Advance diagnostic capabilities to capture higher-fidelity experimental data.	Research and technology from current strategies and efforts will be applied to next -generation pulsed power and accelerator facilities. Definition of new investments will likely emerge, alongside other opportunities.
Next-generation pulsed power experimental capabilities are needed to ensure models that validate safe, secure, and reliable performance of the Nation's weapons.	Develop an experimental and theoretical basis to provide confidence that the next-generation pulsed power experimental capability will attain needed pressures and fusion yields.	
The Annular Core Research Reactor delivers high-power, short bursts of neutron and combined neutron-gamma spectra to qualify designs under extreme combined radiation environments. The facility housing the reactor is older than 50 years and predates modern nuclear safety standards.	Proactively engage with NNSA to ensure an integrated approach to resolving this facility challenge. Develop an Integrated Facilities and Infrastructure Plan to capture infrastructure needs and define priorities.	
Competition is high for certain specialists in radiation effects science.	Develop a pipeline of scientific and engineering expertise in radiation effects via current campus and diversity recruiting programs and initiate targeted, innovative on-campus partnerships, internships, and fellowships to secure highly talented graduates.	See Chapter 7, Section 7.4.1, for enterprise recruitment and hiring challenges and strategies.

High Performance Computing and Codes, Models, Data Analytics		
These capabilities include modeling and simulation capabilities of physical phenomena.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Enhance the predictive capabilities of IDCs to support design, development, qualification, and assessments of non-nuclear components and systems for normal, abnormal, and hostile environments.	Participate in the DOE Exascale Computing Initiative; design and conduct experiments to support validation of IDCs that increase understanding of the physical phenomena and close the gap between models and the physical world.	Investment will be required in computing and test capabilities.
Competition for high-demand disciplines, such as computational modeling with an emphasis on engineering analysis, makes recruiting, training, and retaining technical staff increasingly challenging.	Leverage campus and diversity recruiting programs to develop a pipeline of future-generation HPC scientists and engineers.	See Chapter 7, Section 7.4.1, for enterprise recruitment and hiring challenges and strategies.

Alt = alteration
HERMES = High-Energy Radiation Megavolt Electron Source
HPC = high performance computing
IDC = integrated design codes
Z = Z pulsed power facility

E.2.3.4 Accomplishments

Directed Stockpile Work/Weapon Engineering and Production Focus

- **Delivering on nuclear weapons modernization and development programs.** SNL successfully executed a significant increase in the workload associated with warhead LEPs, Alts, and similar programs—the largest and most complex nuclear deterrence design, development, and qualification workload at SNL in almost 30 years. SNL met or exceeded critical cost, schedule, and technical performance milestones critical to the NNSA mission.
- **Abnormal shock test.** Six drop tests comprised the successful completion of the Abnormal Shock Breach Phase 1 test series. The tests were conducted at SNL's Tech Area-III Drop Tower Complex in partnership with LLNL. This test series provides critical data for qualification teams to further understand W80-4 system response in abnormal mechanical environments.
- **Production success**. As part of SNL's production agency role, SNL delivered nearly 40,000 non-nuclear parts, components, and technologies to support all stockpile system maintenance activities and LEPs. These deliverables included neutron generators, power sources, explosive components and energetic materials, surety technologies and strategic, radiation-hardened microsystems such as custom Application-Specific Integrated Circuits that deliver advanced capabilities needed to support the current and future stockpile.
- **Tonopah Test Range testing.** Executed nine Air Force Initial Operational Test and Evaluation B61-12 surveillance tests in a short amount of time. Operating efficiently, the Tonopah Test Range completed all tests safely and accurately and collected critical data for Air Force certification of the B61-12 and annual assessment for current B61 stockpile systems.
- **P19 project execution**. The P19 project represents SNL's commitment to respond to critical national security challenges, including responding rapidly through contributing expertise in design, qualification, production, acceptance, and fielding to meet a tight deadline. The project capitalizes on SNL's advanced capabilities and commitment to quality to deliver a solution to DoD and DOE/NNSA stakeholders within a highly compressed schedule.

- **Neutron Generator Enterprise (NGE) efficiencies.** Despite the COVID-19 pandemic, NGE production did not stop, and exceeded the original neutron generator delivery plan by three percent.
- **MGT Prototype.** SNL completed a full-scale crash test of MGT Prototype 1 at the Rocket Sled Track, the first of a transporter vehicle in almost 20 years.
- **Advanced surety technology activities.** SNL completed several advanced surety technology activities that led to selection of a design that dramatically reduces cost, weight, and performance compared to currently deployed technology.

RDT&E/Weapon Science and Technology Focus

- **Delivering foundational science and engineering capabilities to advance and sustain the Nation's nuclear deterrent.** SNL served as a leader in multiple weapon science and technology efforts, including an unprecedented number of experiments and improved yields and reproducibility on Z, and analysis of stockpile issues through numerical simulation that will have significant impact on future annual assessment reviews.
- **TABS** (**Thermally Activated Battery Simulator)**. The team received the 2019 DOE/NNSA/Defense Programs Award of Excellence (Defense Programs Awards of Excellence). The TABS model completely reinvented and shortened the battery production process.
- **Microsystems Silicon Fabrication facility (SiFab) revitalization.** SNL achieved substantial completion of this multi-project revitalization, significantly reducing the risks of process tool and site infrastructure failure in the SiFab.
- **Stockpile Responsiveness Program.** SNL successfully completed a series of tests using SNL's unique 16" Mobile Davis Gun. The Stockpile Responsiveness Program team used the Davis Gun tests to provide valuable experimental data for comparison to computer simulations that model impact at high speeds.
- **Hypersonic fluid, material response, trajectory coupling.** SNL researchers completed an effort to tightly couple the trajectory analysis code, TAOS, to their computational fluid dynamics and ablation code, SPARC. The two-way coupled capability enables the prediction of hypersonic reentry flight physics from reentry to impact and reduces the reliance on empirical models that are currently built into SNL's trajectory solvers. The work is part of an effort to develop a virtual flight test capability.
- **Delivering next generation modeling od-simulation capability.** Enabling rapid computer-aided design-to-analysis workflow and generating qualification evidence via simulation are the tenets of SNL's Next Generation Simulation capability development project. Developed as part of NNSA's Advanced Simulation and Computing Program, this cross-laboratory team is delivering automated simulation capabilities to greatly reduce the time to produce an analysis.

Attract, Retain, and Develop Talent

- **Jill Hruby Fellowship.** The newly established Jill Hruby Fellowship, honoring SNL's former Director who was NNSA's first female Laboratory Director, attracted women in engineering and science interested in pursuing technical leadership careers in national security. SNL made one offer, which was accepted.
- **Securing Top Academic Research and Talent with Historically Black Colleges and Universities (START HBCU) program**. SNL launched the START HBCU program to establish partnerships for research collaborations, expose students to the work of a national laboratory, and increase SNL's awareness of each HBCU's capabilities. The four universities selected for the inaugural program

include Florida A&M University, Norfolk State University, North Carolina A&T State University, and Prairie View A&M University.

- **Weapon Intern Program technical professional development.** Since 1998, SNL has sponsored the Weapon Intern Program to accelerate the process of providing training to technical professionals across the nuclear security enterprise in nuclear weapon development. With over 450 program graduates, the Weapon Intern Program turns out about two dozen students each year from all sites in the nuclear security enterprise, NNSA, and DoD officers/civilians. Topics include various weapon technology, design, development, evaluation, production, operations, process, policy, and management areas.
- **Military academic collaboration.** The Military Academic Collaboration is a cooperative research program administered by NNSA's Office of Defense Programs, through which cadets, midshipmen, and faculty are temporarily assigned to one of eight locations across the nuclear security enterprise. The Military Academic Collaboration program gives the opportunity to explore cutting-edge R&D in disciplines and technologies of mutual interest. SNL New Mexico and SNL California sponsor approximately 40 cadets, midshipmen, and faculty each year from the 4 service academies. In response to the COVID-19 pandemic, in FY 2020 all onsite internships were transitioned to remote opportunities.
- **National Security Leadership Development Program.** SNL's leadership participates in the SNL National Security Leadership Development Program, which is built on foundational leadership principles and SNL's heritage; SNL attracted 27 executive leadership participants through this effort.

Awards and Recognition.

- SNL received six coveted R&D 100 awards in each of the last 2 years. SNL employees earned 10 national technical awards, and 10 were named as fellows of national and international technical societies. In addition, 15 others received awards from diversity organizations and universities for outstanding technical accomplishments, leadership, and community service. SNL received the "Inclusive Leadership and Transformative Change" award from *Profiles in Diversity Journal*. The Journal recognized SNL as one of 14 of the world's leading companies, and the only national laboratory, with programs and initiatives that take diversity and inclusion to a new level.

Infrastructure Investments.

- SNL managed 69 active capital projects with a total estimated cost of $241 million, 94 percent within cost and 91 percent within schedule baselines.
- DOE/NNSA selected SNL New Mexico as the preferred alternative for the Power Sources Capability capital acquisition project for conceptual design and Critical Decision 1 (CD-1) in accordance with DOE Order 413.3B. The project will be sited in Technical Area 2. This project will be the first construction project at SNL above the minor construction threshold in approximately 15 years and will consolidate Power Sources capabilities across the SNL New Mexico campus and will ensure sustainment of this capability for the future nuclear deterrent program.

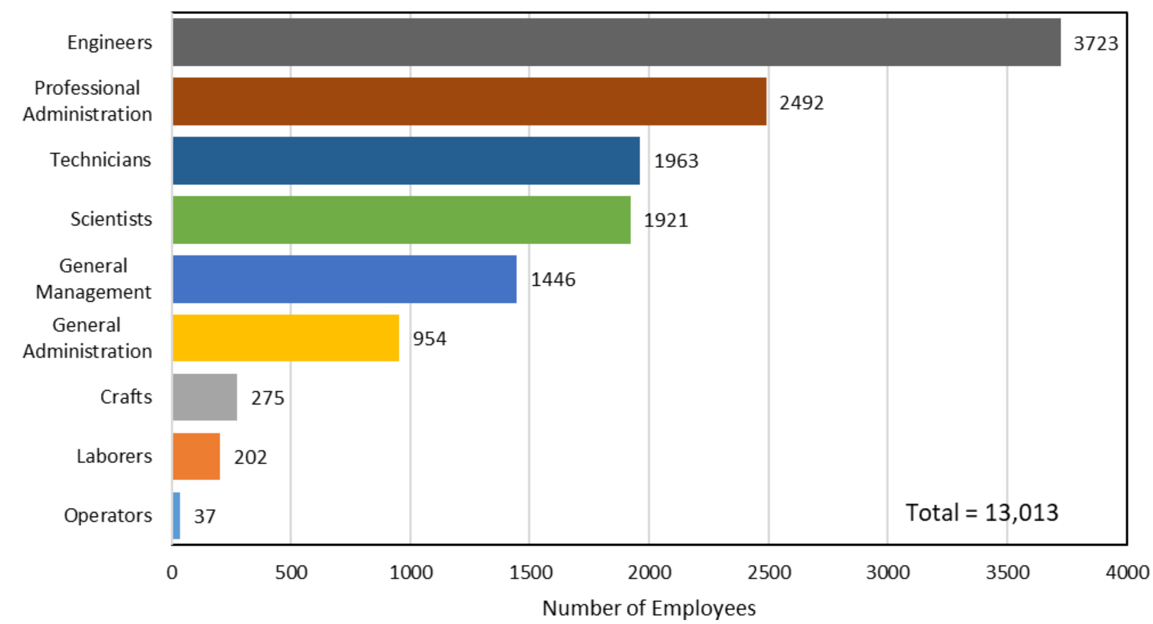
Other DOE/NNSA Accomplishments

- **Response training**. SNL conducted over 90 trainings for more than 800 emergency responders across DOE to maintain response personnel skills and qualifications. The team maintained the Nation's response capability by developing training materials that could be used in a virtual training environment and sending tailored teams to provide safe onsite training.

- **Oil Quality Assessment Program support for Strategic Petroleum Reserve**. In response to a Presidential Directive to fill the U.S. Strategic Petroleum Reserve, SNL led short-turnaround development, integration, and documentation of an oil quality characterization program. The assessment provided specific, actionable recommendations to DOE on maximizing inbound crude oil compatibility with the current U.S. Strategic Petroleum Reserve inventory and maintaining operating requirements for both near-term oil volatility upon return to customers and long-term integrity of the reserve. This effort was key to the success of DOE's crude oil exchange-for-fill program that supported the U.S. energy sector during the pandemic-related economic downturn.
- **SNL COVID-19 monitoring, modeling, and analysis**. SNL developed an integrated monitoring, modeling, and analysis capability to track COVID-19 pandemic surges and risks to help decisionmakers; eased the shortage of testing kits by developing reagents and detection platforms for COVID-19 diagnostics and detection; and developed protocols for sterilizing medical supplies using the Gamma Irradiation Facility, reducing the supply chain challenges for COVID-19 tests.
- **COVID-19 Rapid Response**. SNL responded rapidly to join the fight against COVID-19 to initiate 34 short-term Laboratory Directed Research and Development projects, several of which had a significant impact or received follow-on funding. Examples include transforming 100 noninvasive respiratory machines into ventilators and creating auto-update sequence collection and processing software for all available coronavirus genomic sequences.
- **Cyber Risk Framework supports national strategic planning**. SNL developed a Cyber Risk Framework for the Department of Homeland Security's Cybersecurity and Infrastructure Security Agency National Risk Management Center (NRMC). NRMC leadership adopted the framework to establish a risk architecture vision and goals for strategic planning through 2040. NRMC envisions the framework as the "operating system" it will use to identify, analyze, prioritize, and manage cyber risks to critical infrastructure.
- **Democratic People's Republic of Korea (DPRK) nonproliferation activities**. SNL supports DPRK nonproliferation activities, engaging with 22 countries and 370 participants in FY 2020. To support a State Department program in International Security and Nonproliferation, SNL helps foreign governments increase their international sanctions compliance. During a training session with Honduran officials, the SNL team detected a Honduran vessel illegally present in DPRK waters, in violation of sanctions against the DPRK. Using an SNL-developed risk matrix, the Honduran team has since investigated, deregistered, and reported three additional vessels. This work strengthens NNSA's export control monitoring capabilities.

E.2.3.5 Sandia National Laboratories Workforce

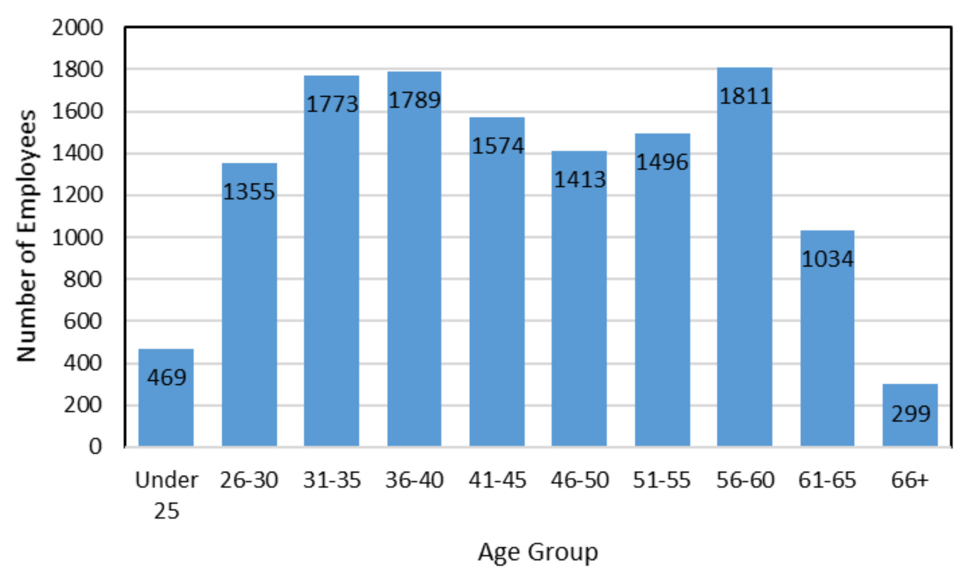
SNL has a headcount of 13,013 employees; the average age is approximately 45 years, and 17 percent of the population is eligible for retirement. The average years of service is 10.5 years, and the population is heavily concentrated among those with 1-10 years of service. Most separations involve retirements among those 51 years of age or older, but younger-aged groups have experienced many voluntary separations. Of the voluntary separations, 51.7 percent were clustered between ages 26 and 40. Retirements were higher among those with 21 to 45 years of service, while a significant number of voluntary separations occurred among those with 0-5 years of service. SNL expects a stable workforce over the FYNSP period. **Figures E–24** through **E–32** illustrate these SNL workforce demographics and others.



Notes:

SNL uses a systems integration approach to workforce assignments across the laboratory. Employees are matrixed to support key mission areas, including the Strategic Partnership Projects. Approximately, 61 percent of SNL's headcount is aligned with technical duties and responsibilities ranging from R&D to applied engineering to operations. Over 52 percent of the workforce have advanced degrees: 16 percent have a Ph.D., and 36 percent have a Masters.

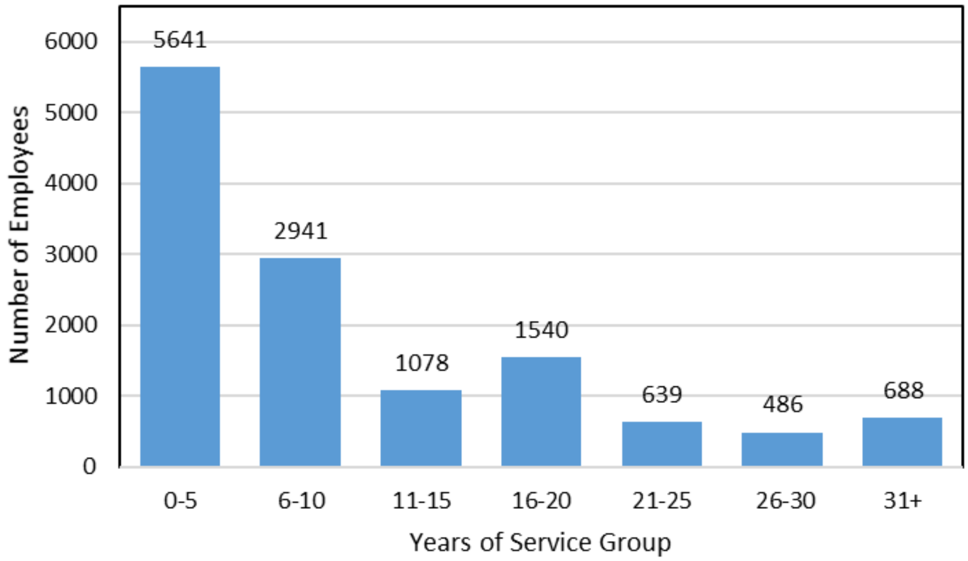
Figure E–24. SNL workforce by Common Occupational Classification System (as of September 30, 2020)



Notes:

A large proportion of the workforce is aged 56 and above (24 percent). Approximately 14 percent of the population is aged 30 or less. The remaining 62 percent is between the ages of 31 and 55. Based on the age distribution, an increase in retirement is anticipated in coming years. These open positions will require a significant increase of effort toward both recruiting future talent and retaining current SNL employees.

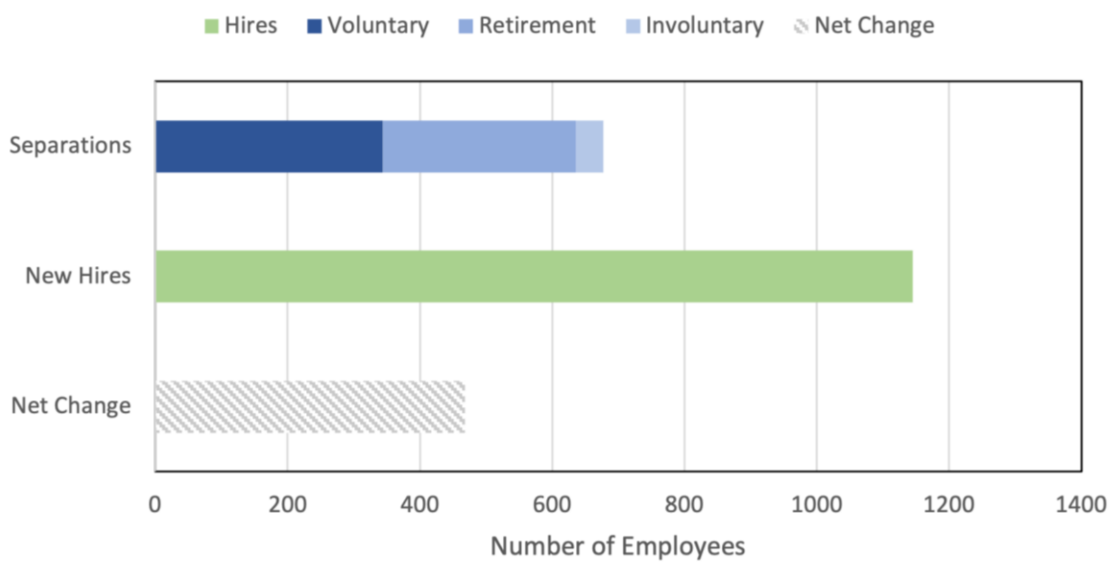
Figure E–25. SNL workforce distributed by age group (as of September 30, 2020)



Notes:

Over 74 percent of employees have 15 or less years of service and 43 percent have 5 or less years of service. These numbers reflect the hiring of 4,228 new regular employees over the past 5 years (FY 2016 through FY 2020). This strong hiring pursuit ensures that a substantial percentage of employees are in the earlier phases of their careers to replace those in later career phases. A hiring mix of both experienced and new college graduates assures that the necessary skills and capabilities are present to support SNL's missions; however, this hiring approach will require an increased focus on knowledge transfer and training programs.

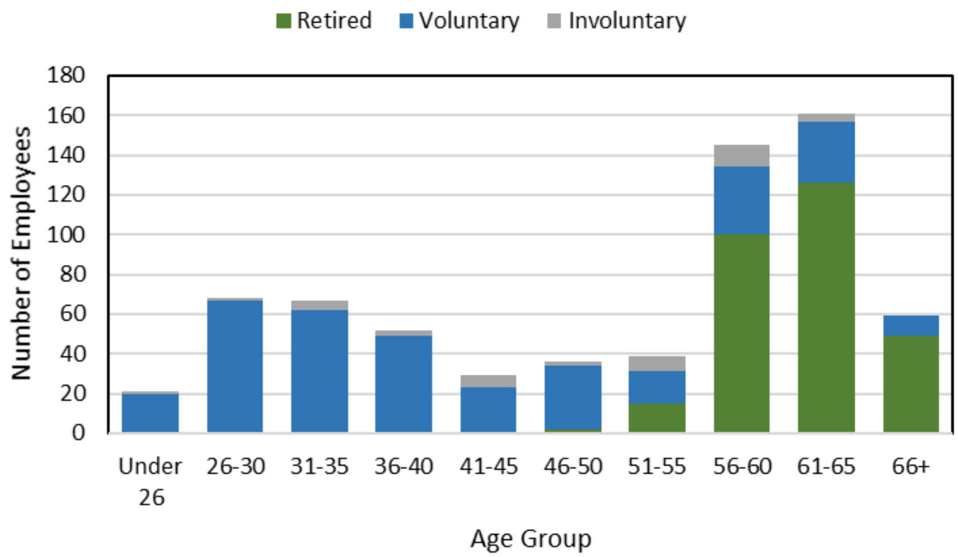
Figure E–26. SNL workforce distributed by years of service group (as of September 30, 2020)



Notes:

SNL's workforce growth is attributable to an expanding mission scope related to stockpile modernization through LEP activities. Other factors include the Strategic Partnership Programs. SNL actively manages the development and size of support organizations to maximize mission support within allocated budgets.

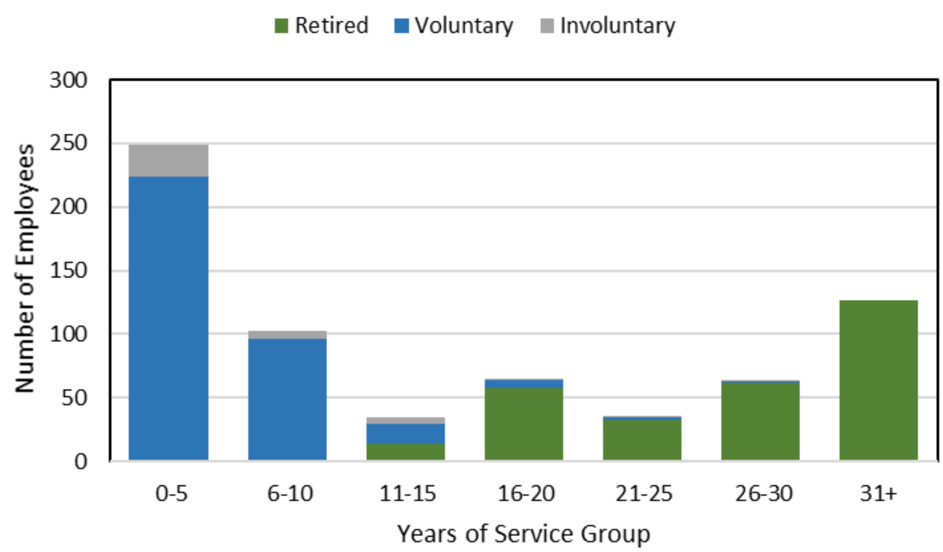
Figure E–27. SNL net change for fiscal year (as of September 30, 2020)



Notes:

Over 51 percent of voluntary separations are clustered between the ages of 26 and 40. A high number of retirements are reflected in the age groups between 56 and 65 years of age, representing 33 percent of separated employees during FY 2020. Departures for resignation and retirement are consistent within the laboratory workforce population. Resignations remain below 7 percent reflecting a generally stable workforce.

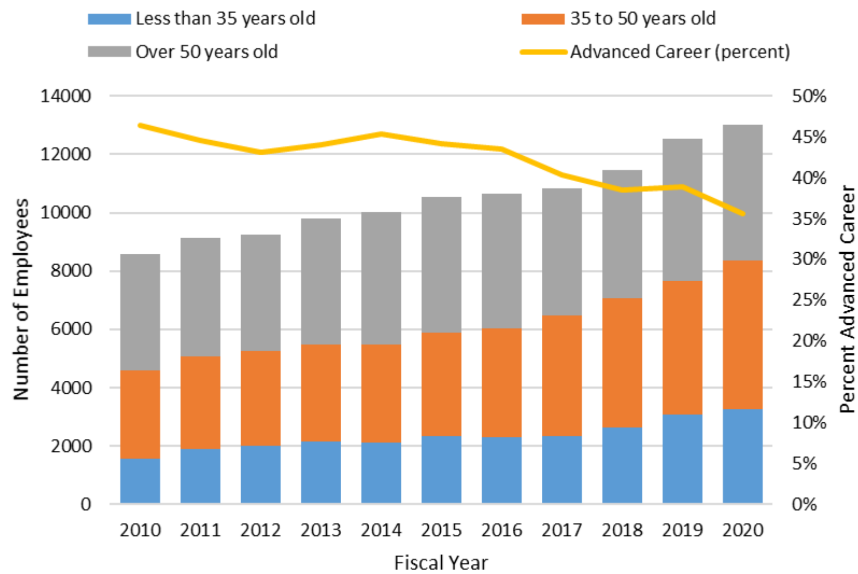
Figure E–28. Age of SNL employees who left service (October 1, 2016 to September 30, 2018)



Notes:

Of the voluntary employee separations, 65 percent had 5 or less years of service; 93 percent had 0-10 years of service, and 97 percent had 15 or less years of service. This data may reflect the external demand for technical skills in a highly competitive market where SNL competes for talent. These losses place increased importance on relevant and acknowledged employee value propositions to not only draw talent from the external market, but also retain current SNL employees. Efficient and effective support processes, such as an expedited clearance process, internal training programs, and knowledge transfer programs, enable new staff to promptly engage and contribute to mission work.

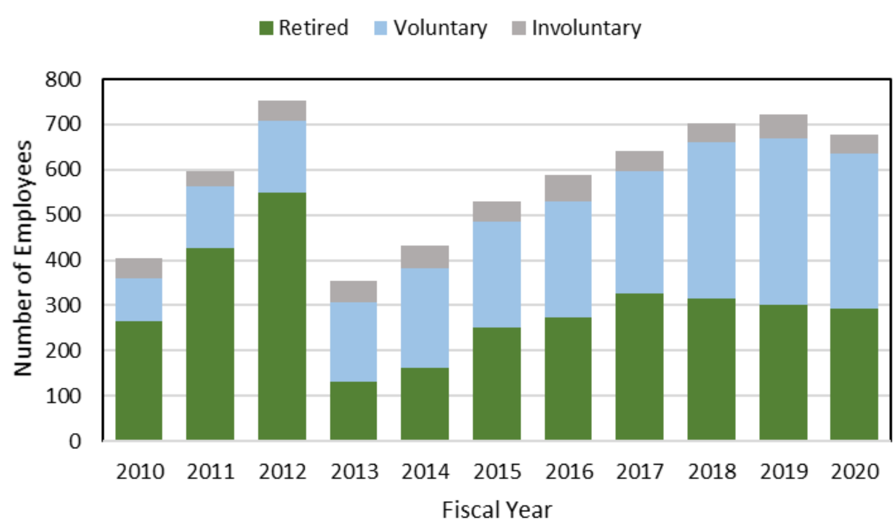
Figure E–29. SNL employee separations by age group (as of September 30, 2020)



Notes:

The increase in headcount is in direct response to mission work and demands. The mix of staff by age group reflects the need for new talent in all three career participation groups. Each group brings a unique skillset to SNL, creating a balanced workforce. For employees over 50 years, the change over time has been heavily influenced by retirements, but has ultimately held steady. Due to the current age distribution, SNL expects an increase in retirements, which will contribute to a slight decrease the over-50-year workforce participation group in the coming years. For all other workforce participation groups, there has been a slight increase over time.

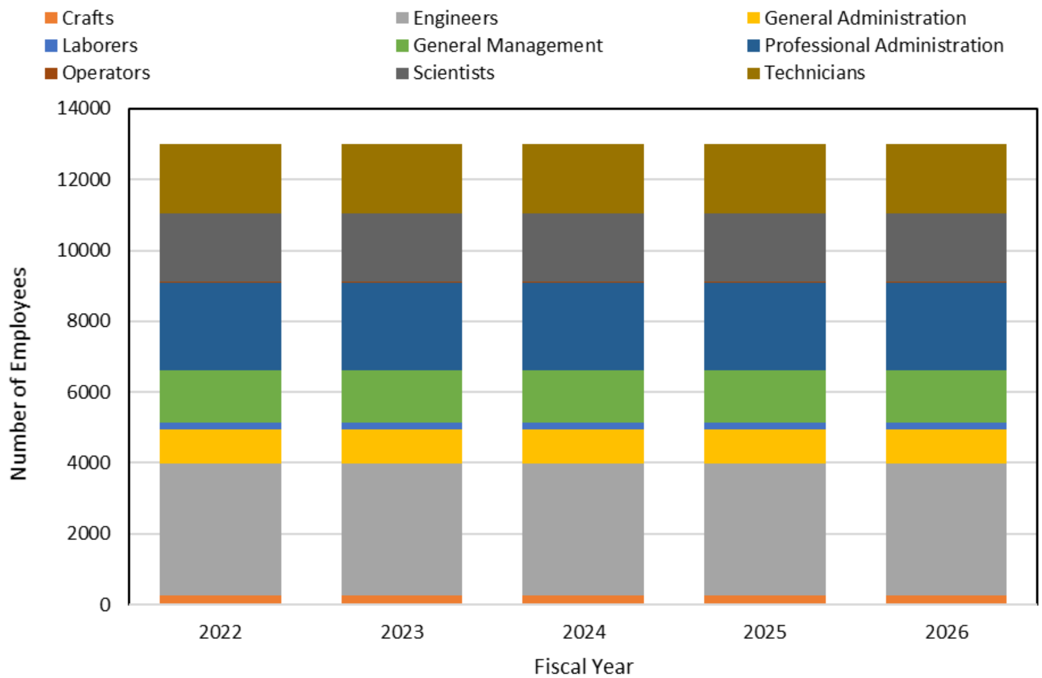
Figure E–30. SNL workforce participation trends by age category and percent advanced career (as of September 30, 2020)



Notes:

Retirements were higher in FY 2011 and FY 2012 because of announced pending changes in retiree benefits, which prompted some employees to leave early. The surge in retirement in FY 2011 and FY 2012 resulted in reduced retirements in FY 2013 and FY 2014. An increase in expected retirements occurred in FY 2015 through FY 2018 as SNL returned to historical retirement rates and workforce age distribution. While headcount has steadily increased over the past few fiscal years, total separations in FY 2020 declined to levels not seen since FY 2017. It is believed that the economic uncertainty caused by COVID-19 is the primary driver of this trend and that it will likely continue through the pandemic.

Figure E–31. SNL employee separation trends



Notes:

The SNL workforce has grown since the FY 2020 SSMP. SNL's total workforce trend is expected to be flat over the next few fiscal years. SNL will monitor workload fluctuations and manage the stability of the workforce through leveraging Strategic Partnership Projects, temporary staffing options, cross-training within programs, and strategic hiring.

Figure E–32. SNL workforce projection needs by Common Occupational Classification System

E.3 Nuclear Weapons Production Facilities

E.3.1 Kansas City National Security Campus

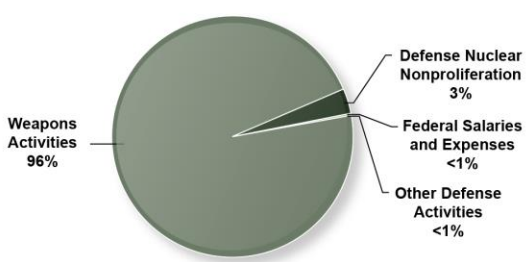
E.3.1.1 Mission Overview

The Kansas City National Security Campus (KCNSC) in Kansas City, Missouri, employs advanced scientific capabilities, statistical controls, simulation and modeling, and materials expertise to manufacture and procure DOE/NNSA's most intricate and technically demanding electronic, mechanical, and engineered materials components. This includes radar systems, arming and fuzing systems, mechanisms, gas transfer systems (GTSs), secure transportation products, joint test assemblies (JTAs), and specialty engineered material products. KCNSC actively manages an extended supplier base to ensure suppliers are qualified and is strategically establishing redundant capabilities to ensure DOE/NNSA requirements are met. KCNSC partners with the national security laboratories to evolve weapon concepts through design and development and into production and sustainment. The site is responsible for life cycle management of over 80 percent of the components in a nuclear weapon across all active and emerging nuclear stockpile systems. In addition to its Nuclear Weapon Programs mission, the site supports Nuclear Nonproliferation, Emergency Management, and Counterterrorism missions. The site also supports a Global Security mission that involves development and delivery of field-ready engineering solutions for other government agencies' national security missions.

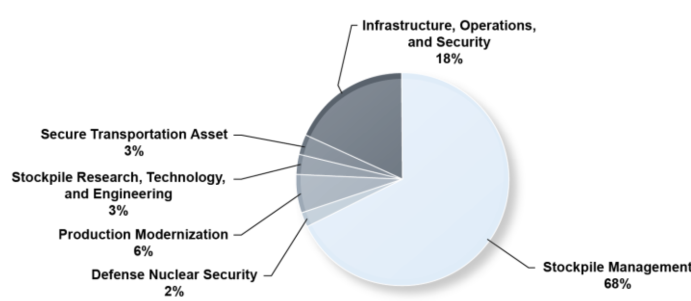
- Locations: Kansas City, Missouri; Albuquerque, New Mexico
- Total Employees: 5,300 (as of end of FY 2020)
- Type: Multi-program nuclear weapons production facility
- Website: www.kcnsc.doe.gov
- Contract Operator: Honeywell Federal Manufacturing & Technologies, LLC
- Responsible Field Office: Kansas City Field Office

E.3.1.2 Funding

FY 2022 request – site funding by source
(total KCNSC FY 2022 request = $1,280 million)



KCNSC split for the FY 2022 Weapons Activities President's Budget Request *($1,234 million)*



E.3.1.3 Site Capabilities

KCNSC's capabilities support both weapon systems currently in the stockpile and those being modernized via LEPs, Alts, and Mods. For legacy systems, these activities include Directed Stockpile Work in the management, production, processing, and delivery of hardware for LLC exchanges and flight test systems; surveillance testing of components and materials; and maintenance and repair of weapons systems. For future stockpile systems, KCNSC's work scope includes development and maturation of manufacturing processes and technologies, production of prototypes to support design development, and manufacturing of components and systems.

KCNSC's capabilities are used to research and develop new materials for legacy and future stockpile systems. Production capabilities include over 40 manufacturing technologies and manufacturing over 1,000 unique product families, including arming, fuzing, and firing devices; safing devices; microcircuits; machined parts; polymers; plastics; and other engineered materials. KCNSC also designs, develops, and produces associated support equipment, tooling, fixtures, and test equipment.

KCNSC provides capabilities integral to the Stockpile Stewardship Program and the Stockpile Responsiveness Program. KCNSC's primary capabilities and their associated challenges and strategies are described in **Table E–4**.

Table E–4. Kansas City National Security Campus Capabilities

<table>
<tr><th colspan="3">Non-nuclear Weapon Component Manufacturing and Assembly</th></tr>
<tr><td colspan="3">KCNSC is the primary site for manufacturing and procuring non-nuclear components including arming, fuzing, and firing systems; gas transfer systems; environmental sensing devices; strong links; and structural components and cushions made from engineered materials. The capability to manufacture and inspect these items is highly dependent on specialized equipment and facilities (cleanrooms, environmentally controlled areas, etc.) and the ability to maintain them (i.e., calibration and metrology).</td></tr>
<tr><th rowspan="2">Challenges</th><th colspan="2">Strategies</th></tr>
<tr><th>Current Strategy Being Implemented</th><th>Future Strategies Needed</th></tr>
<tr><td>• Balancing the growing maintenance needs of aging production equipment with the needs for emerging production technology for the LEPs.
• Availability of a cleared and ready labor force.</td><td>• Continue programmatic and infrastructure-related investment projects.
• Hire hourly resources in advance of needs to allow time for clearance, training, and certification.
• Use expedited clearance methodologies.
• Maximize onboarding efficiencies with training, certification, and working on unclassified product.</td><td>• Continue current strategies.
• Be proactive in identifying and applying technologies and capabilities that offer solutions to enterprise issues.
• Consider options to deploy technology to increase responsiveness, reduce impact of producibility challenges, and provide design alternatives.
• See Chapter 7, Section 7.4.3, for enterprise workforce training and knowledge transfer challenges and strategies.</td></tr>
</table>

<table>
<tr><th colspan="3">Testing Equipment Design and Fabrication</th></tr>
<tr><td colspan="3">KCNSC designs and produces test equipment to support its mission and that of the other sites within the nuclear security enterprise. Often, these test systems are integrated with various types of environmental conditioning equipment, such as thermal chambers or centrifuges, to perform automated testing for weapon environments. These test systems are vital to development, qualification, acceptance and long-term surveillance of weapon systems and components.</td></tr>
<tr><th rowspan="2">Challenges</th><th colspan="2">Strategies</th></tr>
<tr><th>Current Strategy Being Implemented</th><th>Future Strategies Needed</th></tr>
<tr><td>A key challenge is the cyclical workload, which is very heavy during the development phases and lighter during the production phases.
Complexity of test systems to meet program requirements
Ability to staff appropriately in a dynamic business environment
Production Agency/Design Agency coordination and availability of definition and early hardware to support tester development
New capabilities required by emerging programs (e.g., shock, vibration, combined environments)
Difficulty simulating realistic (combined) flight environments</td><td>To maintain the specialized workforce in this area, emphasize level loading of the workload to the extent possible, combined with providing flexibility in assignments. Opportunities for challenging work assignments include the Strategic Partnership Programs.
Deploy Common Tester Architecture.
Provide flexibility in assignment areas.
Better plan and execute resource-loaded program schedules.
Obtain appropriate funding to develop new capabilities.
Ensure milestones for test definitions and early hardware for tester development are included in weapon development schedules
Use RASR [Research and Sounding Rocket] and HOTSHOT [High Operational Tempo Sounding Rocket Flight Test] rocket flight tests to simulate environments.</td><td>Continue current strategies.
Be proactive in identifying and applying technologies and capabilities that offer solutions to enterprise issues.</td></tr>
</table>

<table>
<tr><th colspan="3">Fabrication and Support of Secure Transportation Assets</th></tr>
<tr><td colspan="3">KCNSC prepares Secure Transportation Asset (STA) vehicles in its New Mexico facility, including fabrication, repair, and modification of tractors, trailers, and escort vehicles. KCNSC also supports design, fabrication, and maintenance of multiple system capabilities and facilitates safety engineering; technical documentation; and training of the Federal agents that perform STA functions.</td></tr>
<tr><th rowspan="2">Challenges</th><th colspan="2">Strategies</th></tr>
<tr><th>Current Strategy Being Implemented</th><th>Future Strategies Needed</th></tr>
<tr><td>Manufacturability and sourcing limitations of future secure transportation programs, which could increase cost and schedule risks.
Implementing modifications and upgrades to existing STA systems for compatibility with Integrated Surety Architecture systems.</td><td>Continue partnering with design agencies to ensure that, early in the process, the design work incorporates lessons learned from past trailer production and manufacturability reviews and facilitate multiple-sourcing capabilities to reduce risks and costs.
Early collaboration with design agencies to ensure manufacturability/sourcing risks are minimized.</td><td>Continue current strategies.</td></tr>
</table>

Weapon Component Surveillance and Assessment		
KCNSC supports surveillance and assessment of the Nation's nuclear weapons stockpile through enhanced testing of various weapon components and materials, as well as production of telemetry, JTAs, and other hardware for laboratory and flight testing. The results from those tests are used to demonstrate continued performance of stockpile systems and predict, detect, assess, and resolve aging trends and anomalies in the stockpile. New testing and evaluation methods are also developed and implemented.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
• Long-term sustainment of testers to support weapon life cycle surveillance requirements. • Engaging workforce in older technologies. • Material availability due to sunset technologies for legacy JTA programs.	• Development of a proactive long-term tester sustainment plan and pursuit of appropriate funding sources. • Successfully execute hiring, retention, and knowledge preservation strategies. • Periodically update designs and modernize technology for JTA systems.	• Continue current efforts. • See Chapter 7, Sections 7.4.1-7.4.3, for enterprise workforce strategies.

Metal and Organic Material Fabrication, Processing and Manufacturing		
KCNSC performs R&D activities to identify candidate materials for potential use in stockpile applications. KCNSC partners with the national laboratories to evaluate, select, and qualify new materials for the stockpile, as well as studies and re-engineers obsolete materials that are no longer available to support the legacy stockpile. The site also develops new manufacturing processes for material production and use.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
• Attracting and retaining individuals in specific technology areas. • Materials are no longer available because of obsolescence or supplier interest.	• Partner with universities to identify and develop a pipeline of qualified candidates for potential hiring. • Re-engineer obsolete materials and use microreactors to produce specialty materials in the right quantities and improve safety.	• See Chapter 7, Section 7.4.1, for enterprise workforce recruitment and hiring strategies. • Continue current strategies.

Site-Wide Challenges of the Workforce Associated with Multiple Capabilities		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
• Recruitment and retention of a skilled, diverse, and effective workforce. • Competitive salaries for employers across the region and competition for top talent remain strong. • Extended clearance times. • Limited flexibility due to consumption of office space or non-laboratory production space. • Advanced technology development and emerging programs are driving the need for increased office and manufacturing space.	• Develop innovative methods to shorten clearance times. • Improve onboarding of new staff to meet critical needs. • Implement succession planning and emphasize critical skills bench strength. • Maintain a competitive Total Rewards package. • Maximize the efforts of Career Path and Workforce Agility Teams. • Expand the Manufacturing Innovation Center to prepare and	• See Chapter 7.

	train hourly staff while awaiting clearances. • Hire in advance of needs to allow time for clearance and training. • Partner with university relations programs and third-party targeted recruiting services. • Continue machinist and tool and die maker development program. • Implement advanced manufacturing technologies to regenerate whitespace. • Execute successful move of designated product lines to KCNSC East (Building 23) and subsequent realignment and expansion within current space (Building 2). • Continued planning and analysis of alternatives for securing needed additional workspace.	

JTA = joint test assembly

E.3.1.4 Accomplishments

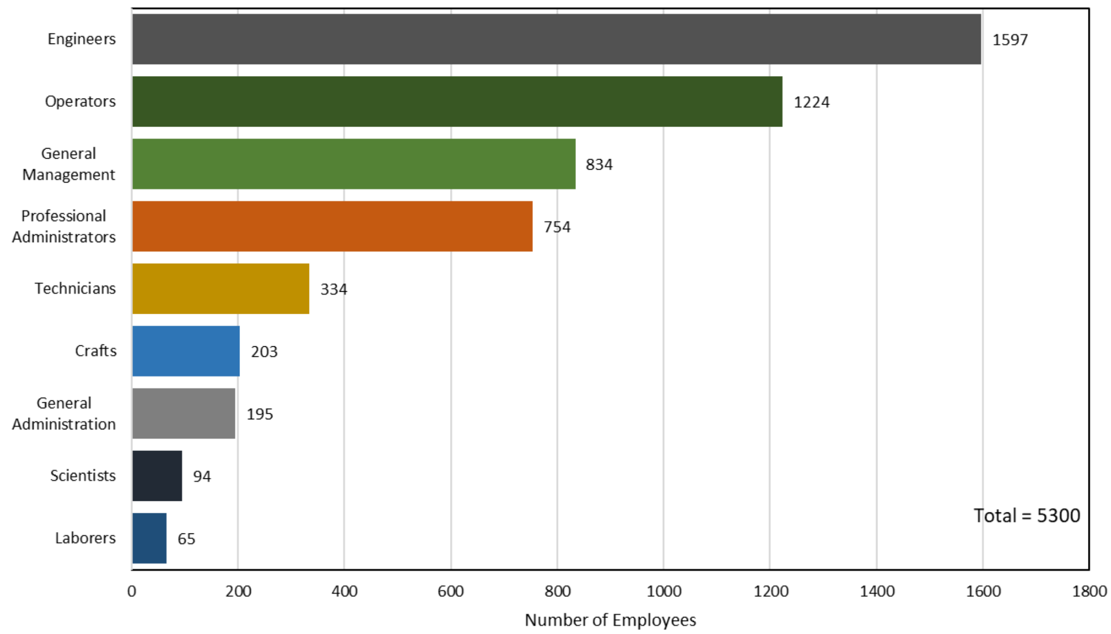
- The B61-12 LEP has completed 112 out of 112 first production units; and completed first production units on all six Respin components (S1 adapter, coded switch, radar, electronics assembly 1, nose bomb subassembly, weapon control unit and the firing control unit). The W88 Alteration (Alt) 370 Program completed six first production units early or on time.
- The W88 Alt 370 Program completed Final Design Review for the Missile Interface and Controller Module, delta Production Readiness Review for the Path Length Module, and six JTA first production units on time or early.
- The B61-12 LEP delivered 91,336 components, and the W88 Alt 370 Program delivered 58,101 components in support of the Defense Programs mission.
- Delivered over 258,900 Defense Programs items in FY 2020.
- Executed seamless 30-day transition of plant leadership with the arrival of the new FM&T president and new Integrated Supply Chain vice president.
- The W76-1 LEP completed all U.S. Program Control Document Requirements, signifying closure of the first major LEP.
- FM&T developed a Category (CAT) Milestone Tracker to monitor and execute NNSA L2 Milestones and CAT milestones. FM&T tracked and managed more than 11,000 CAT milestones in FY 2020 for both stockpile and emerging programs to ensure compliance with customer requirements, increase visibility for critical milestones, and increase execution predictability.
- Achieved a record performance in annual Supply Chain Management Center (SCMC) cost savings and surpassed the $1 billion mark in total (2013–2020) SCMC savings.
- Successfully delivered a short turn request for production of a W78 Neutron Generator Monitor Kit in under 20 days, enabling a Minuteman III Test Flight.

- Effectively executed B83 Stockpile Management prototype flex circuits shipment requests in under a four week turnaround time, enabling the Issue Resolution Group to meet the aggressive First Production Capability Unit schedule.
- Shipped 26+ H1514C containers supporting W88 Stockpile Management production at Pantex and supported the Alt 370 First Production Capability Unit.
- Implemented W80-4 New Product Introduction initiatives that validated FY 2020 cost avoidance at $10.5 million, with $4.2 million in cost avoidances from commercial off-the-shelf parts, and the remaining cost avoidances from cycle time reductions, defect reductions, and improved producibility.
- Completed 16 Conceptual Design Reviews, 28 Conceptual Design Gates, two Component Requirements Reviews, and two Baseline Design Reviews on time to support the FY 2020 high-priority items per DOE/NNSA's "Getting the Job Done" list on the W80-4 Program.
- KCNSC W87-1 team successfully executed Weapon Design Cost Report kickoffs incorporating several improvements and lessons applied, including Production Strategy and Design Definition Package templates, early milestone and funding alignment, reimbursable process improvements, hardware traceability, and early demand visibility.
- FM&T completed Quality Evaluation Release for use of a microreactor process in production of the curing agent Hylene MP; a first for the nuclear security enterprise. The microreactor process was subsequently baselined for the W80-4, avoiding approximately one year of delay to the program.
- FM&T collaborated with a university partner to mature femtosecond (fs) laser machining technology. This laser-assisted technology enables highly accurate machining for gauges and parts to produce results that are unattainable by traditional manufacturing methods. FM&T evaluated new opportunities for combining fs laser-assisted machining capability with metal additive manufacturing, a combination with potential uses in marking soft materials like silicone pads and cushions.
- FM&T teamed with two university partners in the successful launch of six Research and Sounding Rockets (RASR) tests. The RASR program helped KCNSC lead the nuclear security enterprise to a more rapid, high-tempo, and digital future, enabling improved readiness for new technology insertions.
- Completed transition to the KCNSC North facility to support 300+ employees, per plan; initiated a Capital Lease in support of light manufacturing space at KCNSC East.
- Executed 100 percent of Kansas City Short-Term Expansion Program CAT milestones planned for FY 2020; this program remains on-track with the budget and schedule.
- Achieved a Total Recordable Case rate of 0.25 and a Days Away, Restricted, or Transferred case rate of 0.12. The Total Recordable Case rate was a benchmark when compared to federal contractors and similar commercial industry.
- KCNSC increased its headcount by over 27 percent over the last two fiscal years to support production for the B61-12 LEP, W88 Alt 370 Program, and Mk21 fuse, as well as development of the W80-4 LEP, W87-1 Modification Program and other future programs.
- New Mexico Operations built hardware for the Test Article 2 for MGT, per DOE/NNSA's "Getting the Job Done" list.

- FM&T was assigned responsibility for the Integrated Surety Architecture Hub. New Mexico Operations completed lease for a new facility, developed a cost estimate for FY 2020-FY 2026, and developed a schedule for standing up the capabilities necessary to meet DOE/NNSA requirements for the Hub.
- FM&T fostered a strong culture of innovation and intellectual property development through transformative research results, including: 119 invention disclosures, 43 patent applications, and 28 patents issued in FY 2020.
- FM&T manages a resilient supply base to support the mission. KCNSC onboarded eight new suppliers and held a virtual Supplier Summit attended by over 180 suppliers and leaders across the nuclear security enterprise.
- Received four Office of Safety, Infrastructure, and Operations Excellence awards for work at KCNSC and in support of NNSA's mission at other nuclear security enterprise sites.
- Exceeded NNSA Integrated Milestone Schedule performance goals on the W80-4 for Milestone Matching (99.1 percent vs. 95 percent) and Target Date Alignment (96.2 percent vs. 95 percent).
- Participated in Science, Technology, Engineering, Math, and Manufacturing Outreach; to develop the next generation of diverse nuclear security enterprise leaders. FM&T awarded 38 scholarships for students in the Kansas City and Albuquerque communities. Recipient groups included Latinx, Black Achievers, Women in Engineering, and Honeywell Opportunity for Prosperity through Education scholars.

E.3.1.5 Kansas City National Security Campus Workforce

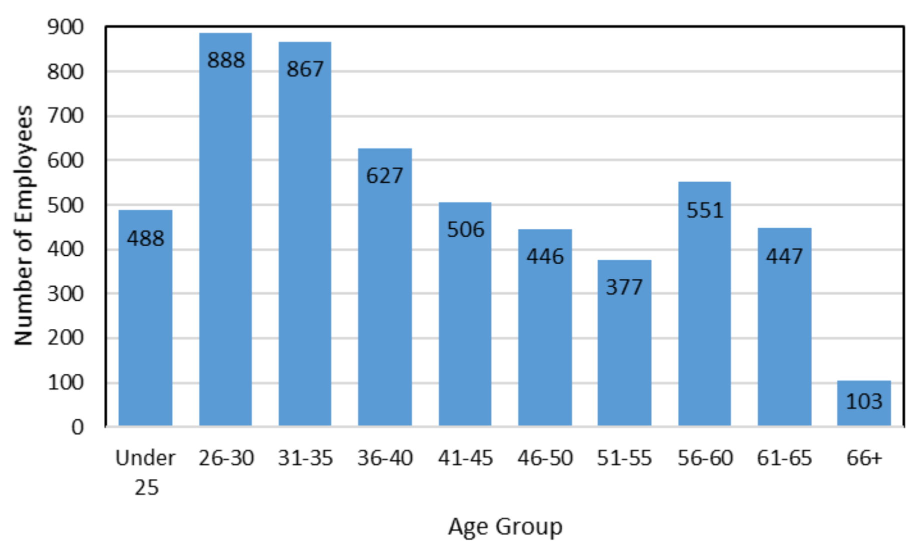
KCNSC has 5,300 employees (census as of end of FY 2020), with an average age of 41.8 years. Two-thirds (67.3 percent) of the employees have 5 years or fewer years of service, and over three-quarters (77.8 percent) have 10 years or less of service. Approximately 16 percent of the KCNSC workforce is eligible to retire. In the past year, KCNSC has hired 637 new employees and experienced 319 separations for a net gain of 318 employees. Over half (56.74 percent) of the 319 separations involved employees with 5 years or fewer years of service, and many were voluntary. The number of early- and mid-career employees has continued to steadily increase since FY 2014. The number of advanced- career employees has continued to remain fairly flat, but the percentage of advanced-career employees of the total population has decreased from about 53 percent in FY 2014 to about 28 percent in FY 2020. KCNSC continues to add staffing to support the forecasted workload for legacy systems, LEPs, and Alts. Workforce demographics are illustrated and discussed in **Figures E–33** through **E–41**.



Notes:

KCNSC has seen steady growth across all of the COCS codes as it continues transitioning into the production phase of B61-12 LEP, W88 Alt 370 Program and Mk21 Fuze. KCNSC is also continuing active development for the W80-4 and is beginning development of W87-1. Overall headcount is up 27 percent from FY 2018 (an increase of 1,144 employees). Production operators continue to make up about 23 percent of the headcount, and engineers/scientists continue to make up about 30 percent.

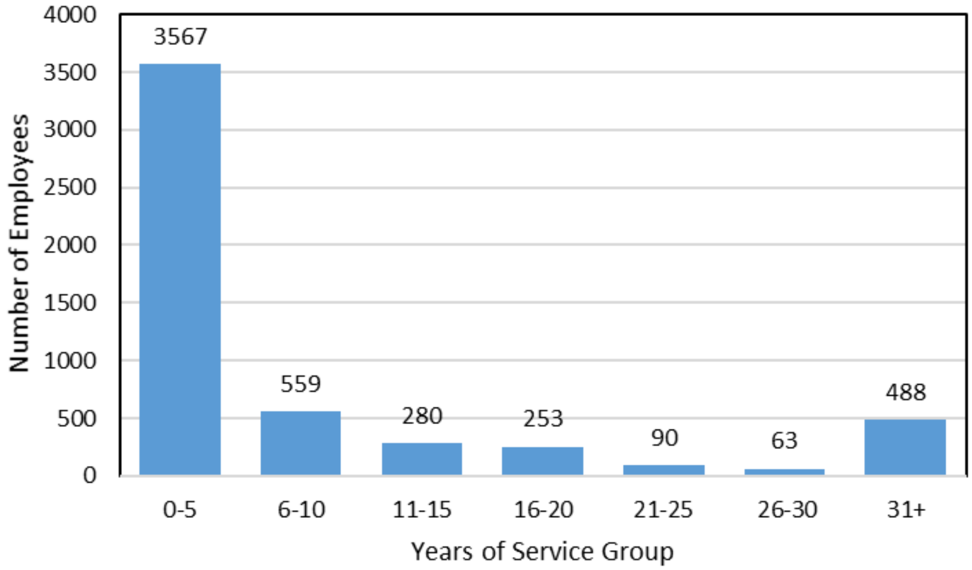
Figure E–33. KCNSC workforce by Common Occupational Classification System (as of September 30, 2020)



Notes:

The average age of plant employees continues to decrease from approximately 43 in FY 2018 to 42 in FY 2020. There has been a shift in employee count from employees in their early 30s and late 50s in FY 2018 to the late 20s and early 30s in FY 2020. Retirement eligibility decreased from 23 percent in FY 2018 to 16 percent in FY 2020.

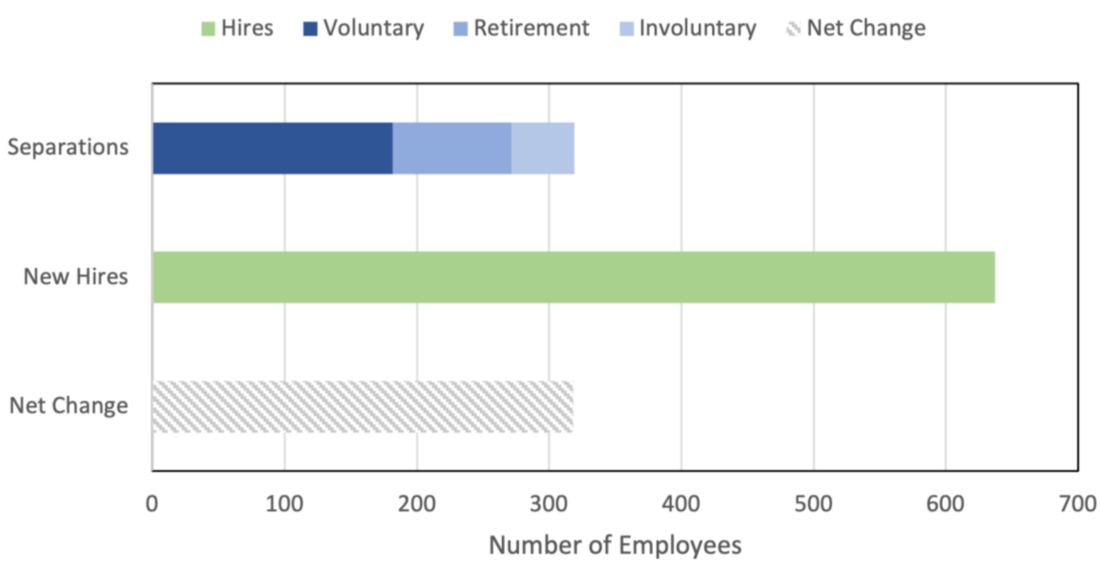
Figure E–34. KCNSC workforce distributed by age group (as of September 30, 2020)



Notes:

Over two-thirds (67.3 percent) of employees have less than 5 years of service, an increase compared to FY 2018 at 58 percent for the same years of service group. Average years of service increased to approximately 10 in FY 2020 from 8 in FY 2018.

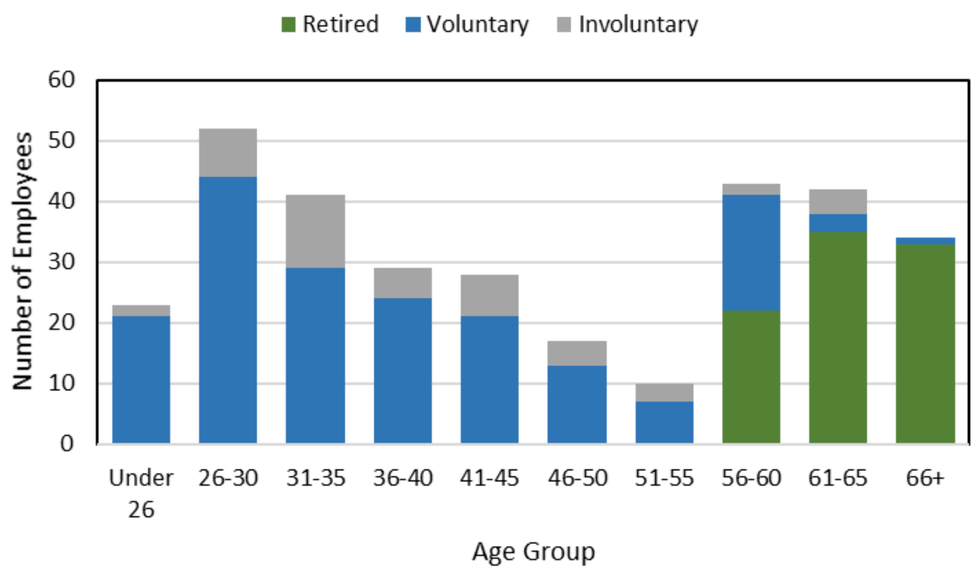
Figure E–35. KCNSC workforce distributed by years of service group (as of September 30, 2020)



Notes:

KCNSC hired 637 employees in FY 2020, but due to 319 separations, there was only a net increase of 318 employee.

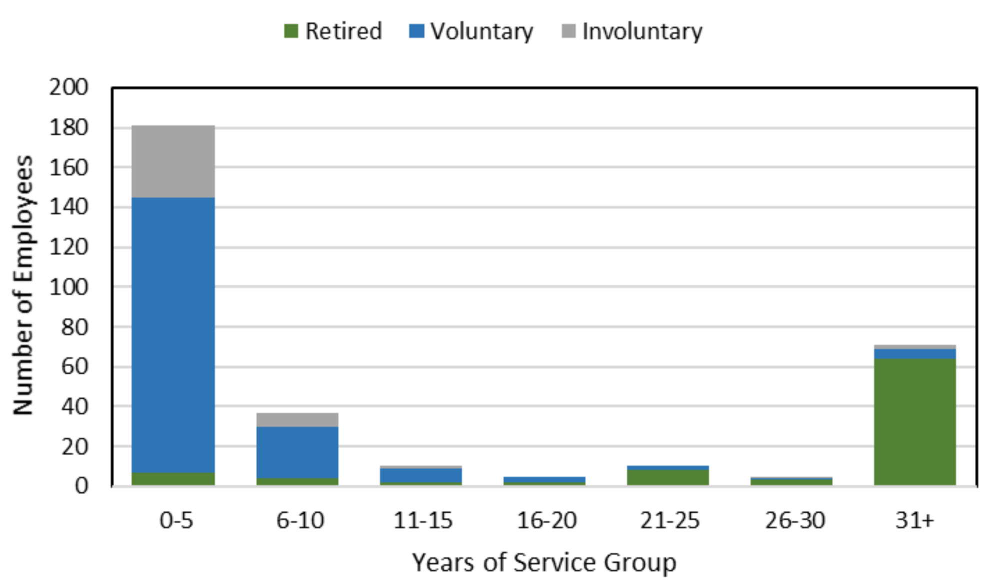
Figure E–36. KCNSC net change for fiscal year (as of September 30, 2020)



Notes:

Of the 319 separations in FY 2020, 40 percent were greater than 50 years of age and 36 percent were less than 35 years of age, compared to FY 2018, when 48 percent of the 605 separations were greater than 50 years of age, and 34 percent were less than 35 years of age. The possible influence of the COVID-19 epidemic may have impacted separation decisions.

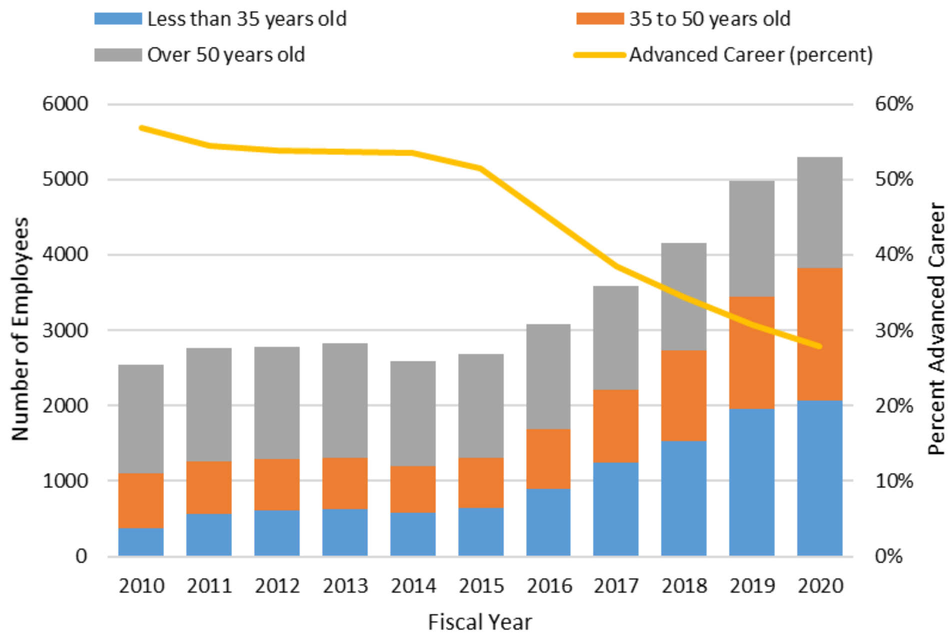
Figure E–37. KCNSC employee separations by age group (as of September 30, 2020)



Notes:

More than half (57 percent) of the 319 separations were within the 0–5 years of service group in FY 2020, compared to 47 percent in FY 2018. Two-thirds (68 percent) of separations were employees with 10 years of service or less, compared to 55 percent in FY 2018. The impacts of COVID-19 may have affected retirement and company transfer decisions.

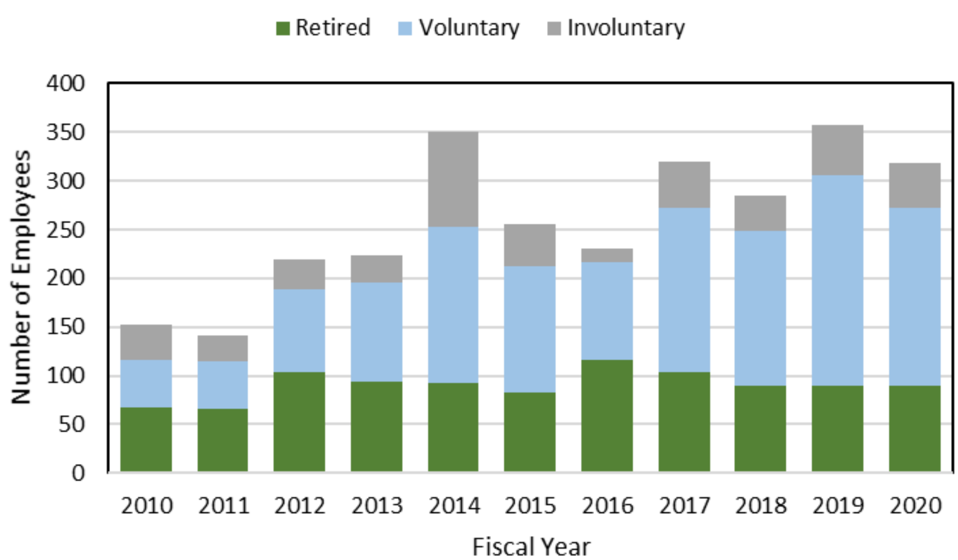
Figure E–38. KCNSC employee separation by years of service group (as of September 30, 2020)



Notes:

The total number of employees in the over 50 years old participation group has remained relatively consistant, but the percentage of individuals in their advanced career is half what it was 10 years ago. This would seem to reflect not only younger employee hiring needs being met, but also employee movement into the 35 to 50 year participation group as individuals over 50 years old retire.

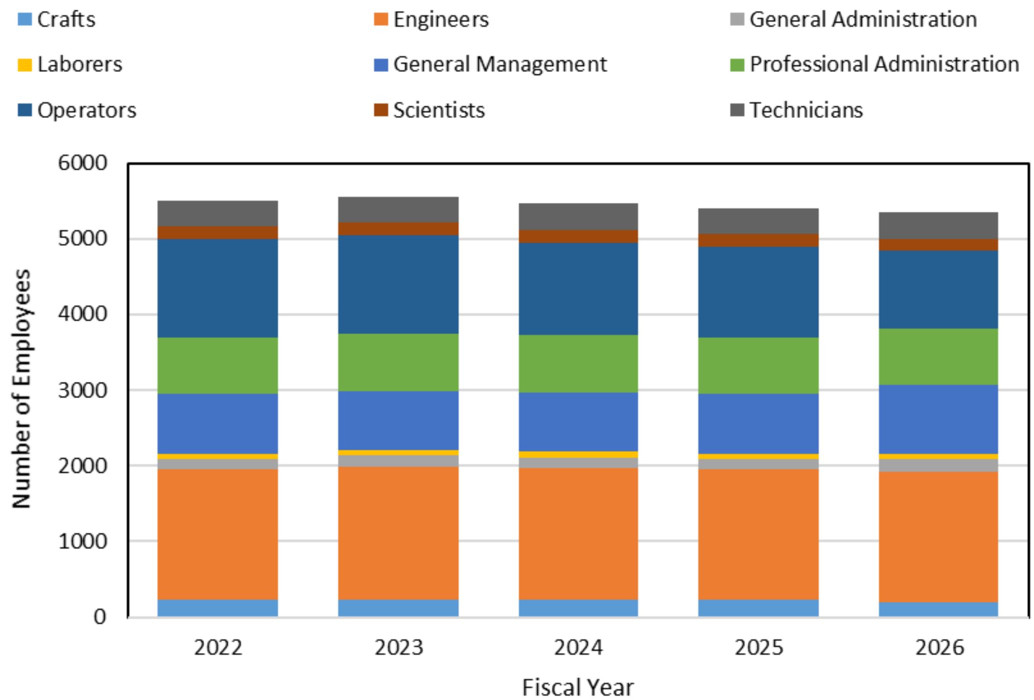
Figure E–39. KCNSC workforce participation trends by age category and percent advanced-career (as of September 30, 2020)



Notes:

The number of employees who left voluntarily continues on an upward trend, but is down from FY 2019. Retirements have remained relatively consistent over the last 3 fiscal years.

Figure E–40. KCNSC employee separation trends



Notes:

Facilities and infrastructure are a limiting factor on workforce growth. Projections reflect early business cycle preliminary estimates.

Figure E–41. KCNSC workforce projection needs by Common Occupational Classification System

E.3.2 Pantex Plant

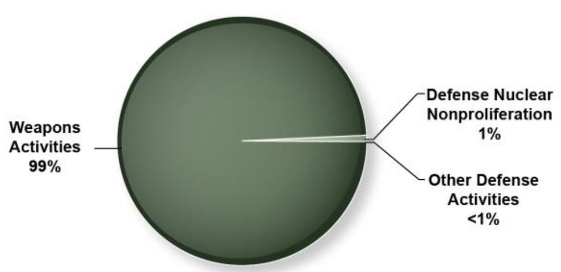
E.3.2.1 Mission Overview

The Pantex Plant (Pantex) located outside of Amarillo, Texas, is the only DOE/NNSA site authorized to assemble or disassemble nuclear weapons and, as DOE/NNSA's High Explosive Production Center of Excellence, has cradle-to-grave responsibilities for high explosive (HE) production. As a collaborative partner with the national security laboratories, Pantex provides capabilities to transition HE R&D from bench-scale to production-scale. In addition, Pantex collaborates and provides capabilities to DoD, the United Kingdom, universities, and commercial vendors. Pantex also supports the reduction of global nuclear threats through its nonproliferation activities.

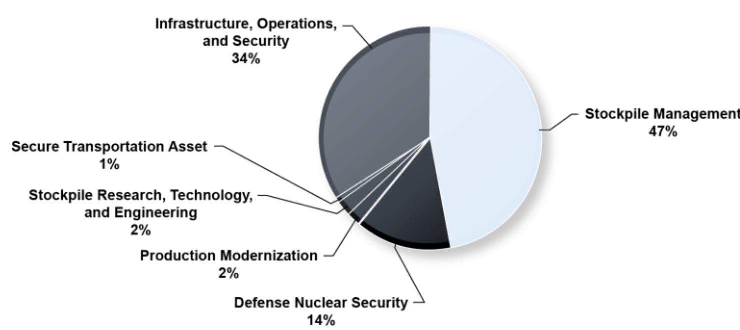
- Location: Amarillo, Texas
- Total Employees: 3,623 (as of the end of FY 2020)
- Type: Single-program nuclear weapons production facility
- Website: www.pantex.energy.gov
- Contract Operator: Consolidated Nuclear Security, LLC (CNS), a corporate subsidiary of Bechtel National, Leidos, ATK Launch Systems, and SOC, LLC[1]
- Responsible Field Office: NNSA Production Office

E.3.2.2 Funding

FY 2022 request – site funding by source
(total Pantex FY 2022 request = $1,016 million)



Pantex split for the FY 2022 Weapons Activities President's Budget Request *($1,009 million)*



[1] On November 29, 2021, DOE/NNSA announced that Nuclear Production One (NPOne), a limited liability company consisting of Fluor Federal Services and AECOM Energy and Construction, was selected as the new management and operating contractor for the Y-12 and Pantex production facilities. A four-month transition period will begin in December.

E.3.2.3 Site Capabilities

Pantex's mission capabilities include manufacture of specialty explosives; fabrication and testing of HE components; assembly, disassembly, refurbishment, maintenance, and surveillance of weapons and weapon components; dismantlement of retired weapons; sanitization and disposition of components from dismantled weapons; interim staging and storage of nuclear components from dismantled weapons; pit requalification; pit surveillance; and pit packaging (including container surveillances and recertification).

Pantex's key capabilities and their associated challenges and strategies are described in **Table E–5**.

Table E–5. Pantex Plant capabilities

Weapons Assembly and Disassembly		
Assembly and disassembly of nuclear explosive warheads and bombs, assembly and post-mortem analysis of joint test assemblies (JTAs), assembly and disassembly analysis of test bed units, and electrical and mechanical tests of weapons and weapon components.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Development, establishment, and implementation of the Documented Safety Analysis process for new programmatic weapons activities.	While vast improvements have been made, continue to streamline the Documented Safety Analysis process methodology for efficiency and effectiveness.	Continue current strategy.
Weapons Assembly/Disassembly facilities continue to age and will require replacement at some point.	Continue modernizing the existing bays and cells. Conduct aging studies and develop strategy and required timing for replacement of the bays and cells with new, modern assembly/disassembly facilities.	Continue current strategies.
Surveillance		
Nondestructive evaluation of pits and weapon components from stockpile units to support the Annual Assessment Reports and destructive and nondestructive evaluation of HE from stockpile units.		
Challenges	***Strategies***	
Production downtime associated with aging pit surveillance equipment.	***Current Strategy Being Implemented***	***Future Strategies Needed***
	Develop and evaluate options for upgrading or acquiring replacement equipment.	Continue current strategy.
High Explosives		
Pantex is responsible for HE pressing, assembly of mock HE for JTAs, assembly of conventional high explosives and insensitive high explosives for LEPs and stockpile rebuilds, and disassembly and disposition of HE from surveillance and dismantlement units.		
Challenges	***Strategies***	
Programmatic infrastructure (i.e., equipment) is aging, and some of the general-purpose infrastructure (i.e., buildings) is Manhattan-era.	***Current Strategy Being Implemented***	***Future Strategies Needed***
	Planned projects, High Explosive Science and Engineering, HE Synthesis, Formulation, and Production, and the HE Component Assembly facilities are planning recapitalization of end-of-life equipment needs and establishing major modernization plans. Continue replacement of end-of-life HE machining equipment.	Continue line item planning, and coordination with DOE/NNSA. Initiate construction of replacement HE facilities.

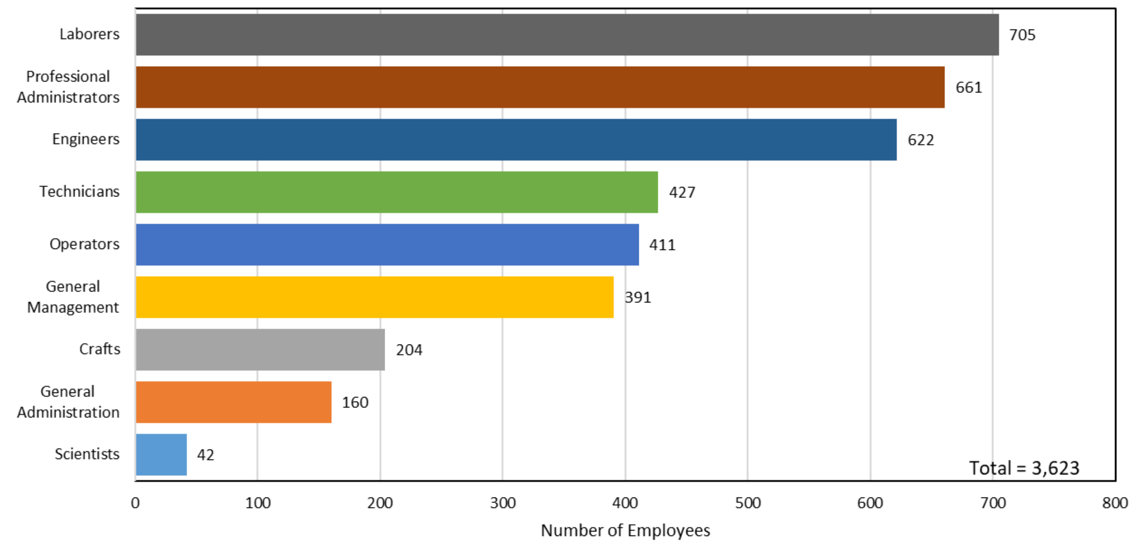
Special Nuclear Material Accountability, Storage, Protection, Handling, and Disposition		
These capabilities involve requalification for pits for LEPs and storage of pits and weapons.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Pit storage capacity to support future directed stockpile work and production downtime associated with aging pit requalification equipment.	Implement pit staging projects to reconfigure operational facilities to increase the site storage capacity to address near-term staging constraints until the Material Staging Facility project is re-started. Deploy new requalification equipment for upcoming LEPs. Upgrade existing requalification equipment.	Continue implementation of pit staging projects and equipment upgrades.

E.3.2.4 Accomplishments

- Completed the W76-2, providing the Navy with a low-yield, sea-launched ballistic missile warhead capability.
- Delivered First Production Capability Units for both the B61-12 LEP and the W88 Alt 370 Program.
- Exceeded baseline deliverables on both the W80 Alt 369 (104 percent) and W87 limited life component exchange (104 percent) programs.
- Broke ground on the Flexible Support Facility; completed design on the High Explosive Science and Engineering Facility and received CD-3A approval; and submitted the CD-1 conceptual design package for the High Explosives Synthesis, Formulation, and Production Facility.

E.3.2.5 Pantex Plant Workforce

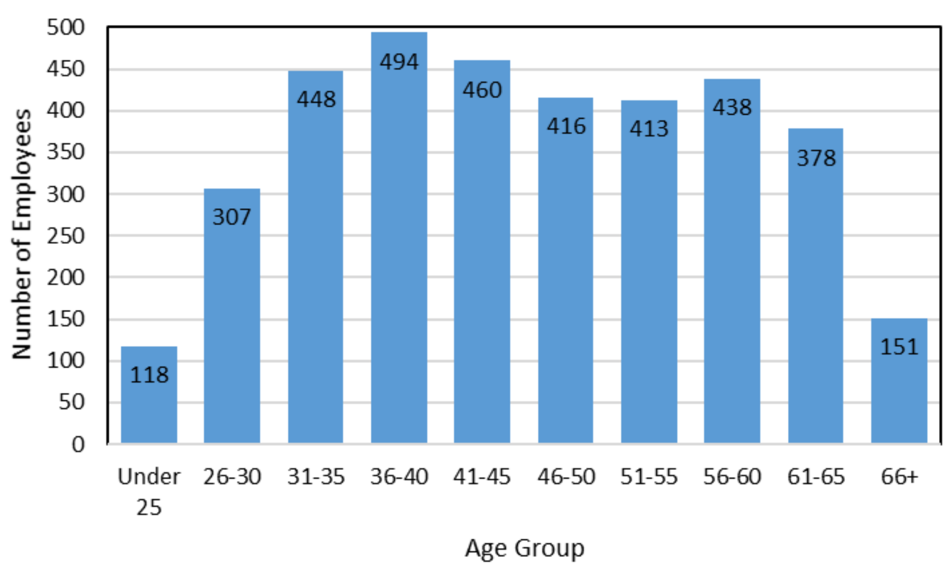
Pantex's headcount at the end of FY 2020 was 3,623. The average age is 46 years, with approximately 24 percent of the employees being retirement-eligible. Most employees are between 31 and 65 years of age. The average years of service is 12.5 years, and most employees have 1-5 years of service. In FY 2020, Pantex had an overall increase of 132 employees. Retirement of older, advanced-career employees accounted for most of the separations, while those with fewer years of service accounted for more voluntary separations. Since FY 2017, the percentage of advanced-career employees has declined, while early and mid-career employees have increased. Workforce demographics are illustrated and discussed in **Figures E–42** through **E–50**.



Notes:

Total headcount increased from 3,491 at the end of FY 2019 to 3,623 at the end of FY 2020. Significant recruiting and hiring efforts replaced vacancies from attrition and built the technical skill base in preparation for the increased workload in FY 2021 and beyond. FY 2021 will focus on hiring in preparation of increasing weapons workload. This will include acquiring the necessary security clearances and developing new talent. The most significant increases were in engineers, security, professionals, and technicians. This as a positive change, enabling CNS to have the technical skills needed to fulfill mission work.

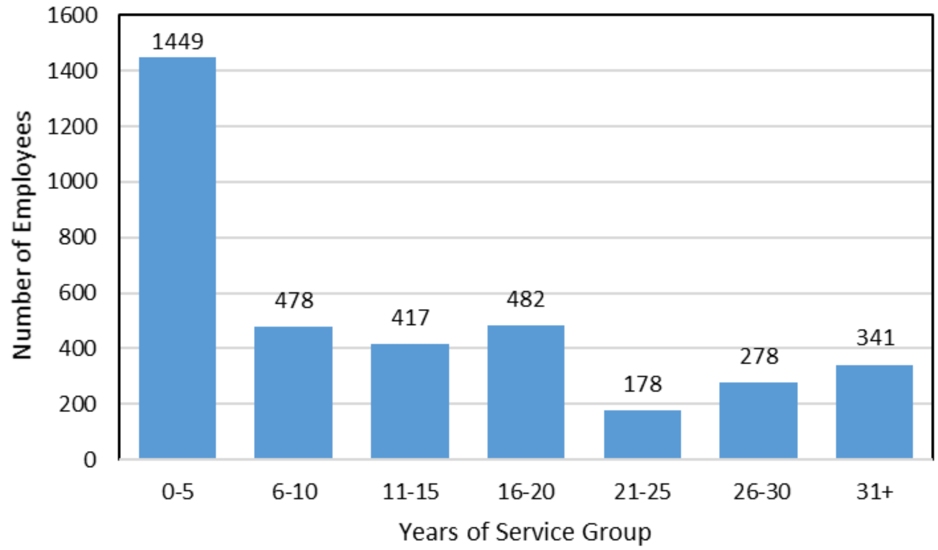
Figure E–42. Pantex workforce by Common Occupational Classification System (as of September 30, 2020)



Notes:

The average age of the Pantex workforce is 46 years old. The percentage eligible to retire at Pantex dropped from FY 2019 at 26.55 percent to 24 percent in FY 2020 due to increased hiring and replacement of retirees. Age diversity is well distributed. Many employees elect to work beyond their earliest eligibility retirement age. Pantex remains one of the best employers in the area. Crafts, labor, operators, technicians, and clerical staff are hired locally and tend to remain until retirement.

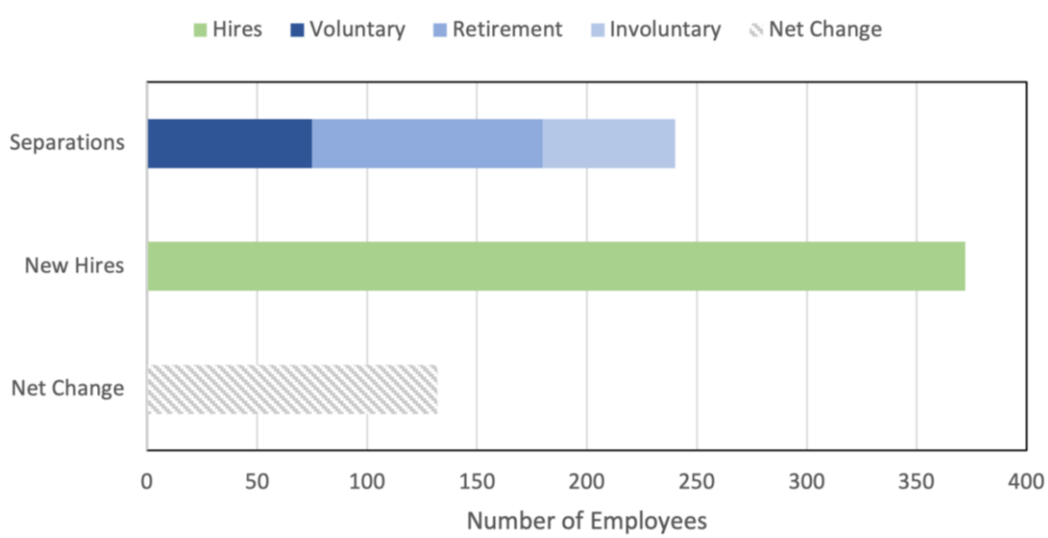
Figure E–43. Pantex workforce distributed by age group (as of September 30, 2020)



Notes:

The average years of service at Pantex is 12.5 down from 13.3 due to the increase in hires, as seen in the 0-5 years of service group. This indicates that Pantex is replenishing its workforce for future needs and offsetting attrition due to retirements and other separations.

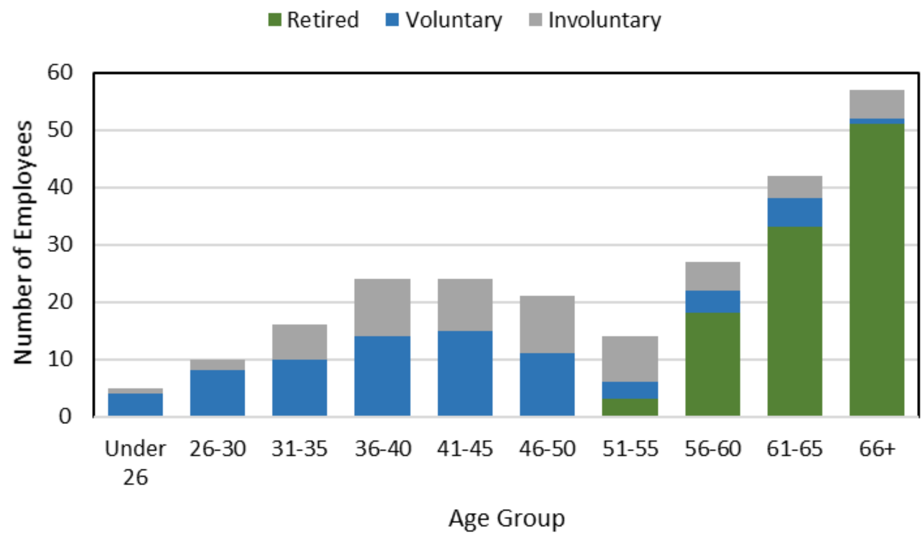
Figure E–44. Pantex workforce distributed by years of service group (as of September 30, 2020)



Notes:

FY 2020 was a strong year for recruiting, with a net gain of 132 employees. Pantex and the Y-12 National Security Complex combined efforts for virtual recruiting during the COVID-19 pandemic. SuccessFactors, a new consolidated application system, was implemented, streamlining the application and hiring process and improving the overall candidate experience. CNS joined the nuclear security enterprise in joint virtual and in-person recruiting initiatives at military bases and top schools pre-pandemic. Additionally, CNS contracted with Shaker Recruitment Marketing to enhance visibility nationally. Candidate sourcing was expanded to LinkedIn, Indeed, and Glassdoor. Competitive pay and benefits aid in offer acceptance and retention of talent.

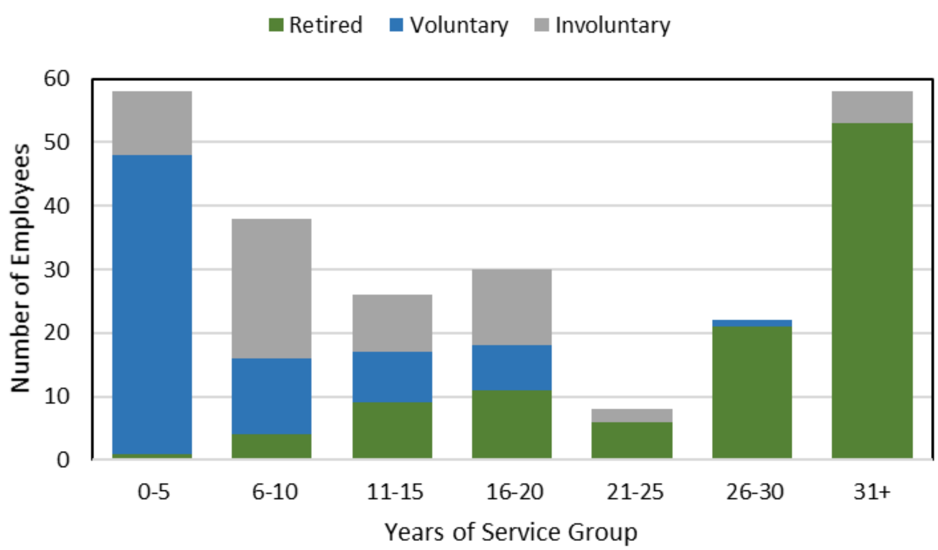
Figure E–45. Pantex net change for fiscal year (as of September 30, 2020)



Notes:

Those leaving under age 35 are typically engineers or professionals who are more mobile. Factors include location, electronics restrictions, security clearances, and national competition for these skills. A large proportion of employee separations over 60 years old is due to retirement.

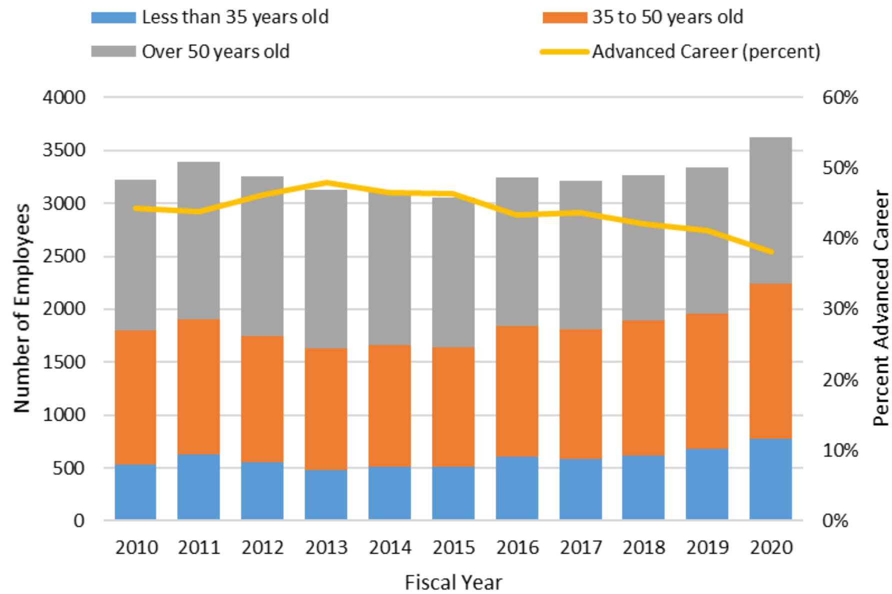
Figure E–46. Pantex employee separations by age group (as of September 30, 2020)



Notes:

The majority of those leaving after from 0-5 years of service are engineers or professionals under age 35 who are early in their career and more mobile. There are several factors that impact retention for this group: (a) location and commute are less desirable than competition; (b) electronic restrictions for iPhones, iPads, etc.; (c) waiting for security clearances can cause professionals to lose interest; and (d) other high-tech industries compete for the same skilled professionals. To address these concerns, CNS increased teleworking for select positions; improved work environments; implemented talent management opportunities for career development; improved clearance processing cycle time by increasing investigators to address the volume of hiring; and re-designed compensation to attract and retain critical skills. Those separating after over 20 years of service are typically retiring.

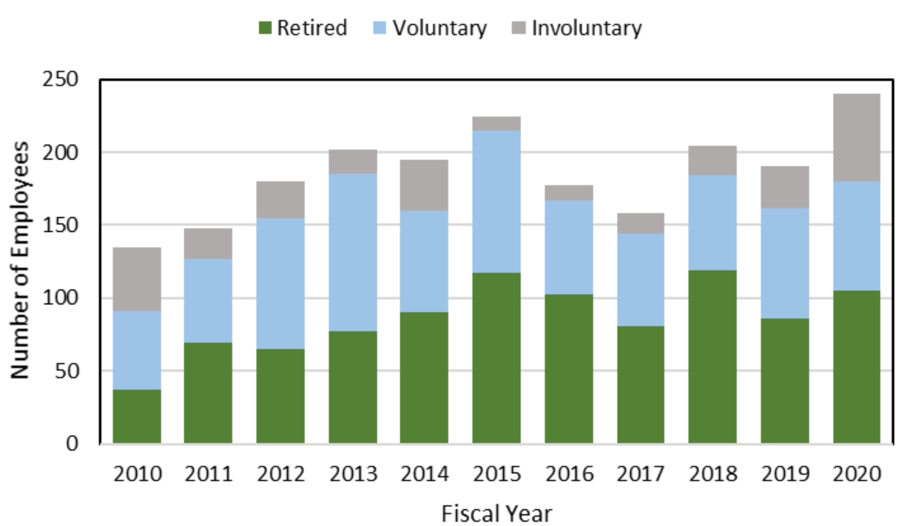
Figure E–47. Pantex employee separation by years of service group (as of September 30, 2020)



Notes:

The total Pantex employee population grew specifically among employees less than 50 years old due to increased hiring and low attrition. Many employees over 50 years old are electing to work longer. For the first time in 10 years, workforce participation in the 35-to-50-years-old range surpassed employee participation in over 50 years old.

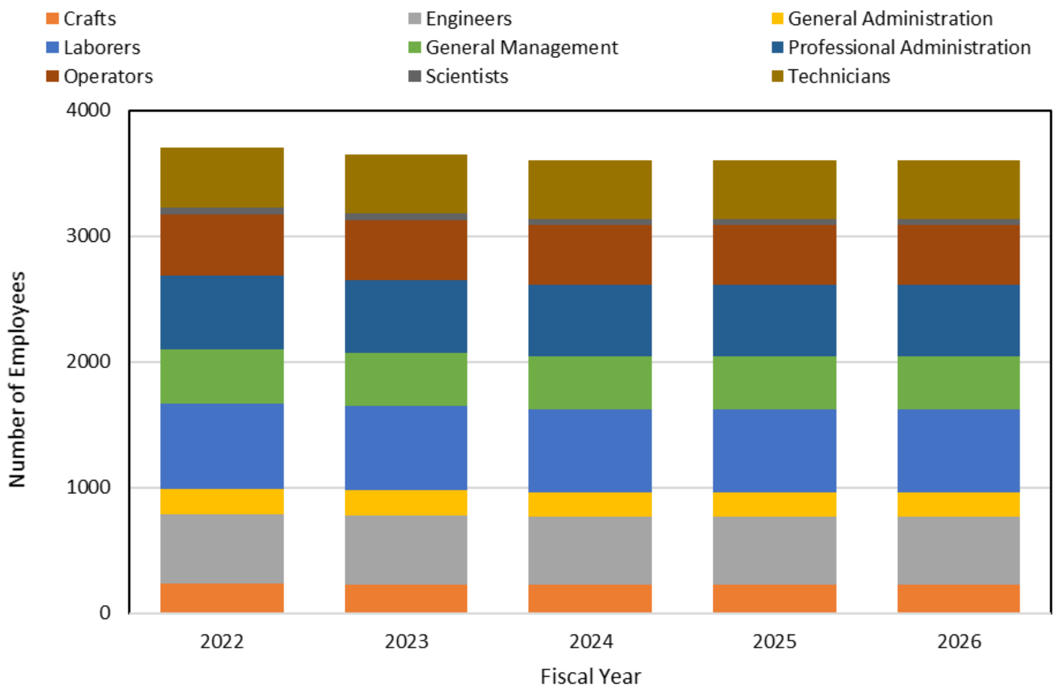
Figure E–48. Pantex workforce participation trends by age category and percent advanced career (as of September 30, 2020)



Notes:

Just under half (43.75 percent) of separations are due to retirements. The average age of retirees is increasing as retirement-eligible employees are electing to work longer. Several factors may be considered for this shift such as better health, cognitive activity, opportunity to telecommute and uncertainty about the COVID-19 pandemic and the impact on travel, family and the economy. Those now turning 65 typically work until 66+ to receive full social security benefits. Pension plans were phased out for new hires around 2012 and replaced by enhanced 401(k) plans for retirement planning. This change removed the perceived retirement trigger (pension eligibility at age 55 with 10 years of service) for those hired after 2012. Retention efforts have been successful, which is a positive trend.

Figure E–49. Pantex employee separation trends



Notes:

The total estimated number of personnel needed to support work in the near term is relatively static. CNS anticipates hiring for attrition replacement with emphasis on engineers, safety basis personnel, IT, technicians, and Security Police Officers. Technicians and Security Police Officers are usually filled from the local market and military. Engineers, IT, and safety basis personnel are being recruited from job fairs and universities. Internal realignment is used in some cases to fill critical vacancies. Plant attrition is expected to remain low, around 5 percent – 6 percent. Crafts, technicians and administration personnel typically have lower attrition, while engineers have higher attrition due to national demand. This is an ongoing concern, as other technology companies are competing for the limited market of engineering and technology skillsets. Based on current hiring/termination statistics, CNS anticipates gaps in engineering, safety basis, IT, risk management, and fire protection in the next 10 years. CNS is using national recruiting search engines and working closely with universities and military bases to help fill the pipeline for engineers and technology for years to come.

Figure E–50. Pantex workforce projection needs by Common Occupational Classification System

E.3.3 Savannah River Site

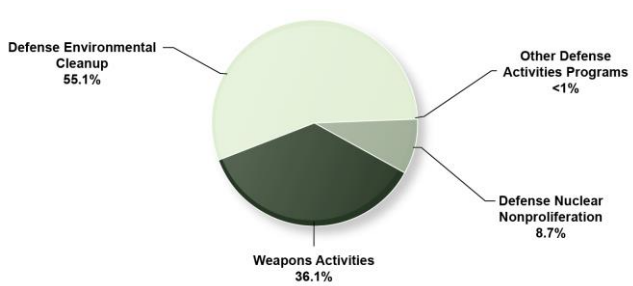
E.3.3.1 Mission Overview

The Savannah River Site (SRS), which spans Aiken, Allendale, and Barnwell Counties in South Carolina, includes mission areas in tritium supply, stockpile maintenance, stockpile evaluation, tritium R&D, and helium-3 recovery. SRS is managed by the DOE Office of Environmental Management with DOE/NNSA as a tenant, making it unique across the nuclear security enterprise sites. Approximately 35 percent of the SRS M&O workforce is dedicated to NNSA missions. DOE/NNSA pays its share of an indirect allocation for personnel to maintain infrastructure and services (e.g., roads, steam, fire water, electricity, medical, emergency services personnel). The scope of Defense Programs work resides in the Savannah River Tritium Enterprise[1] (SRTE), which is managed as a separate entity within SRS, and through the Plutonium Sustainment Program and the proposed Savannah River Plutonium Processing Facility (SRPPF).

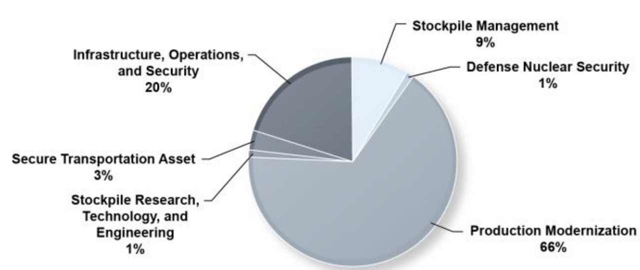
- Location: Aiken, South Carolina
- Total Employees: 885 (82 Plutonium, 803 SRTE at the end of FY 2020)
- Type: Multi-program site; DOE's Office of Environmental Management is the SRS landlord; NNSA is a tenant on site
- Website: www.srs.gov and www.savannahrivernuclearsolutions.com
- Contract Operator: Savannah River Nuclear Solutions, LLC (SRNS; Fluor, Honeywell, Huntington Ingalls Industries)
- Responsible Field Office: Savannah River Field Office

E.3.3.2 Funding

FY 2022 request – site funding by source
(total SRS FY 2022 request = $2,860 million)



SRS split for the FY 2022 Weapons Activities President's Budget Request *($1,098 million)*



[1] SRTE is the collective term for the facilities, capabilities, people, and expertise at SRS related to tritium, and the SRTE umbrella extends beyond the tritium area to include vital mission-support functions. Unless otherwise noted, the information in this appendix will reference SRTE.

E.3.3.3 Site Capabilities

SRS has unique capabilities related to nuclear weapon LLCs and the broader national security mission of reducing global nuclear security threats to the United States and its allies. Tritium is a critical component of the Nation's defense systems and must be continually replenished to meet deterrent needs. SRS conducts large-scale tritium operations, and SRTE is the DOE/NNSA Center of Excellence Involving Large Quantities of Tritium. To sustain the tritium inventory, tritium is recovered from two sources: end-of-life GTS reservoirs that are returned to SRS and irradiated tritium-producing burnable absorber rods (TPBARs) received from the Tennessee Valley Authority.

SRPPF will support plutonium pit production by repurposing the former Mixed Oxide Fuel Facility (MFFF) into a safe, secure, compliant, and efficient pit production facility. 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. As described in Chapter 3, Section 3.2.1.3, SRPPF will provide a sustained production capacity of no fewer than 50 War Reserve pits per year as close to 2030 as possible at SRS.

SRS's key capabilities and associated challenges and strategies are described in **Table E–6**.

Table E–6. Savannah River Site capabilities

Tritium Recycling (Tritium Recycle and Recovery Program)		
Systems for recovering and recycling tritium from returned GTS reservoirs.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Tritium inventory systems contain LLCs, many of which are nearing life expectancy. Recovering the contents of the LLCs requires careful planning and coordination to avoid mission interruption.	In the short-term, schedule replacement projects to maximize efficiency and reduce impact on operating schedules.	In the long-term, deploy new technologies to enhance system operating efficiency and reduce footprint.
Tritium Extraction (Tritium Modernization Program)		
Tritium extraction from irradiated TPBARs.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
To meet supply requirements, SRTE requires additional workforce with training, qualifications, and proficiencies.	SRTE examines multi-year staffing needs and develops appropriate processes to ensure a continuous pipeline of knowledge, skills, and abilities to sustain tritium capabilities.	Continue to examine multi-year staffing needs and work on retention of current employees by leadership engagement and focus on career development.

Replenishing Tritium in Gas Transfer System Reservoirs		
Replenishing tritium in GTS reservoirs.		
	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Maintain facilities and equipment to support stockpile deliverables and future warhead modernization activities.	SRTE uses a strategic investment process and prioritizes its infrastructure needs to ensure mission continuity. Priorities are identified through engineering analysis and risk assessment, vetted by leadership teams, and captured on a strategic roadmap. This process also includes infrastructure and equipment improvements.	Revitalizing SRTE infrastructure includes (1) relocating and right-sizing remaining operational functions from functionally obsolete facilities into existing and new space via the Tritium Responsive Infrastructure Modifications (TRIM) program and (2) recapitalizing and sustaining enduring facilities. TRIM consists of one line-item project (the Tritium Finishing Facility,) and a suite of minor construction and operating expense-funded projects. The Tritium Finishing Facility will replace the Cold War-era H-Area Old Manufacturing Facility.
Addressing infrastructure needs in a high-hazard area without interrupting the mission schedule while adapting for multiple, more complex operations.	SRTE is modifying the process and infrastructure equipment and executing a strategic investment process to ensure continuity. SRTE is also evaluating critical systems to ensure optimal product capacity while carefully planning the production outages to maximize benefit.	Continue current strategy.

Gas Transfer System Surveillance and Tritium Research and Development		
SRTE function testing for GTS surveillance and tritium R&D.		
	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Maintain original function test equipment.	SRTE is initiating R&D projects and transitioning to an extended schedule that will allow additional enhanced operations to eliminate the potential for capacity constraints.	Execute R&D projects.

SRS Plutonium Modernization		
Proposed pit production mission at Savannah River.		
	Strategies	
Challenges	***Current Strategy Being Implemented***	***Future Strategies Needed***
Repurposing of the former MFFF at SRS to achieve a production rate of 50 ppy as close to 2030 as possible.	Implement a tailored approach to achieve CD-1 (*Approve Alternative Selection and Cost Range*)/CD-2 (*Approve Performance Baseline*) and CD-3A Long Lead Procurements, to support producing 50 War Reserve ppy as close to 2030 as possible.	Re-establish the supply chain for weapons-related components and commodities needed to support the 50 ppy mission.

E.3.3.4 Accomplishments

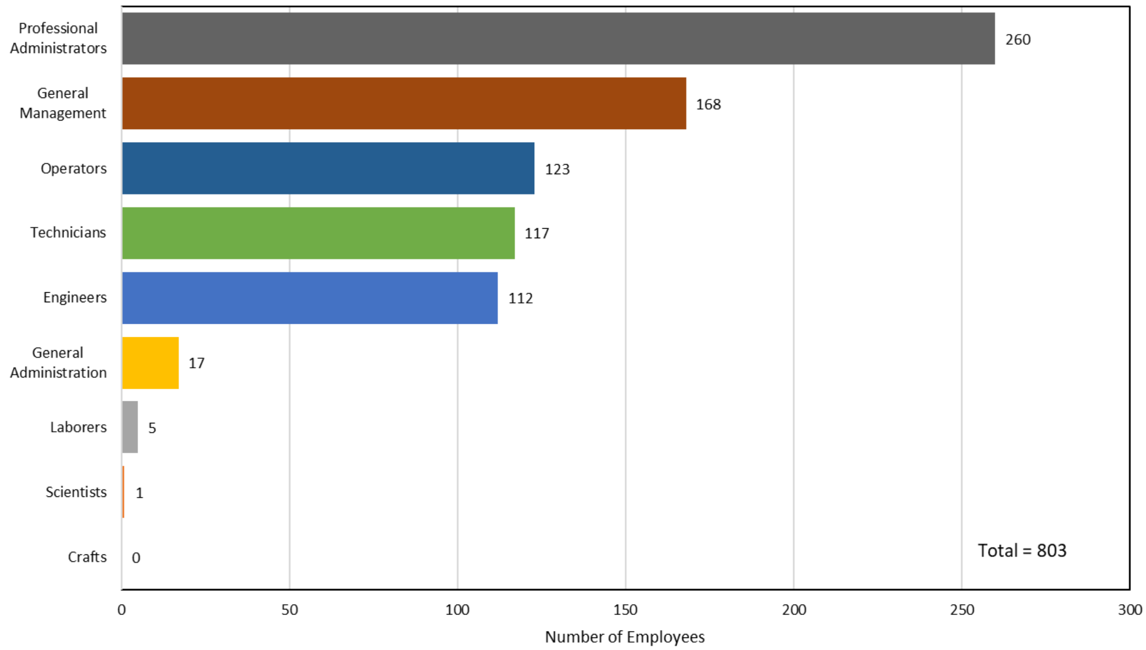
- Delivered all LLC exchanges, JTAs, and minor Alts on schedule. Accommodated 39 schedule changes inside 90-day window.
- SRNS dedicated much of FY 2020 to SRTE infrastructure improvements to ensure robust plant operation, contributing to overall efficiency and the ability to meet future mission needs. SRNS increased operational capabilities and flexibility through completion of the Diffuser Stacking project. This provides a means to directly process waste gas out of the Tritium Extraction Facility and eliminates dependency on H Area New Manufacturing as that facility transitions into higher production periods.
- Strong advance lead times, facilitated by DOE/NNSA and the Defense Threat Reduction Agency, provided a buffer for process upsets and bolstered sprint capability. At the height of the pandemic, SRNS was asked to accelerate shipments to DoD. In one case, the entire finishing, assembly, and packaging process, which normally requires several weeks, was done in 7 days.
- Supported DOE/NNSA completion of three environmental impact statements supporting plutonium pit production which earned SRNS employee inclusion among the National Environmental Policy Act Integrated Project Team that won an NNSA NA-50 Award of Excellence.
- Started a plutonium pit production Knowledge Transfer Program with LANL where SRS personnel will spend 2 years working with LANL personnel and then return to SRS to serve as subject matter experts and train others.
- Evaluated over 130 plutonium pit production process flowsheet technology elements, with 14 down-selected as critical technology elements and hosted subject matter experts from across the enterprise in performing Technology Readiness Level evaluations of the critical technology elements.

E.3.3.5 Savannah River Site Workforce

As of September 30, 2020, SRS reported a headcount of 885 personnel supporting DOE/NNSA programs. 82 of those personnel are involved in the SRS portion of DOE/NNSA's Plutonium Strategy. For the plutonium workforce, a multi-year training and qualification process will be undertaken to ensure the necessary people, processes, procedures, and commodities are in place to meet the minimum 50 ppy requirement at SRS as close to 2030 as possible. Essential to this process will be the transition of an existing facility into the SRS Training and Operations Center, beginning with design work in FY 2021. LANL and LLNL are supporting the training rotation pipeline for the SRS pit production mission through a knowledge transfer program initiated in FY 2020 with the Savannah River National Laboratory. This knowledge transfer program will form the foundation of the Training and Operations Center knowledge and experience base. SRS will support hiring and training through experience and programs with regional universities and trade schools.

The plutonium workforce has an average age of 47 years and average years of service of roughly 6 years. The tritium workforce has an average age of 44 and an average of 12 years of service. Most SRS employees are within the 0-5 years of service category. Similar to the other sites, a significant number of separations were also in this category. During FY 2020, SRS experienced 69 separations for personnel supporting DOE/NNSA programs, the majority of which were voluntary and, similar to the existing split between programs, were located in the tritium workforce. SRS expects significant growth, almost doubling the amount of personnel required to perform its share of the nuclear security mission.

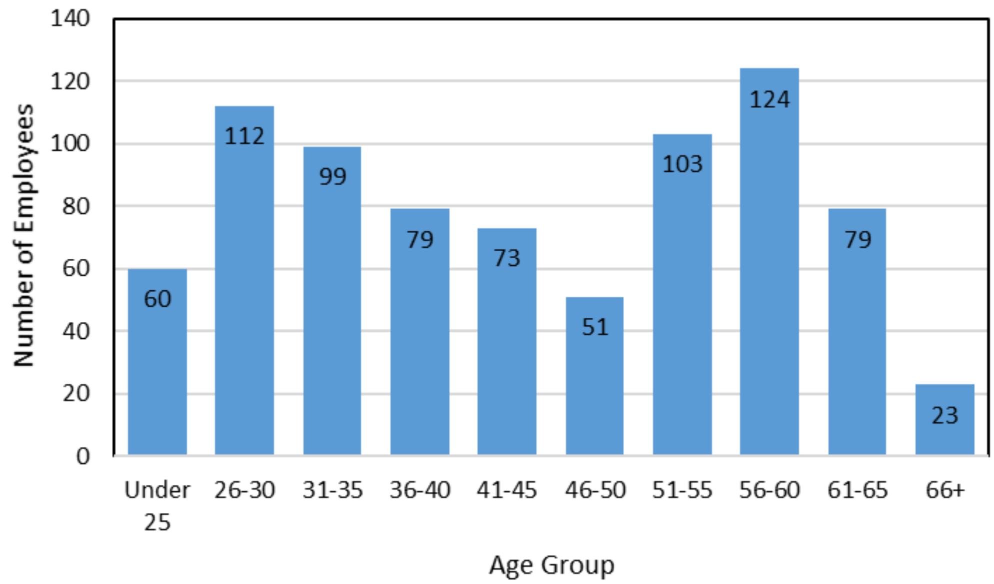
Workforce demographics are illustrated and discussed in **Figures E–51** through **E–59**.



Notes:

In FY 2020, hiring was focused on replacements for attrition and additions for increased work scope in small projects and engineering. SRTE ended FY 2020 at an actual headcount of 97 percent of that which was projected. The challenges in FY 2020 shifted to potential attrition related to new and increased NNSA missions on site. In FY 2020, SRTE managed retention by leadership engagement and focusing on career development of employees. The loss of workforce to the commercial nuclear industry has continued to diminish to almost nonexistent levels with attrition largely due to opportunities outside of the industry, as well as to other areas on site due increased DOE/NNSA missions.

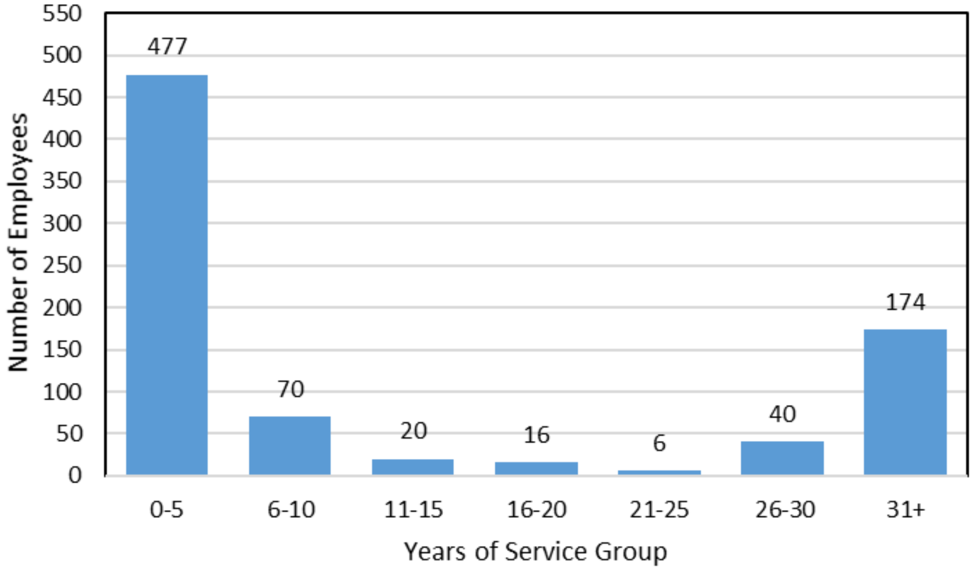
Figure E–51. SRTE total workforce by Common Occupational Classification System (as of September 30, 2020)



Notes:

In FY 2020, the average age of the overall workforce remained at 44 years old, though it had been trending down. The average age in FY 2018 was 45, a decrease from 47 the previous year. The average age of personnel hired within the last 5 years is 37, an increase of 1 year from FY 2019. The consistent SRNS and SRTE focus on hiring and the time necessary for clearance, training, and qualification has yielded positive results in having the workforce available for work to meet mission requirements. In addition, continued focus on employee-leader engagement, development and retention of new employees, and knowledge transfer and preservation has had a positive impact on retention and succession planning for bench strength of talent in the organization. SRNS-Tritium continues to develop its Knowledge Preservation Management Program and initiatives to retain legacy knowledge. Retirement eligibility remains steady. SRNS-Tritium remains focused on retention of key critical resources due to onsite competition for a skilled workforce. Retirement impacts are greater in some organizations than others. In general, 16 percent of the SRNS-Tritium workforce is fully retirement-eligible as of FY 2020. Employees hired after August 2008 were no longer eligible for pension, so retention of those employees is key. NNSA Operations and Programs measures retirement eligibility and risk through both Social Security Administration retirement eligibility and pension eligibility. SRNS-Tritium is expected to experience continued steady retirement over the next 5 to 8 years, with possible upticks to coincide with new missions, M&O turnover, and impacts related to national events/disease.

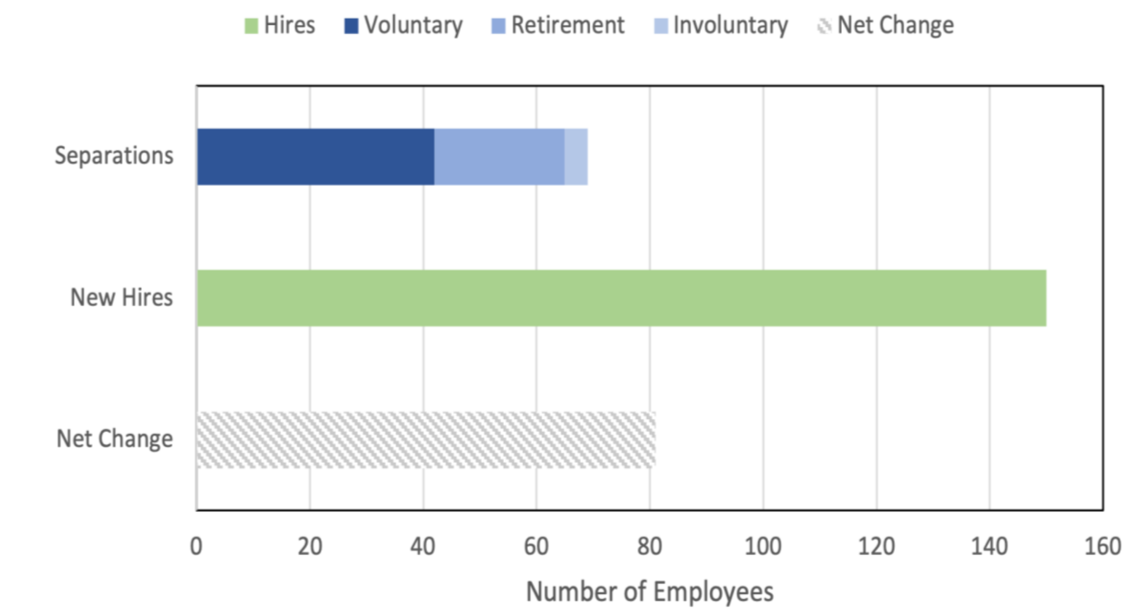
Figure E–52. SRTE employees by age (as of September 30, 2020)



Notes:

The SRNS-Tritium workforce is in transition. Currently, 57 percent of the workforce has between 0-5 years of service. That is an increase of 2 percent over FY 2019, and that percentage continues to increase. 29 percent have 21+ years of service. That is a 5 percent decrease from FY 2019. SRNS-Tritium continues to manage hiring with a focus on replacement for attrition and increased work scope. The previous years' targeted recruiting efforts for candidates with a military background and those with nuclear industry experience have provided SRTE with competent employees who have been able to advance in their careers and provide the organization with excellent operations leadership. With the projected increase in mission scope, anticipated retirement, and onsite competition, SRTE has continued to hire ahead of need to allow adequate time for onboarding and qualification. This strategy has yielded positive results. SRNS-Tritium has worked creatively to decrease the onboarding process, such as the use of an unclassified simulator and a restructured training program. To prepare in advance for anticipated continued steady attrition and increased mission requirements, an overlap in staffing might be hindered by budgetary constraints. Adequate and timely funding to allow hiring in advance is crucial. Partnerships with the Nuclear Workforce Initiative organization, Aiken Technical College, the University of South Carolina–Aiken, and regional universities continue. The SRNS Engineering Leadership Development Program continues to attract and hire new talent. Corporate reach-back and restructured recruiting practices will become a focus for external sources of experienced personnel. SRNS-Tritium will face steady retirements over the next 5 to 8 years with a possible uptick near the end of the contract. As experienced employees leave the organization, the focus has shifted to development and retention of new employees and achieving and maintaining mission essential staffing levels.

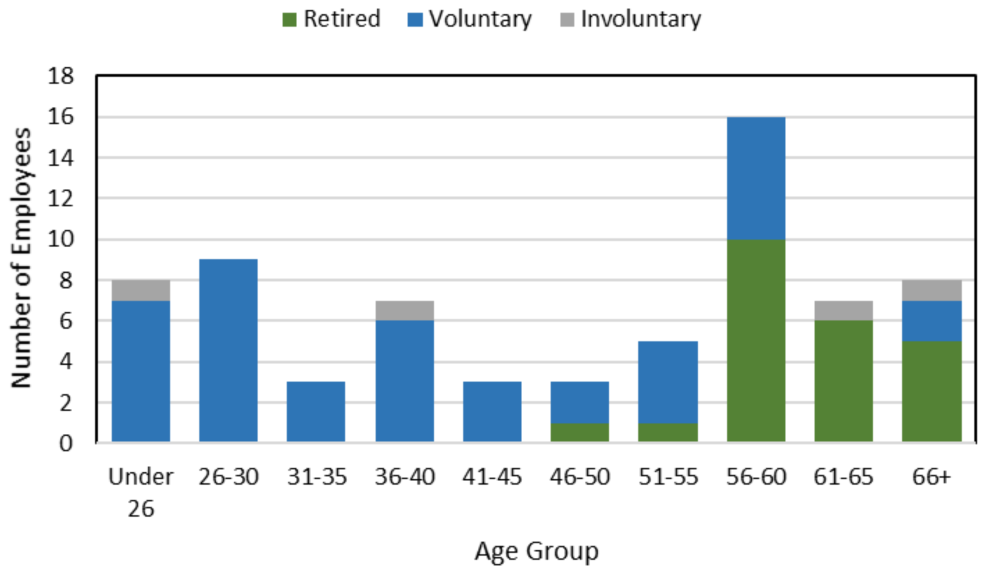
Figure E–53. SRTE employees by years of service (as of September 30, 2020)



Notes:

Hiring for the SRNS-Tritium organization continued to meet its strategic staffing plan in terms of numbers and exceed expectations in terms of quality of new hires. Following an uptick in hiring over the past 5 years, hiring leveled in FY 2019 and FY 2020 to reflect replacements for attrition and focus on the increased work scope and mission expansion. Attrition continued to remain steady. Most workers left for retirement, followed by SRNS business need and development/promotional opportunities within the site. External competition for employees with regional nuclear companies remains low due to a slowdown in the commercial nuclear industry. The greatest challenge is to retain talent by focusing on engagement and career development opportunities in SRTE. Leadership remains focused on employee engagement and linking work to the mission. With discontinuation of the retirement program, SRNS-Tritium has found other ways to motivate, recognize, and compensate employees, including a Savings Investment Plan and corporate matching, leadership engagement, certification stipends, meaningful work, and career development opportunities within the organization. SRNS-Tritium continued its New Employee Orientation, which introduces new hires to leadership, emphasizes that people are our most important asset, and enhances knowledge of the facility. The New Employee Orientation has been well received, and an overall focus on the importance of the Mission to National Security has led to greater employee engagement in the work they are performing

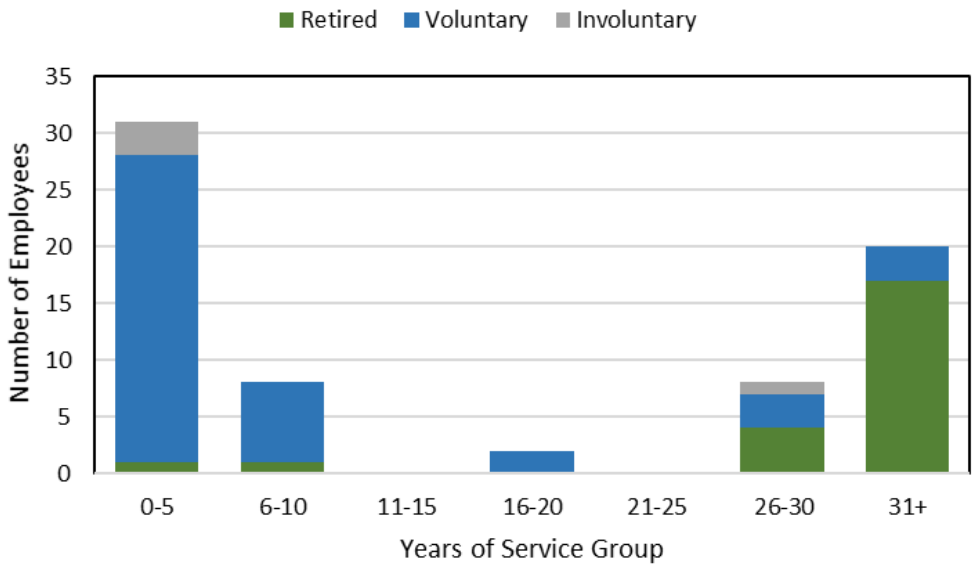
Figure E–54. Change in last 2 fiscal years at SRTE (October 1, 2016 to September 30, 2020)



Notes:

At SRNS-Tritium, attrition has increased slightly, but remained steady. Retirement accounted for 33 percent of all attrition in FY 2020 and remains steady. Overall, retirements and voluntary and involuntary attrition have remained steady. Twenty-five of the 41 voluntary transfers out of SRNS-Tritium to SRNS were related to new mission scope and developmental/promotional opportunities elsewhere on site. The remainder were for outside opportunities related to family relocation, other opportunities outside the nuclear industry, and personal reasons. Exit interviews did not implicate workplace issues of concern. This is attributed to greater leadership focus and engagement with the workforce, as well as the culture centered around mission and national security. Attrition is expected to remain steady and may increase as the end of the contract approaches and new opportunities arise on site. Over the past 5 years, an aggressive hiring strategy was deployed, and we are now largely sustaining current workforce levels. The main areas of focus will be design agency, design engineering, electrical engineering, and hires related to increased small projects, including the Tritium Finishing Facility. SRNS and SRNS-Tritium continued to enhance the screening, hiring, and onboarding processes to early-identify and align employees to the work that is performed. Over the past 3 years, continuous improvements have resulted in better quality hires and levels of staffing in SRTE that allow us to meet the mission.

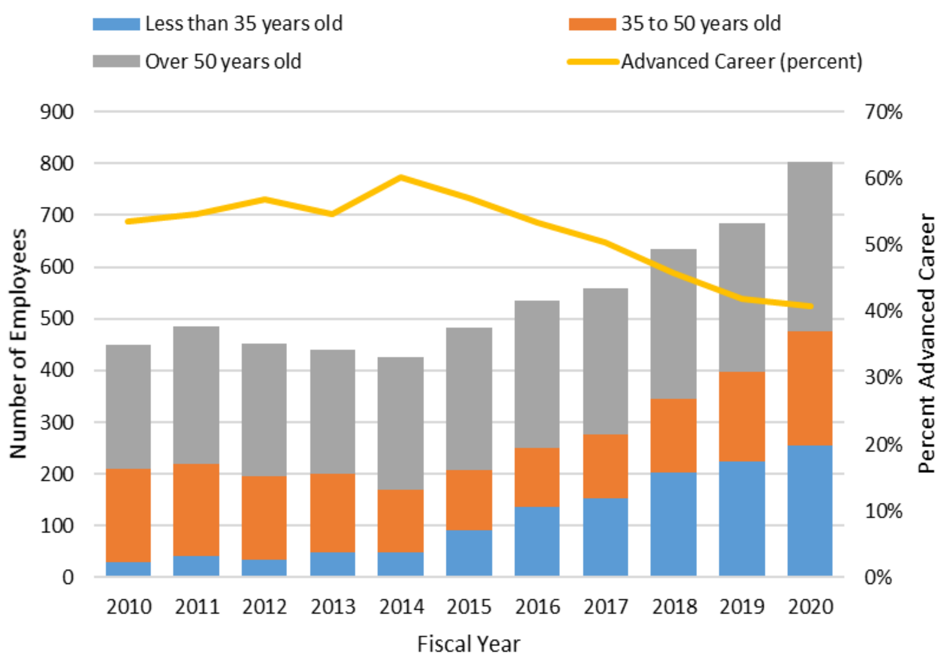
Figure E–55. Age of SRTE employees who left service (October 1, 2016 to September 30, 2020)



Notes:

SRNS-Tritium continued to experience a steady level of retirements occurring in the 31-35 years of service range. This is consistent with FY 2018 and FY 2019. No concerning trends were detected. Employees retiring and leaving voluntarily and involuntarily also remained steady. Those who left within the 0-5 year category were primarily related to new mission requirements, promotional opportunities on site, and opportunities outside the nuclear industry. Outliers included employees moved to other roles on site for business needs due to the new/expanded mission at SRS. The focus continues on retention strategies for employees hired under a restructured benefits plan that features the portability of a Savings Investment Plan as opposed to a pension plan. Engagement initiatives, including New Employee Orientation, a focus on the national security mission, and leadership development, are succeeding in creating a compelling place to work and are having a positive impact on retention.

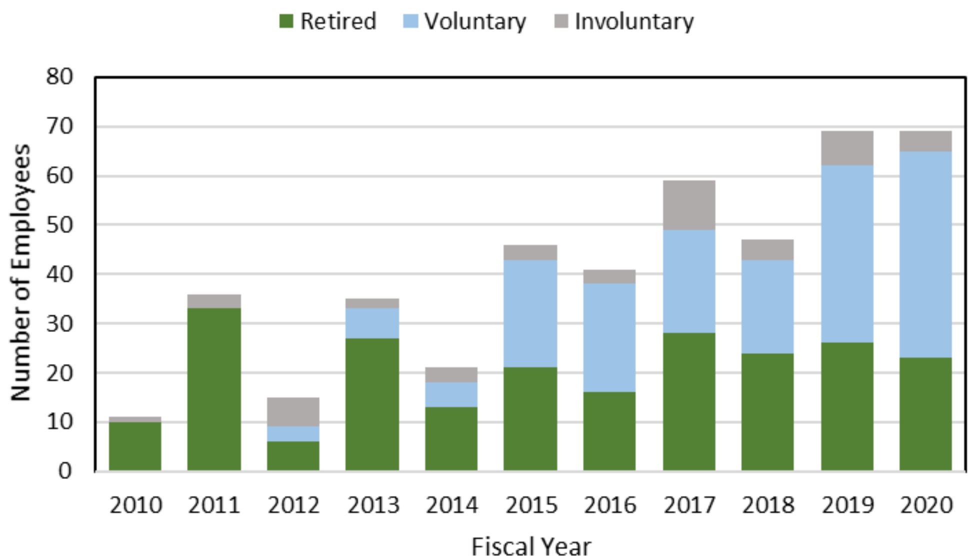
Figure E–56. Years of service of SRTE employees who left service (October 1, 2016 to September 30, 2020)



Notes:

Increased and sustained hiring combined with career development, succession, and other retention efforts have led to an increase in the early-career and mid-career populations at SRNS-Tritium. A steady level of retirement and transfer or promotions to other opportunities at SRS have led to a decrease in advanced-career workers. The mid-career population will continue to be monitored to help ensure career development opportunities are available to retain and grow the workforce. This, combined with compelling workplace improvements, should impact all career groups in a positive way.

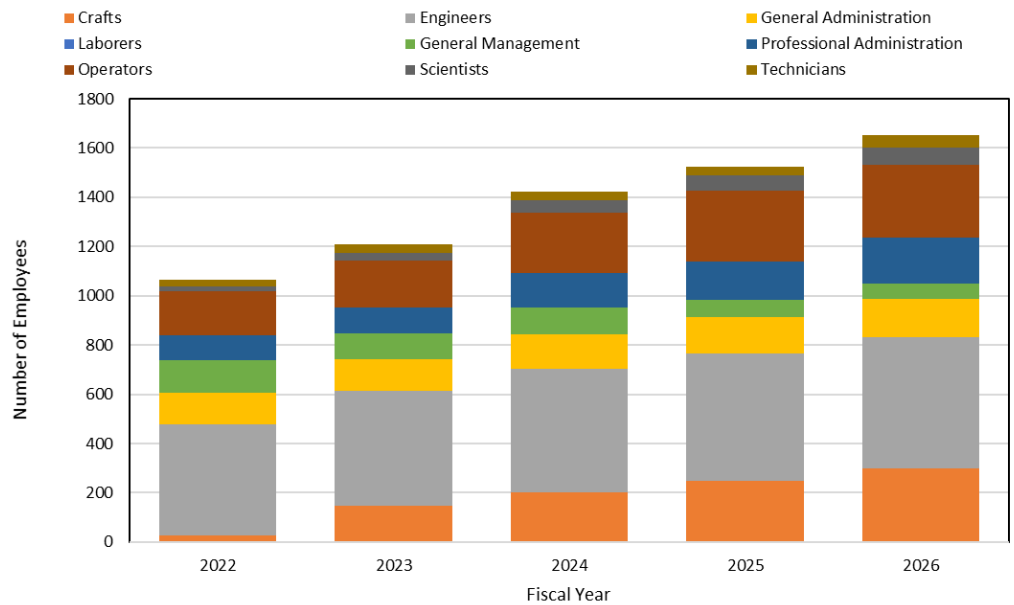
Figure E–57. SRTE trends by career stage (as of September 30, 2020)



Notes:

Workforce retirement is expected to remain steady over the next 5 years. Voluntary separations increased as a result of promotional opportunities on site and mission-related business needs. SRNS-Tritium continues to plan and execute workforce growth commensurate with mission requirements to recapitalize process equipment and surrounding infrastructure, increasing GTS work scope due to the LEPs, and expected retirements of personnel requiring clearance and training processes. The goal is to remain aware of the constantly changing business conditions and environment, continue to hire for replacements and increased work scope, and to retain new employees by providing meaningful work, leadership engagement, development opportunities and a compelling place to work.

Figure E–58. SRTE employment separation trends (as of September 30, 2020)



Notes:

We expect mission growth primarily due to the Tritium Extraction Facility tritium supply production increase; the plutonium mission; increased project activity (Tritium Finishing Facility Program line item and minor construction projects); a growing effort to reduce the maintenance backlog on facilities and infrastructure; and implementation of Nuclear Enterprise Assurance requirements. SRTE will also experience some growth in reservoir processing and surveillance due to increases in workload complexity due to the new LEPs. This will increase housing requirements, including the need for new office space. In addition to mission increases, SRNS-Tritium will continue to manage steady attrition (retirements and resignation) and employee retention.

Figure E–59. Total projected SRTE workforce needs by Common Occupational Classification System (as of September 30, 2020)

E.3.4 Y-12 National Security Complex

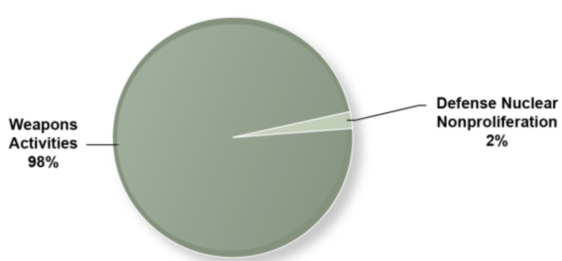
E.3.4.1 Mission Overview

Every weapon in the U.S. nuclear stockpile has components manufactured, maintained, or dismantled at the Y-12 National Security Complex (Y-12) in Oak Ridge, Tennessee. Y-12 is DOE/NNSA's Uranium Center of Excellence and the Nation's only source for enriched uranium components for nuclear weapons. For the legacy stockpile, Y-12 manufactures uranium components for nuclear weapons, cases, and other weapons components and evaluates and tests these components. Through LEP activities, Y-12 produces refurbished, replaced, and upgraded weapon components to modernize the enduring stockpile. Y-12 also serves as the main storage facility for Category I/II quantities of highly enriched uranium (HEU); conducts dismantlement, storage, and disposition of HEU; and supplies HEU for use in naval reactors.

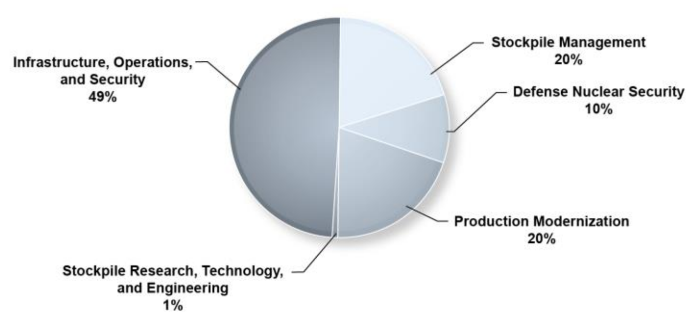
- Location: Oak Ridge, Tennessee
- Total Employees: 6,603 (Total, includes Weapons Activities, as of the end of FY 2020)
- Type: Multi-program nuclear weapons production facility
- Website: www.y12.doe.gov
- Contract Operator: Consolidated Nuclear Security, LLC (CNS), a corporate subsidiary of Bechtel National, Leidos, ATK Launch Systems, and SOC, LLC[1]
- Responsible Field Office: NNSA Production Office

E.3.4.2 Funding

FY 2022 request – site funding by source
(total Y-12 FY 2022 request = $2,109 million)



Y-12 split for the FY 2022 Weapons Activities President's Budget Request *($2,064 million)*



[1] On November 29, 2021, DOE/NNSA announced that Nuclear Production One (NPOne), a limited liability company consisting of Fluor Federal Services and AECOM Energy and Construction, was selected as the new management and operating contractor for the Y-12 and Pantex production facilities. A four-month transition period will begin in December. The Uranium Processing Facility will continue under CNS.

E.3.4.3 Site Capabilities

Key mission capability areas at Y-12 are primarily in three areas: uranium and canned subassembly production; lithium; and material and process R&D. Key to all of these capabilities is the supporting infrastructure that provides power, water, and other critical services. Y-12's key capabilities and their associated challenges and strategies are described in **Table E–7**.

Table E–7. Y-12 National Security Complex capabilities

<table>
<tr><th colspan="3">Uranium and Canned Subassembly Production Capability</th></tr>
<tr><td colspan="3">Y-12 produces uranium weapon components to refurbish the Nation's nuclear stockpile. Y-12 also recycles and reprocesses the Nation's existing supply of enriched uranium. The recycled metal serves as feedstock for the Navy's nuclear-powered submarines and aircraft carriers, for commercial power reactors that generate U.S. electricity, for medical isotope production, and for some domestic and foreign research reactor programs. Y-12 also helps recover and secure at-risk nuclear materials around the globe. The Highly Enriched Uranium Materials Facility at Y-12 houses the Nation's cache of weapons-grade uranium. The Uranium Processing Facility now under construction will be a state-of-the-art facility for the enriched uranium operations that are currently performed in Building 9212.</td></tr>
<tr><th rowspan="2">Challenges</th><th colspan="2">Strategies</th></tr>
<tr><th>Current Strategy Being Implemented</th><th>Future Strategies Needed</th></tr>
<tr><td>To continue supporting all uranium missions, Y-12 must address its aging infrastructure. Current facilities are aging, necessitating sustainment through the Extended Life Program. Enriched uranium capabilities must be maintained while the Uranium Processing Facility is being constructed. Maintaining this capability necessitates relocation of enriched uranium functions to other Y-12 facilities and startup and proving of replacement technologies before uranium programmatic operations cease in current facilities by 2025. Y-12 must also complete reduction of material-at-risk quantities in current processing facilities by consolidating storage into the Highly Enriched Uranium Materials Facility.</td><td>The Uranium Processing Facility will replace most of the HEU production functions currently performed in Building 9212. The uranium strategy also includes upgrades and advanced technologies that will be started in existing facilities.</td><td>Additional replacement facilities will be needed and are currently planned for the late 2030s and 2040s.</td></tr>
<tr><td>Depleted Uranium operations produce and maintain a reliable inventory of depleted uranium, depleted uranium alloy, and other non-nuclear industrial material components and tooling through a variety of metalworking processes in support of LEPs, JTAs, and other national security and government programs. Depleted uranium infrastructure is also aging, and Increased throughput and capacity is required for future programs, which requires both additional equipment and personnel.</td><td>Purchase the limited commercial high-purity depleted uranium (HPDU) supplies and investment in feedstock capabilities to ensure steady stream of HPDU in the future.

Invest in maintenance of the legacy alloying processes. Plan to purchase additional equipment to reduce the strain on legacy equipment and processes.

Identify bottlenecks and develop bridging strategies to fulfill near-term mission requirements should new technology not be employed in the immediate future</td><td>Replace depleted uranium and fabrication/ manufacturing functions in current facilities with the Depleted Uranium Manufacturing Capability.</td></tr>
</table>

Lithium Capability		
Y-12 provides material purification, material preparation, component fabrication and inspection, salvage operations, and storage for lithium operations to support LEPs, JTAs, and complementary work. Without enriched lithium, the Nation's nuclear deterrent could not be maintained.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Current lithium capabilities are housed in a Manhattan Project-era facility with infrastructure well beyond its expected life and rapidly deteriorating. The process equipment is inefficient for its current mission scope, is rapidly deteriorating, and has far exceeded its life expectancy. Current Lithium production capabilities will be placed under additional strain because of material supply issues and the projected increase in mission scope. Combined, these challenges represent significant risk to the mission.	DOE/NNSA's lithium strategy necessitates sustainment of the current infrastructure; sustainment of the supply to meet customer demand; and maturation and deployment of technologies to replace hazardous processes. Design and construct the Lithium Processing Facility.	Continue to maintain legacy processing lines of effort through identified facility lifecycle extension projects until the Lithium Processing Facility is fully operational. Future projects to maintain capability include electrical, utility upgrades, and other identified structural life extending efforts.

Material and Process Research and Development Capability		
Y-12's Development Division serves as the focal point for development and preservation of uranium and lithium materials sciences and manufacturing technologies. R&D activities include material and metallurgical synthesis, forming, evaluation techniques and processes, material purification, and material characterization. Advanced technologies have been developed and are at varying stages of deployment readiness for enriched uranium and lithium.		
Challenges	***Strategies***	
	Current Strategy Being Implemented	***Future Strategies Needed***
Development is essential to Y-12's production mission, providing a ready pool of subject matter experts to tackle production problems, developing new technology to meet future production requirements, and performing strategic partnership projects as needed to support global security missions. Aging electrical, cooling water, and other process support systems in Y-12's infrastructure increase risk to mission work as the infrastructure ages.	The current strategy for development includes acquisition of an off-site facility and implementing electrical and cooling water system recapitalization projects to address infrastructure concerns, until replacement facilities are available.	The development strategy ultimately results in a new line item replacement facility to consolidate all development capabilities back at Y-12.

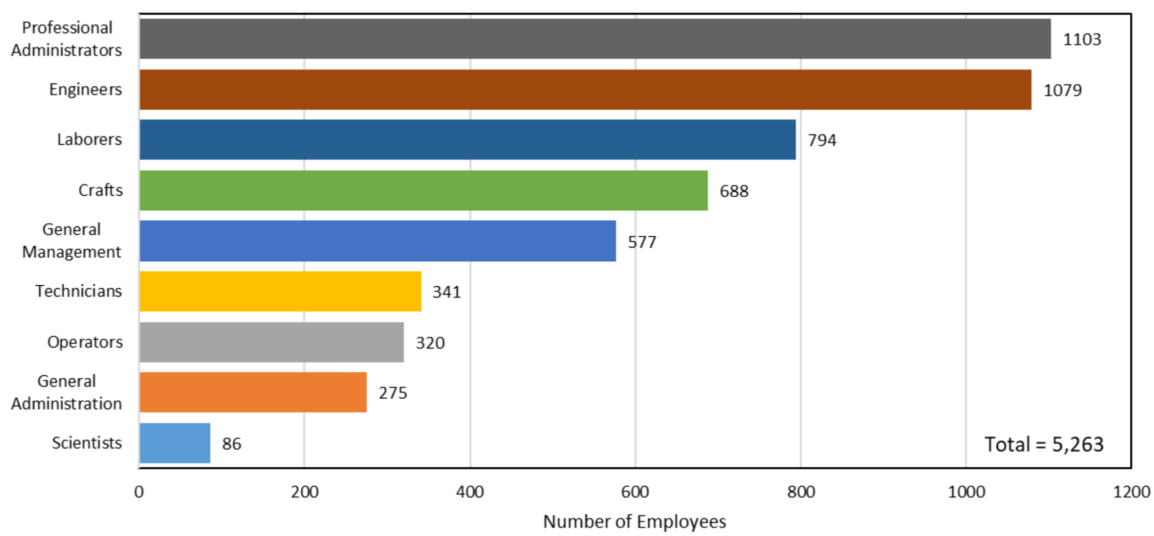
E.3.4.4 Accomplishments

- Completed 102 percent of FY 2020 baseline production deliverables.
- Produced 329 kilograms of purified uranium metal, exceeding the COVID-19-adjusted annual goal of 315 kilograms.
- Produced the first production-spec purified metal button using the Electrorefining Development Glovebox system.
- Completed the full binary alloy production cycle, using both onsite and offsite equipment, in support of mission-critical binary production restoration.
- Fabricated two enriched uranium safety blocks for the White Sands Missile Range Fast Burst Reactor Upgrade project.
- Performed computed tomography scans of High-Flux Isotope Reactor fuel elements, including one ahead of schedule at Oak Ridge National Laboratory's request, to avoid disrupting the reactor's critical COVID-19-related experiments.

- Completed 50-year sprinkler replacements, an 8-year effort that replaced nearly 10,000 sprinkler heads in six different Y-12 production facilities, enabling those facilities to continue adherence to fire protection requirements.
- Continued progress on Uranium Processing Facility construction in FY 2020, including:
  - Completed second-floor structural steel installation and all first and second elevated deck placements on the Salvage and Accountability Building.
  - Completed structural steel erection and reinforced concrete walls on the East and West side, and began placement of reinforced concrete floors of Main Process Building.
  - Completed foundation piling, started formwork, rebar, and placed first steel for the Process Support Facility.

E.3.4.5 Y-12 National Security Complex Workforce

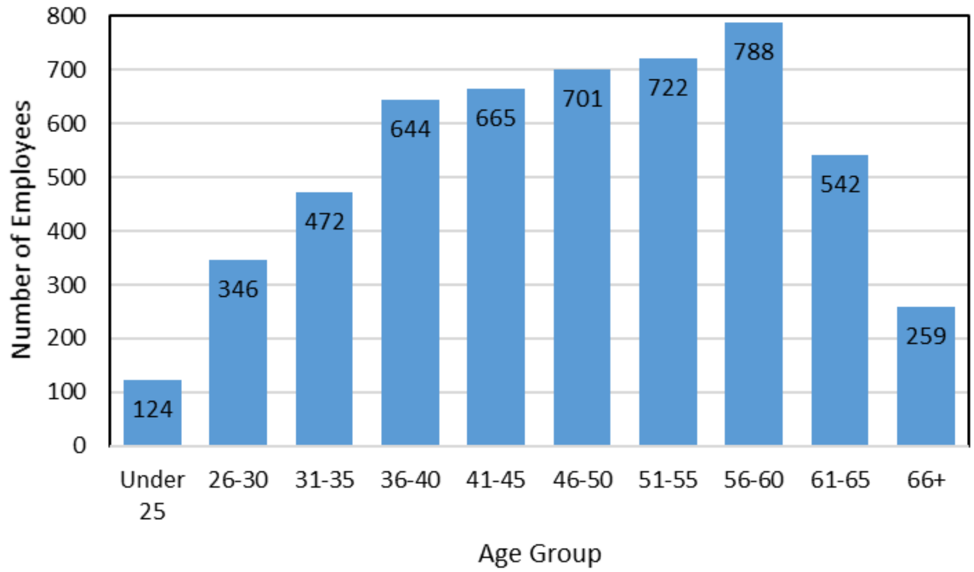
Y-12 had 5,263 employees as of September 30, 2020. The Y-12 workforce's average age is around 48 years old, with 31 percent retirement-eligible. Y-12 is replenishing its workforce for future needs, and more than half of the population has 10 or less years of service. The average number of years of service is 11 years. Most separations in FY 2020 were retirements, with about 66 percent of separations occurring at age 56 and above. A large number of voluntary separations occurred among those with 0-5 years of service. Since FY 2017, the early-career population has increased because of increased hiring. Workforce demographics are illustrated and discussed in **Figures E–60** through **E–68**.



Notes:

Total headcount increased from 5,063 at the end of FY 2019 to 5,263 at the end of FY 2020. Significant recruiting and hiring efforts replaced vacancies from attrition and built the technical skill base in preparation for the increased workload in FY 2021 and beyond. FY 2021 will focus on hiring in preparation of increasing weapons workload. This will include acquiring the necessary security clearances and developing new talent. The most significant increases were in engineers, security, professionals, and technicians to provide CNS with the technical skills needed to fulfill mission work.

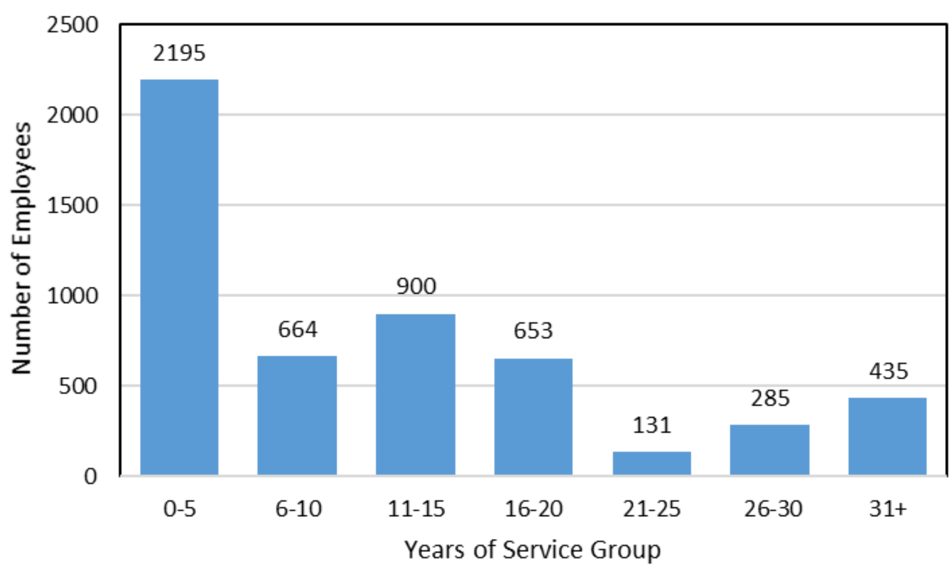
Figure E–60. Y-12 workforce by Common Occupational Classification System (as of September 30, 2020)



Notes:

The average age of the Y-12 workforce is approximately 48 years old. The percentage eligible to retire is 31 percent. Increased hiring and replacement of retirees is gradually lowering the average age of the workforce. Age diversity is well distributed. Many employees elect to work beyond their earliest eligibility retirement age. Y-12 remains one of the best employers in the area. Crafts, labor, operators, technicians, and clerical skill groups are hired locally and tend to remain until retirement.

Figure E–61. Y-12 workforce distributed by age group (as of September 30, 2020)



Notes:

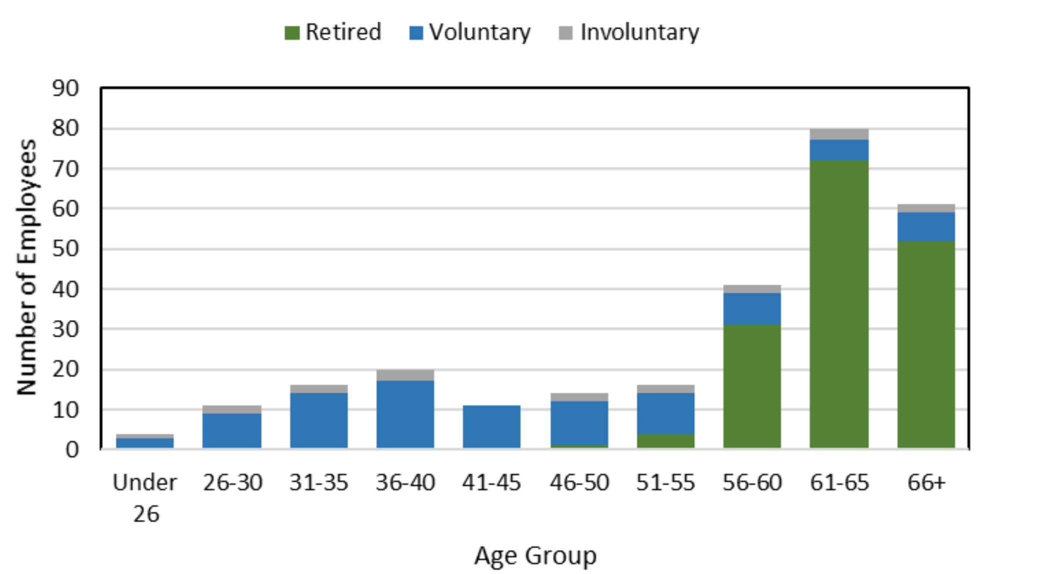
The average years of service at Y-12 is approximately 11.6 down from 12 due to the increase in new hires in the 0-5 group. This indicates that Y-12 is replenishing its workforce for future needs and offsetting attrition due to retirements and other separations.

Figure E–62. Y-12 workforce distributed by years of service group (as of September 30, 2020)

Notes:

FY 2020 was a strong year for recruiting, with a net gain of 200 employees. Pantex and Y-12 combined efforts for virtual recruiting during the COVID-19 pandemic. SuccessFactors, a new consolidated application system, was implemented, streamlining the application and hiring process and improving the overall candidate experience. CNS joined the nuclear security enterprise in joint virtual and in-person recruiting initiatives at military bases and top schools pre-pandemic. Additionally, CNS contracted with Shaker Recruitment Marketing to enhance visibility nationally. Candidate sourcing was expanded to LinkedIn, Indeed, and Glassdoor. Competitive pay and benefits aided in offer acceptance and retention of talent.

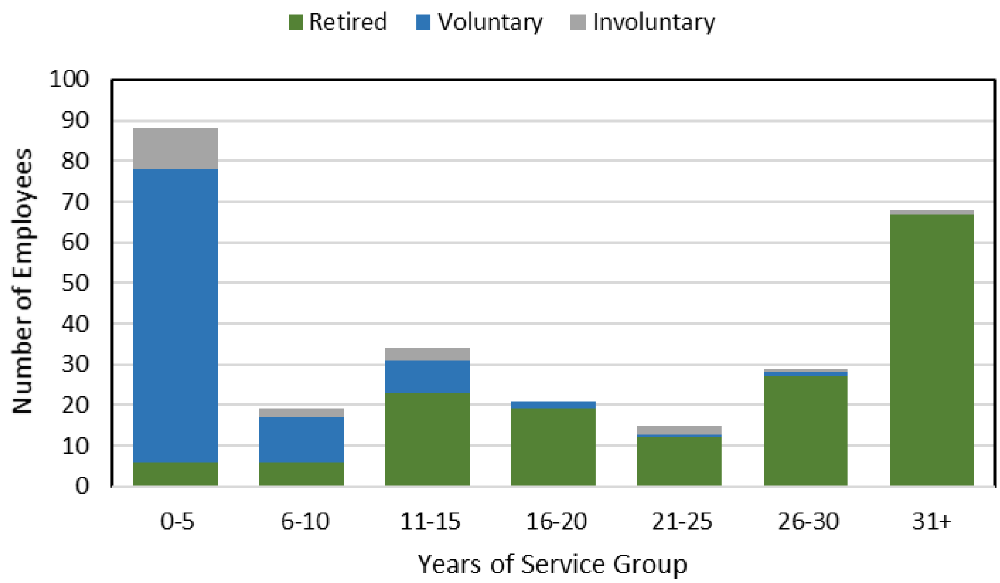
Figure E–63. Y-12 net change for fiscal year (as of September 30, 2020)



Notes:

Those leaving under age 35 are typically engineers or professionals who are more mobile. Factors include location, electronics restrictions, security clearances, and national competition for these skills. The large number leaving over age 60 are retiring.

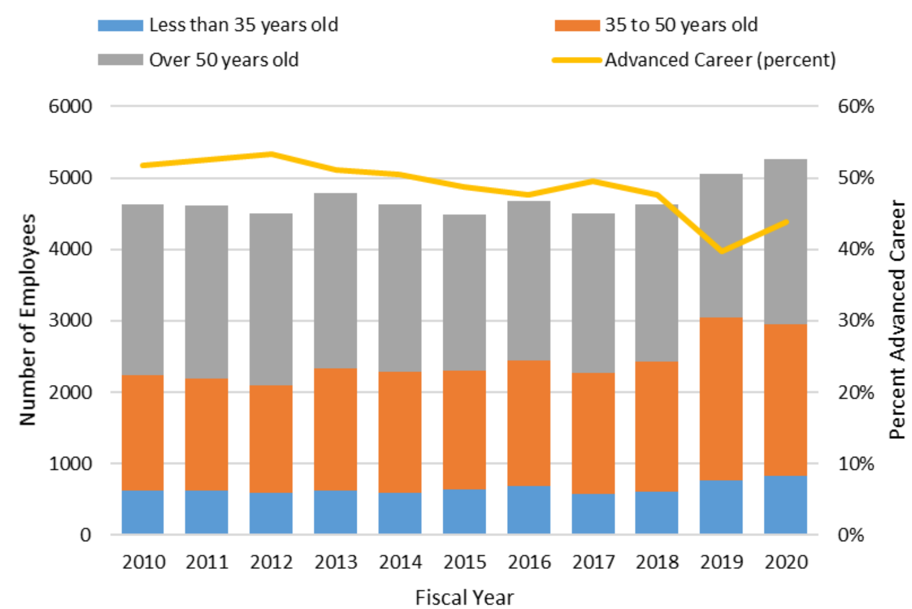
Figure E–64. Y-12 employee separations by age group (as of September 30, 2020)



Notes:

The majority of those leaving from 0-5 years of service are typically engineers or professionals under age 35 who are early in their career and more mobile. There are several factors that impact retention for this group: (a) location and commute are less desirable than competition; (b) electronic restrictions for iPhones, iPads, etc.; (c) waiting for security clearances can cause professionals to lose interest; and (d) other high-tech industries compete for the same skilled professionals. To address these concerns, CNS has increased teleworking for select positions, improved work environments, implemented talent management opportunities for career development, improved clearance processing cycle time by increasing investigators to address the volume of hiring, and redesigned compensation to attract and retain critical skills. Those leaving with over 20 years of service are typically retirees.

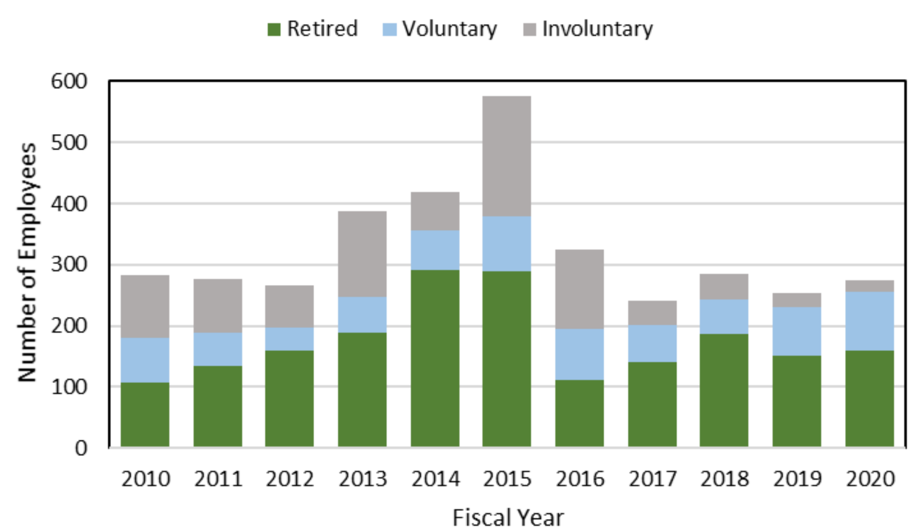
Figure E–65. Y-12 employee separation by years of service group (as of September 30, 2020)



Notes:

Total population grew due to increased hiring in the workforce participation group less than 35 years and low attrition. Many workforce participants over 50 years old are electing to work longer.

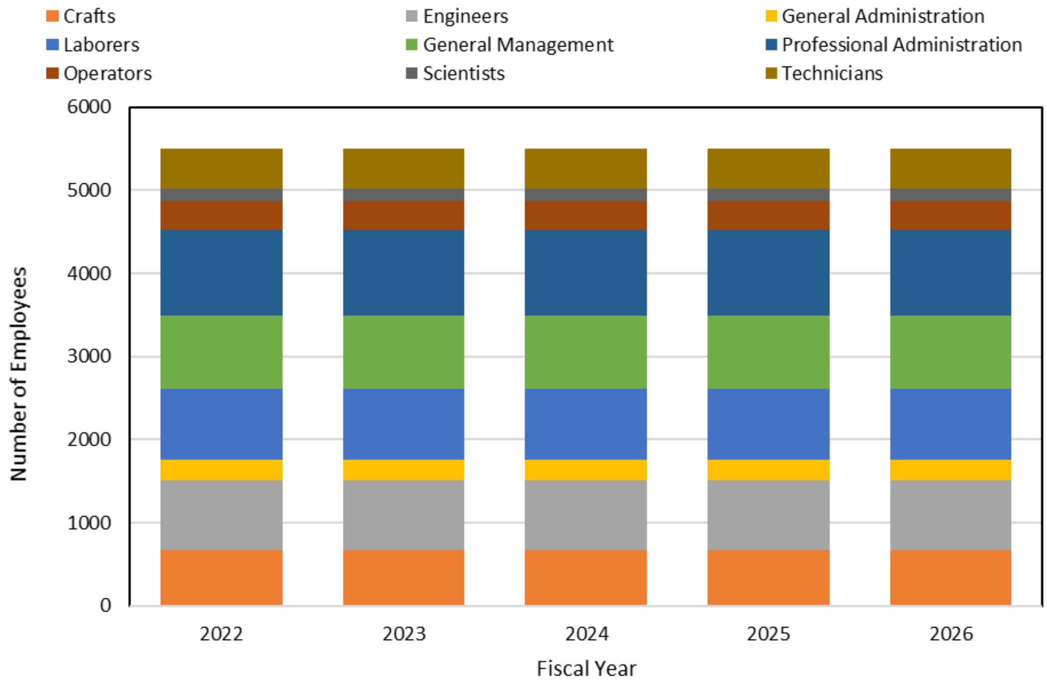
Figure E–66. Y-12 workforce participation trends by age category and percent advanced career (as of September 30, 2020)



Notes:

Over half of separations are due to retirements. The average age of retirees is increasing as more retirement-eligible employees are electing to work longer. Several factors may be considered for this shift, such as better health, cognitive activity, opportunity to telecommute, and uncertainty about the pandemic and the impact on travel, family, and the economy. Those turning 65 typically work until 66+ to receive full social security benefits. Pension plans were phased out for new hires around 2012 and replaced by enhanced 401(k) plans for retirement planning. This change removed the perceived retirement trigger (pension eligibility at age 55 with 10 years of service) for those hired after 2012. Retention efforts have been successful and are viewed as a positive trend.

Figure E–67. Y-12 employee separation trends



Notes:

The total estimated number of personnel needed to support the work in the near term is relatively static. CNS anticipates hiring for attrition replacement with emphasis on engineers, safety basis personnel, IT, technicians, and Security Police Officers. Technicians and Security Police Officers are usually filled from the local market and military. Engineers, IT, and safety basis personnel are being recruited from job fairs and universities. Internal realignment is used in some cases to fill critical vacancies. Plant attrition is expected to remain low between 5 percent–6 percent. Crafts, technicians and administration typically have lower attrition while engineers have higher attrition due to national demand. This is an ongoing concern as other technology companies are competing for the limited market of engineering and technology skills. Based on current hiring/termination statistics, CNS anticipates gaps in Engineering, safety basis, IT, risk management, and fire protection in the next 10 years. CNS is utilizing national recruiting search engines and working closely with universities and military bases to help fill the pipeline for engineers and technology for years to come.

Figure E–68. Y-12 workforce projection needs by Common Occupational Classification System

E.4 The National Security Site

E.4.1 Nevada National Security Site

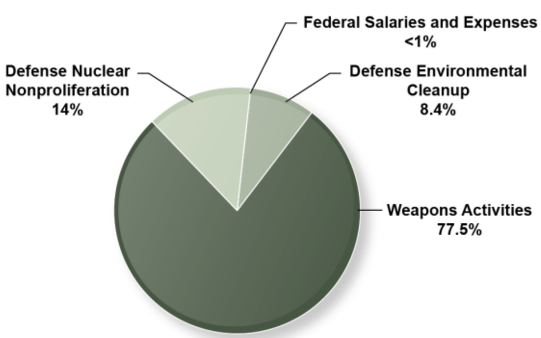
E.4.1.1 Mission Overview

The Nevada National Security Site (NNSS), located outside of Las Vegas, Nevada, is the primary location within the DOE/NNSA complex where high-hazard experiments with radiological and other high-hazard materials are conducted. It is the only location in the United States that is authorized to conduct subcritical experiments with weapons-relevant geometries and quantities of both high explosives (HE) and plutonium.

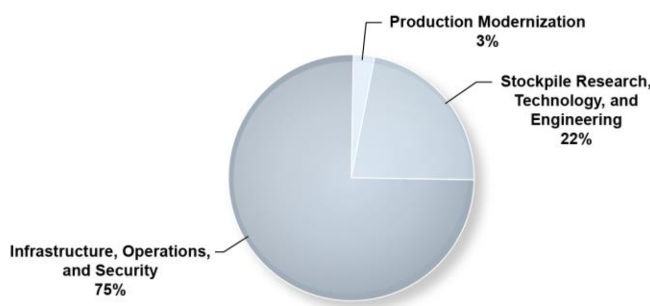
- Location: Las Vegas, Nevada
- Additional Operating Capabilities: Offices at LANL, LLNL, and SNL; Remote Sensing Laboratory at Nellis Air Force Base and Andrews Air Force Base; and the Special Technologies Laboratory in Santa Barbara, California
- Total Employees: 2,377 (as of the end of FY 2020)
- Type: Multi-program experimental site
- Website: www.nnss.gov
- Contract Operator: Mission Support and Test Services LLC, a joint venture between Honeywell International, Inc.; Jacobs Engineering Group; and Huntington Ingalls Industries Nuclear, Inc.

E.4.1.2 Funding

FY 2022 request – site funding by source
(total NNSS FY 2022 request = $666 million)



NNSS split for the FY 2022 Weapons Activities President's Budget Request *($517 million)*



E.4.1.3 Site Capabilities

NNSS supports stockpile stewardship through plutonium experiments in collaboration with LANL, LLNL, and SNL; data analyses from those experiments; diagnostic R&D; and reanalysis of legacy underground test data.

NNSS' capabilities and their associated challenges and strategies are described in **Table E–8**.

Table E–8. Nevada National Security Site capabilities

<table>
<tr><th colspan="3">Hydrodynamic and Subcritical Experiments at Weapon's Relevant Scales</th></tr>
<tr><td colspan="3">NNSS performs subcritical experiments at the U1a Complex (U1a), enabling characterization of early explosion-time hydrodynamic behavior of plutonium, plutonium surrogates, and other relevant materials in weapon-relevant geometries. NNSS, LLNL, LANL, and SNL plan to enhance U1a to enable well-diagnosed, early- and late-time radiographic and neutron reactivity measurements on hydrodynamic tests. These new data will inform efforts to assess the effects of aging and manufacturing processes on stockpile weapons.</td></tr>
<tr><th rowspan="2">Challenges</th><th colspan="2">Strategies</th></tr>
<tr><th>Current Strategy Being Implemented</th><th>Future Strategies Needed</th></tr>
<tr><td>Increase the tempo, flexibility, and sophistication of subcritical experiments by exploring major efficiency improvements in experiment and U1a operations.</td><td>Implement a multi-user U1a operating model and an integrated, logic-linked framework schedule to optimize critical path contributors. Invest in U1a, the Device Assembly Facility (DAF), diagnostics, and transportation for future subcritical experiments.</td><td>Ensure operational sustainability for all necessary radiographic capabilities in U1a.

Enhance efficiencies in experimental operations to reduce fielding time and the number of experiments required for assessment and certification.

Field next generation diagnostics to meet stockpile experimentation needs.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><th colspan="3">Weapons Science Experiments Using High-Hazard Materials</th></tr>
<tr><td colspan="3">Activities include maturing capabilities in shock and compression experiments; dynamic phase change studies; capture of thermodynamic and constitutive properties; platform and source development; and materials diagnostic R&D on the Joint Actinide Shock Physics Experimental Research Facility (JASPER), the Dynamic Science Launcher, Z pulsed power facility; and a variety of shock physics platforms at NNSS and the Special Technologies Laboratory. JASPER is a two-stage light gas gun for studying the behavior of plutonium and other materials at high pressures, temperatures, and strain rates. Material property data are obtained on a wide variety of national security materials of interest in various phases and compositions owing to differences in manufacturing processes, surface preparations, and ages.</td></tr>
<tr><th rowspan="2">Challenges</th><th colspan="2">Strategies</th></tr>
<tr><th>Current Strategy Being Implemented</th><th>Future Strategies Needed</th></tr>
<tr><td>Breakthroughs in materials science are limited by the rate of experimentation, staffing constraints, the range of dynamic conditions that are available to DOE/NNSA, as well as the need for higher-precision diagnostics that can measure phase changes, temperature, density, and two-dimensional displacement/velocity-fields at very short time scales and very high temperatures, pressures, and densities.</td><td>NNSS is seeking efficiencies in operations to increase scientific throughput at its many shock physics platforms. Some of these efficiencies are realized through increased recruitment activities and development of newer, higher-precision diagnostics.</td><td>NNSS will leverage site-directed, R&D-initiated new diagnostics; mature these diagnostics; and optimize them for multi-platform use (e.g., hydrodynamic experiments, subcritical experiments, and JASPER) interferometry, diffractometry, radiography, pyrometry, and other spectroscopic techniques.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><th colspan="3">Device Assembly Facility</th></tr>
<tr><td colspan="3">DAF supports nuclear weapon experimental capabilities and is one of two facilities in the nuclear security enterprise that allows collocation of HE and SNM, including staging of large quantities of SNM in independent buildings, and provides the backbone to support various missions using those materials in conjunction. For Stockpile Stewardship, the facility's glovebox, downdraft table, and radiography capabilities support assembly of SNM targets for JASPER, as well as SNM and HE packages for subcritical experiments at U1a. DAF also hosts the National Criticality Experiments Research Center (NCERC), a unique national asset. NCERC supports a mix of critical and subcritical benchmark quality experiments, detector development, inspector and first responder training, criticality safety training, and handling of damaged nuclear weapons. NCERC has the largest collection of nuclear critical mass assembly machines in the western hemisphere.</td></tr>
</table>

Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
DAF has a wide range of unique capabilities. As demand for these capabilities grows across DOE/NNSA, space and scheduling challenges can be expected to grow.	Current capabilities will be maintained to meet U.S. Government needs. Options to increase these capabilities on a timescale complementary to anticipated experimental needs will need to be explored (e.g., enhanced surveillance and storage).	Enhance efficiencies in experimental operations to reduce fielding time and number of experiments required for assessment and certification. Field next-generation diagnostics to meet stockpile experimentation needs.

Advanced Experimental Diagnostics and Sensors		
NNSS' core capabilities, in addition to fielding high-value, high-risk experiments in the national interest, include developing the next generation of high-precision, transformational diagnostics for subcritical, hydrodynamic, and dynamic materials experiments. Some of the groundbreaking diagnostics that have been developed with NNSS' collaboration and efforts include photon Doppler velocimetry; optical ranging (i.e., broadband laser ranging); surface imaging; soft X-ray radiography; holography; dynamic pyrometry and emissivity; dynamic X-ray diffraction; prompt neutron and X-ray detectors; and advanced radiography sources for subcritical experiments (now approaching an $800 million cost) and other hydrodynamic platforms.		
Challenges	*Strategies*	
	Current Strategy Being Implemented	*Future Strategies Needed*
Advanced diagnostics and sensors provide detailed measurements of materials, objects, and dynamic processes critical to weapon operation. Standard diagnostics provide lower-resolution data that are suitable for basic inquiries, but not detailed part, process, or physics qualification. Continued diagnostic and sensor development is critical to addressing these limitations.	NNSS will involve nuclear security enterprise laboratories in defining and prioritizing diagnostic needs for future experiments at NNSS and other facilities.	Continue current strategy. Field next generation diagnostics to meet stockpile experimentation needs

E.4.1.4 Accomplishments

- Nightshade A, the first subcritical experiment in the Red Sage series; provided ejecta data from multiple plutonium samples under conditions relevant to the stockpile. The successful experiment followed a confirmatory preparatory experiment run by NNSS that resulted in 100 percent data return. This experimental series is led by LANL and executed by NNSS. NNSS also executed the Red Sage confirmatory experiment, Iris, with LANL on March 3, 2020, with 100-percent data return. Iris verified the experimental, diagnostic, and testbed improvements for the Red Sage series, allowing the series to proceed.
- Diagnostic development – NNSS delivered next-generation diagnostic R&D to national laboratories to support stockpile experiments. Investments will provide control systems, software, detectors, instruments, and camera systems in 2 to 5 years. NNSS developed an experiment-quality Kraken imager and built a series of Kraken cameras, a 5-year development effort. The eight-frame camera improves image quality and sensitivity and provides solutions for visible and radiographic imaging applications. Ejecta diagnostics have focused on source term ejecta characteristics and transport in a gas.
- JASPER Experimental Program – NNSS completed nine JASPER experiments with LLNL in FY 2020, collecting temperature to support stockpile surveillance and enhance predictive plutonium models for pit lifetime and qualification assessments. NNSS also executed the first two 40-millimeter two-stage experiments for velocity ranging of the larger projectile capability.
- North Las Vegas Dense Plasma Focus (NLV DPF) – NNSS continued to execute experiments using the NLV DPF pulsed energy source. Using the NNSS and NLV DPF to improve methods for

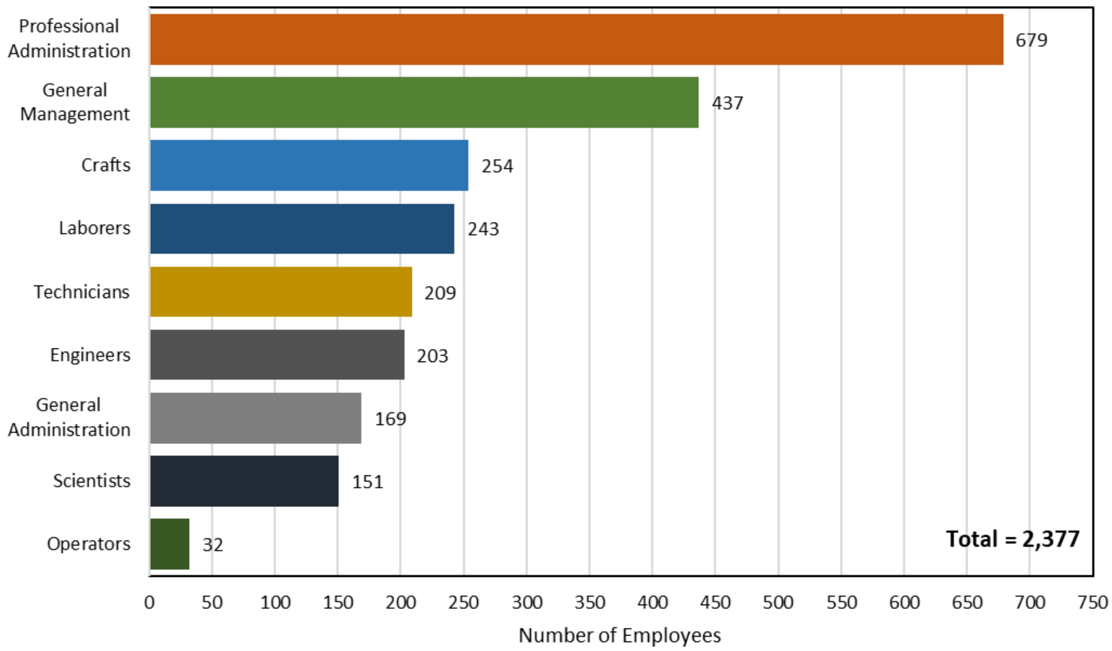
subcritical experiments and refine measurement techniques for the U1a.03 drift NDSE capability. NNSS improved its neutron generation technology with a second-generation diamond detector and paddle detector to measure neutron input signals; data will influence detector design for electromagnetic interference shielding and reduce low-frequency noise in the U1a.03 testbed. This work was pivotal in developing a major new diagnostic tool as a mainstay of subcritical experiments. Neutron diagnosis will allow investigation into several new areas of physics that are important to DOE/NNSA, including dynamic internal temperature measurement, neutron reactivity rates, and neutron radiography. NNSS also deployed an advanced neutron radiographic imaging system to evaluate source spot size with NLV DPF for consideration on the Excalibur subcritical experiment series, resulting in high-energy neutron images.

- NNSS completed the Argus line-item project at DAF with Nevada Enterprise partners. CD-4 was approved 5 months early in August and $900,000 under budget. The Argus security system is now fully operational, eliminating the risk of process equipment control system failure. This meets the critical commitment made to NNSA in 2017.
- Nevada completed the DOE/NNSA Office of Emergency Operations Emergency Communications Network migration to Switch on schedule and under budget while employing COVID-19 protocols. The project culminated in a ribbon cutting in September with the DOE/NNSA Administrator. NNSS is analyzing Switch capabilities for future upgrades to support national security assets.

E.4.1.5 Nevada National Security Site Workforce

NNSS had 2,377 employees at the end of FY 2020.[3] The age of the workforce is concentrated between the ages of 51 and 65 years, and the average age of 49 years. The percent of employees eligible for retirement is 27 percent. The average years of service is around 10 years, while the population is concentrated below 20 years of service. The largest experience group consists of those with 1–5 years of service. Involuntary separations were the largest overall category of separations during FY 2020 and were spread among several age groups. They were greatest among those with 1–5 years of service. About 22 percent of separations in FY 2020 were retirements, and another 23 percent were involuntary terminations, many of which resulted from contract transition. Since FY 2018, early- and mid-career trend populations have slowly increased, while the overall percentage of advanced-career employees declined. Workforce demographics are illustrated and discussed in **Figures E–69** through **E–77**.

[3] A large portion of the security workforce is not managed by the M&O contractor and is not included in the Site headcount (or subsequent charts). The security contractor has over 300 employees that are funded by Weapons Activities.



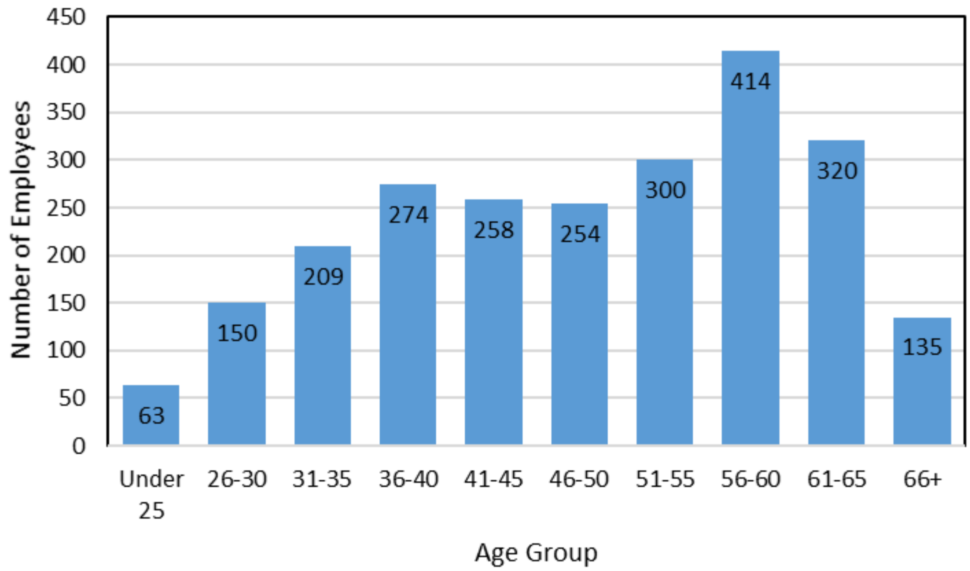
Notes:

Total site headcount decreased by approximately 5 percent in FY 2020. All COCS categories experienced a decrease in headcount except for general management and professional administration. Overall, bargaining unit personnel[4] decreased by approximately 18 percent in FY 2020. Several bargaining unit personnel were laid off due to lack of work, as no new projects were projected at the time.

Figure E–69. NNSS total workforce[5] by Common Occupational Classification System (COCS) (as of September 30, 2020)

[4] Bargaining unit personnel are identified as those employees in the crafts, laborers, and operators COCS.

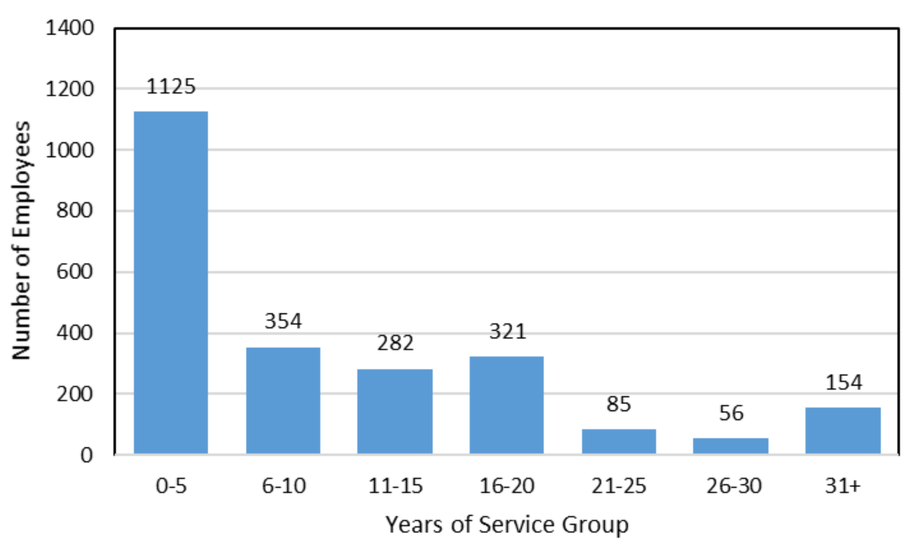
[5] A large proportion of the security workforce is not managed by the M&O contractor and is not included in the site headcount (or subsequent charts). The security contractor, SOC, has an additional 328 employees that are funded by Weapons Activities.



Notes:

The average age of the workforce increased slightly from 48 in FY 2019 to 49 in FY 2020. The percent of retirement-eligible employees decreased from 29 percent to 27 percent. Approximately 50 percent of the NNSS workforce is 51 years or older. This explains both the high average age and high percentage of retirement-eligible employees. Due to the COVID-19 pandemic, much of the workforce has relied on teleworking to meet mission needs. With an increased availability to work from home, more retirement-eligible employees are electing to continue working past retirement.

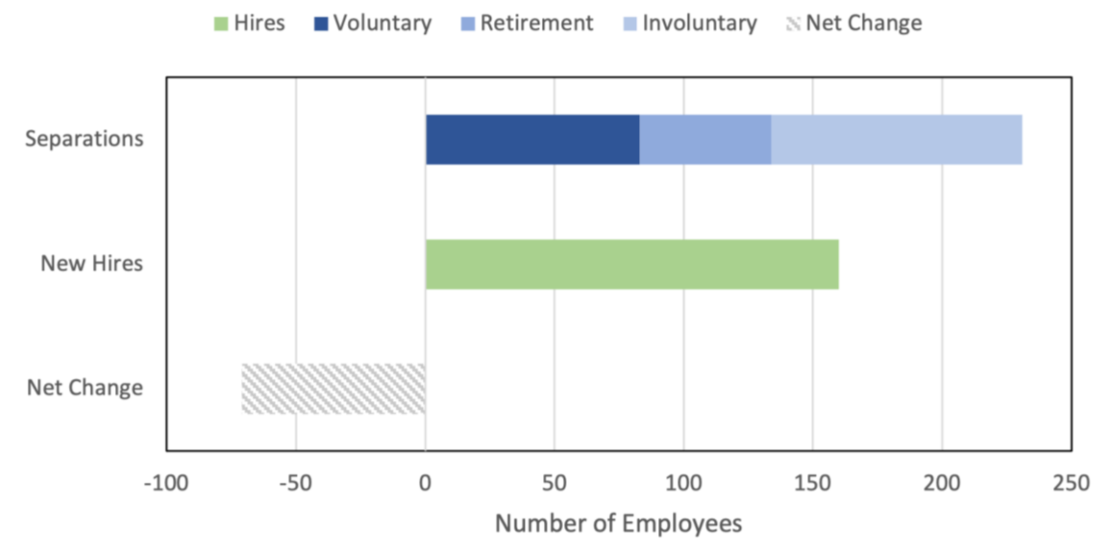
Figure E–70. NNSS employees distributed by age (as of September 30, 2020)



Notes:

The average years of service of the workforce increased from 9.5 in FY 2019 to 10.1 in FY 2020. This change can be attributed to a decrease in hiring due to the COVID-19 pandemic and other issues within an unpredictable job market. The most significant decrease in years of service occurred in the 0-5 years range (8 percent). Voluntary and involuntary terminations (see Figure E–74) and movement into a higher years of service category attributed to this decrease.

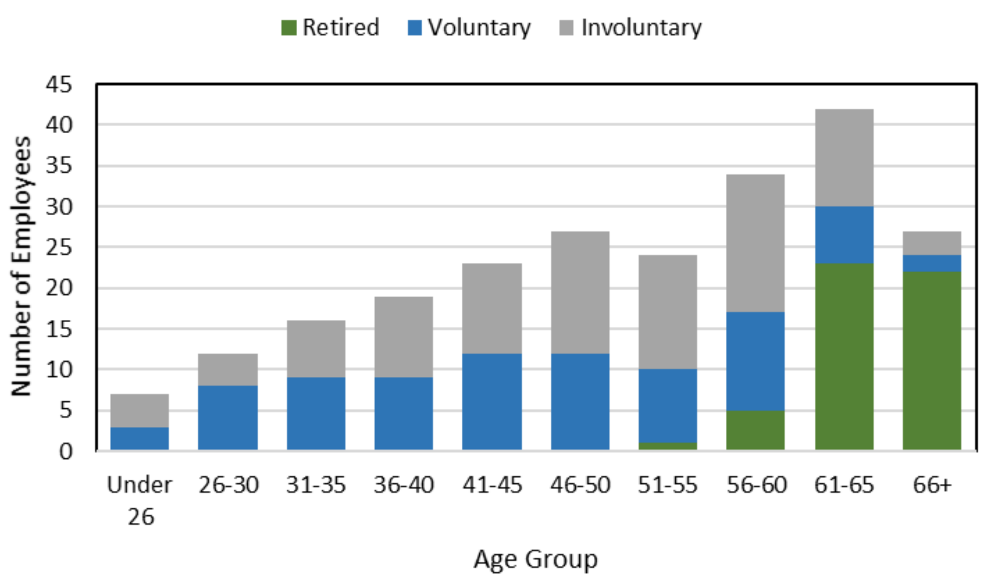
Figure E–71. NNSS employees distributed by years of service (as of September 30, 2020)



Notes:

NNSS experienced a negative net change with a 44 percent loss of employees for in FY 2020. As the site continues to make strategic organizational changes and analyze hiring needs, new employment opportunities will be available.

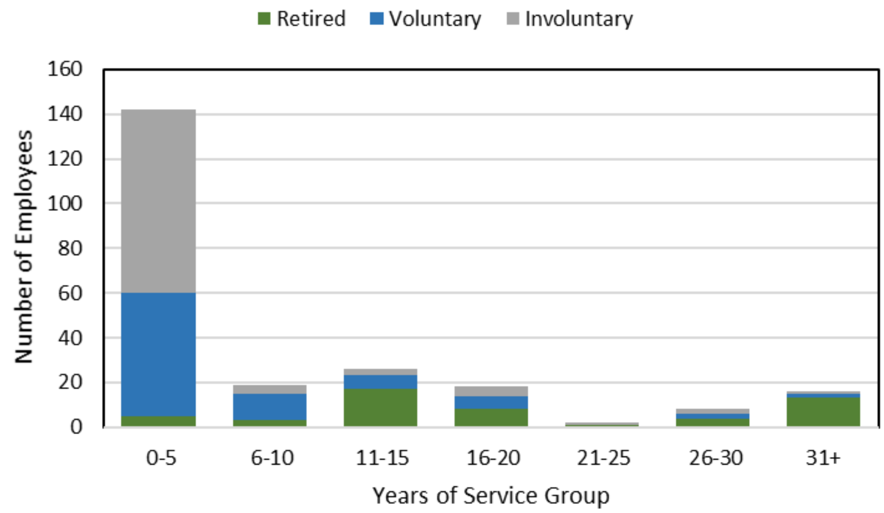
Figure E–72. NNSS net change for fiscal year (as of September 30, 2020)



Notes:

Total separations decreased 5 percent from last year. The number of involuntary terminations were greater than last year due to significant layoffs among bargaining unit personnel. Retirements and voluntary terminations decreased from last year due to less employee retirement and/or job transitions and the increase in ability and approvals to work from home.

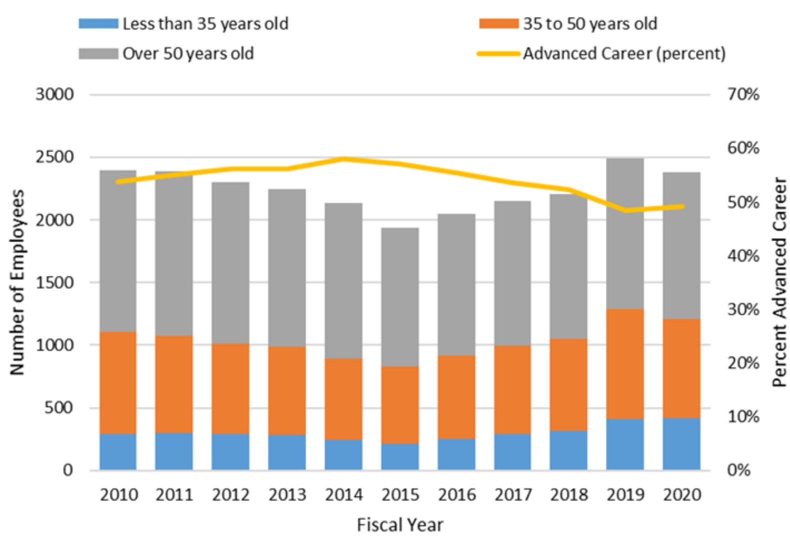
Figure E–73. NNSS employee separations by age group (as of September 30, 2020)



Notes:

Over 60 percent of terminations occurred within the 0-5 years of service group. This percentage is due to the large number of involuntary terminations and layoffs expected in a bargaining unit environment where seniority is a career factor. Layoffs constituted 58 percent of all bargaining unit employee terminations; 26 percent were resignations. Among non-bargaining employees, approximately 41 percent of all terminations were due to retirement, and approximately 18 percent were due to career advancement opportunities.

Figure E–74. NNSS employee separations by years of service group (as of September 30, 2020)

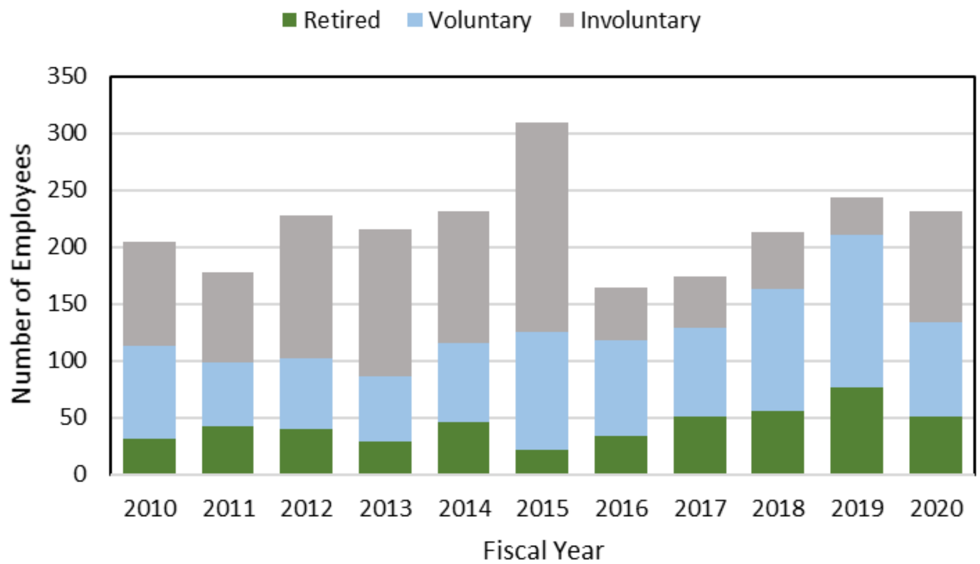


Notes:

While employees over 50 years old continue to make up almost 50 percent of the workforce, there was a slight increase in employees less than 35 years old for FY 2020.

Figure E–75. NNSS workforce participation trends by age category and percent advanced career[6] (as of September 30, 2020)

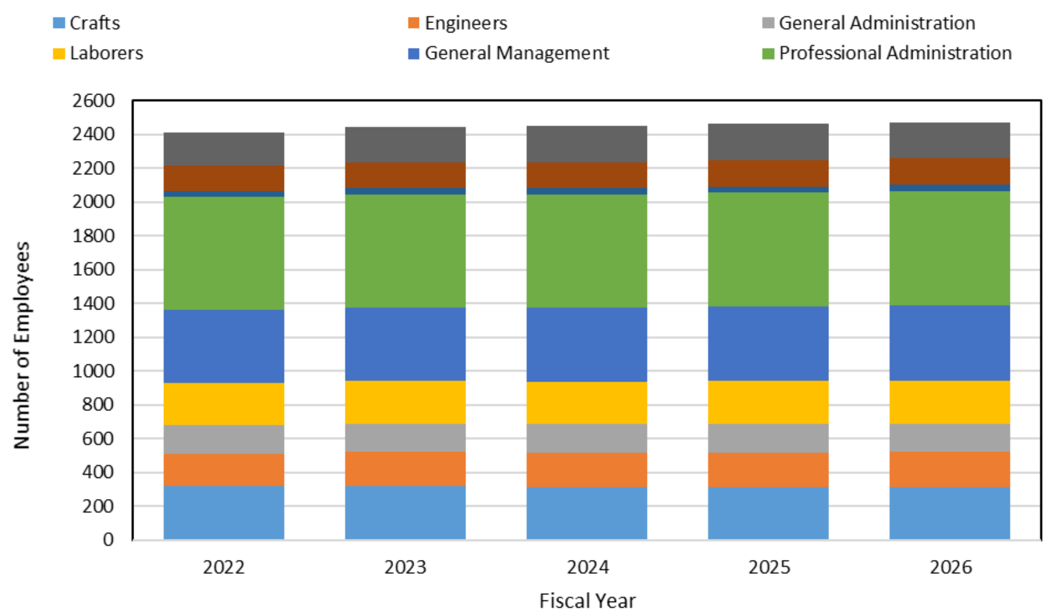
[6] The percentage of advanced-career workers is calculated by taking the ratio of employees over the age of 50 years and total workforce participation. The over 50 years of age group assumes the minimum age for retirement eligibility and captures the minimum retirement age for most Federal employees.



Notes:

Approximately 58 percent (80 employees) of bargaining unit employee terminations were due to layoffs. Retirements and voluntary turnover went down in FY 2020, which was expected due to the pandemic impacts on the economy and job market. NNSS will continue tracking the reasons for all terminations, analyzing for trends, and focusing on attracting, retaining, and growing employees, especially in the early and mid-career positions.

Figure E–76. NNSS employment separation trends (as of September 30, 2020)



Notes:

Workforce needs are fairly consistent across the near-term with minor increases anticipated in FY 2023 for engineers and technicians to support Enhanced Capabilities for Subcritical Experiments. There is also a minor reduction in craft resource needs starting in FY 2024 after completion of the U1a Complex Enhancements Project line item project.

Figure E–77. NNSS workforce projection needs by Common Occupational Classification System

Appendix F
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 (Alt)—A material change to, or a prescribed inspection of, a nuclear weapon or major assembly that does not alter its operational capability, yet is sufficiently important to the user regarding assembly, maintenance, storage, or test operations to require controlled application and identification.

annual assessment 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 also ensure the weapon will operate correctly when a unique signal to do so is properly activated.

artificial intelligence—Computer systems able to perform tasks intelligently, similar to humans, such as visual perception, speech recognition, decision-making, and translating between languages.

B61—An air-delivered gravity bomb.

B61-12 Life Extension Program (LEP)—An LEP to consolidate three variants of the B61 bomb in the active stockpile into one and improve the safety and security of the oldest weapon system in the U.S. arsenal.

B83-1—An air-delivered gravity bomb.

boost—The process that increases the yield of a nuclear weapon's primary stage through fusion reactions.

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

calciner—A dry thermal treatment process to convert low-equity enriched uranium liquids to a dry stable form for storage.

canned subassembly—A component of a nuclear weapon that is hermetically sealed in a metal container. A canned assembly 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.

controlled thermonuclear fusion—Thermonuclear fusion that is achieved in the laboratory, as opposed to during underground nuclear explosive testing.

conventional high explosive (CHE)—A high explosive that detonates when given sufficient stimulus by a high-pressure shock. Stimuli from severe accident environments involving impact, fire, or electrical discharge may also detonate a 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.

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 is recognized due to the highly interactive nature of various systems and networks. For example, 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.

depleted uranium (DU)—Uranium from which most of the fissile isotope uranium-235 has been removed. It is required for nuclear component production to maintain and modernize the stockpile through life extension, modification, and limited life component exchange programs.

design 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.

direct chip melt—The recovery of enriched uranium machine tool chips and turnings by collecting and remelting them in furnaces.

dismantlement and disposition—Disassembling retired weapons into major components that are then assigned for reuse, storage, surveillance, or disposal.

downblending—Processing highly enriched uranium into a uranium byproduct that contains less than 20 percent uranium-235.

down-select—The process of narrowing the range of design options during the *Phase 6.X Process*, culminating in a final design (normally exercised when moving from Phase 6.1 to 6.2, from Phase 6.2 to 6.2A, and from Phase 6.2A to 6.3). Down-selecting involves analysis of the option's ability to meet military requirements, and assessment of schedule, cost, material, and production impacts.

*electrorefining—A*n electrochemical metal purification system designed to provide a replacement capability for the current metal purification process.

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.

enriched uranium—Uranium that contains higher concentrations of the fissile uranium-235 isotope than natural uranium. It is required at varied enrichment levels for national security and medical isotope production.

enterprise forensics—The performance of real-time, remote inspections at the binary level of all data on a given computer 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 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—Information 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)."

Federally Funded Research and Development Center (FFRDC)—A public-private partnership that conducts research and development, study and analysis, and/or systems engineering and integration for the Federal Government. Typically, FFRDCs are operated by consortia of universities and industrial corporations.

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 (FY)—The Federal budget and funding year that starts on October 1 and goes to the following September 30.

fission—The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial energy.

floating point operations per second (FLOPS)—The number of arithmetic operations performed on real numbers in a second; used as a measure of the performance of a computer system.

fusion—The process whereby the nuclei of two light elements, especially the isotopes of hydrogen (i.e., deuterium and tritium), combine to form the nucleus of a heavier element with the release of substantial energy and a high-energy neutron.

Future Years Nuclear Security Program (FYNSP)—A detailed description of the program elements (and associated projects and activities) for the fiscal year for which the annual budget is submitted and the four succeeding fiscal years.

gas transfer system (GTS)—A warhead component that enables tritium, a radioactive isotope of hydrogen, to boost the yield of a nuclear weapon.

general plant project (GPP)—A miscellaneous minor construction project of a general nature, for which the total estimated cost may not exceed the congressionally established limit. GPPs are necessary to adapt facilities to new or improved production techniques, to effect economies of operations, and to reduce or eliminate health, fire, and security problems. These projects provide for design, construction, additions, and/or improvements to land, buildings, replacements or additions to roads, and general area improvements.

general purpose infrastructure—The buildings, equipment, utilities, roads, etc., that support operation of the nuclear security enterprise, but are not-focused on a particular program.

high energy density (HED) physics—The physics of matter and radiation at very high energy densities, i.e., extreme temperatures and pressures.

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 fusion yield—A release of fusion energy in excess of 100 megajoules from an inertial confinement fusion target. This is three orders of magnitude greater than today's best performing experiments.

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.

infrastructure—For the purposes and scope of the SSMP, infrastructure refers to the comprehensive inventory of facilities, structures, utilities, equipment, and other physical assets required to operate the national security enterprise in service to its national security missions.

insensitive high explosive—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 system—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 nuclear weapons life cycle process—Nuclear weapons are conceptually designed, developed, produced, and maintained in the stockpile, and then retired and dismantled. This sequence of events is known as the nuclear weapons life cycle. DOE, through NNSA, and in partnership with DoD (through the Nuclear Weapons Council) conducts activities in a joint nuclear weapons life cycle process to manage weapons sustainment and modernization needs from concept assessment to full scale production, and finally to retirement.

Joint Technology Demonstrator (JTD)—A United States and United Kingdom strategic collaboration dedicated to the design and execution of joint, integrated system demonstrations supporting new safety, security, and advanced manufacturing technologies.

joint test assembly (JTA)—(1) An electronic unit that contains sensors and instrumentation that monitor weapon hardware performance during flight tests to ensure that the weapon components will function as designed. (2) An NNSA-developed configuration, based on NNSA-DoD requirements, for use in the flight test program.

life cycle—The series of stages through which a component, system, or weapon passes from initial development until it is consumed, disposed of, or altered 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 in other extreme, high-voltage, high-temperature environments.

limited life component (LLC)—A weapon component or subsystem whose performance degrades with age and must be periodically replaced. Examples are gas transfer systems, power sources, and neutron generators.

line item project—A distinct design, construction, betterment and/or fabrication of real property for which Congress will be requested to authorize and appropriate specific funds.

lithium—A soft, light-weight, silvery-white alkali metal (symbol: Li) used as a target element in nuclear weapons. Lithium reacts with a neutron to produce tritium. It is considered a strategic material in nuclear weapon manufacture.

machine learning—A type of artificial intelligence characterized by computer algorithms that improve automatically through experience, so the computer learns without being explicitly programmed.

Manufacturing Readiness Level (MRL)—A means of communicating the degree to which a component or subsystem is ready to be produced. MRLs represent many attributes of a manufacturing system (e.g., people, manufacturing capability, facilities, conduct of operations, and tooling). There are nine MRLs, with the lowest being product development and the highest being steady-state production.

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.”

military characteristics—Required characteristics of a nuclear weapon upon which depend its ability to perform desired military functions, including physical and operational characteristics, but not technical design characteristics.

modernization—The changes to nuclear weapons or infrastructure due to aging, unavailability of replacement parts, or the need to enhance safety, security, and operational design features. In the context of the physical infrastructure that support the nuclear security missions, modernization refers to recapitalization and refurbishment investments to restore and refresh aging facilities, structures, utilities, equipment, and other physical assets to a state that fully supports mission functionality and underpins key Weapons Activity capabilities into the future.

modification (Mod)—A program that changes a weapon's operational capabilities. A Mod may enhance the margin against failure, increase safety, improve security, replace limited life components, and/or address identified defects and component obsolescence.

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 laboratories—Los Alamos National Laboratory, Sandia National Laboratories, and Lawrence Livermore National Laboratory. These laboratories guide research and development on behalf of DOE/NNSA Mission needs and address science and engineering challenges, from basic science questions through weapons design and production. They also support nuclear counterterrorism and counterproliferation.

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 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 partners 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.

nuclear explosive package—An assembly containing fissionable and/or fusionable materials, as well as the main charge high-explosive parts or propellants capable of producing a nuclear detonation.

nuclear forensics—The investigation of nuclear materials to find evidence for the source, trafficking, and enrichment of the material.

nuclear security enterprise—The physical infrastructure, technology, and workforce at the national security laboratories, the nuclear weapons production sites, and the Nevada National Security Site, that sustain the research, development, production, and dismantlement capabilities needed to support the nuclear weapons stockpile.

Nuclear Weapons Council—The joint DOE/DoD Council composed of senior officials from both Departments who recommend the stockpile options and research priorities that shape national policies and budgets to develop, produce, surveil, and retire nuclear warheads and weapon delivery platforms, and who consider the safety, security, and control issues for existing and proposed weapons programs.

nuclear weapons production site—The Kansas City National Security Campus, Pantex Plant, Y-12 National Security Complex, and Savannah River Site. Los Alamos National Laboratory and Sandia National Laboratories also perform some specific weapons production activities beyond their design responsibilities and may be referred to as production sites on occasion.

nuclear weapons stockpile—Both active and inactive nuclear warheads. Active warheads include strategic and non-strategic weapons maintained in an operational, ready-for-use configuration, ready for possible deployment within a short timeframe, with logistics spares.

neutron generator—A limited life component that provides neutrons at specific times and rates to initiate weapon function.

Other Program Money—Funding that is found outside of a life extension program (LEP) funding line (in other program lines), but is directly (uniquely) attributed to an LEP. Such funding would not be needed were it not for the LEP, although the activity or effort might still be done at some future point along a different timeline.

out-years—The years that follow the 5-year period of the Future Years Nuclear Security Program.

Phase 6.X Process—A time and organizational framework to manage the existing nuclear weapon systems that are undergoing evaluation and implementation of refurbishment options to extend their stockpile life or enhance system capabilities. The *Phase 6.X Process* consists of sub-phases that correspond to Phases 1 through 6 of the nuclear weapons life cycle.

physical security—The physical or technical methods that protect personnel; prevent or detect unauthorized access to facilities, material, and documents; protect against espionage, sabotage, damage, and theft; and respond to any such acts that occur.

pit—The critical core component in the primary of a nuclear weapon that contains fissile material.

power source—Power sources for current and future planned nuclear weapons and life-extended warheads are compact, specialized, limited-life components that fulfill power requirements for weapons.

primary—The first stage of a two-stage nuclear weapon.

production sites—(Sometimes also referred to as production facilities, plants, and agencies) Savannah River Site, Y-12 National Security Complex, Kansas City National Security Campus, and Pantex Plant. These facilities produce most of the designed weapon components and assemble weapons.

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. Qualification authorizes the listed items for an intended use (i.e., War Reserve, Training, Evaluation, etc.), and it generally includes national security laboratory (design) review of production and inspection processes. Qualified items are reviewed for possible requalification after a significant process change or if production is inactive for 12 months.

quantification of margins and uncertainties—The methodology used in the post-underground-nuclear-explosive-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.

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

Recapitalization—In the context of physical infrastructure that supports nuclear security missions, recapitalization refers to investments in existing facilities, structures, utilities, equipment, and other assets that upgrade, renew, or otherwise improve and extend the usable life of the asset.

reservoir—A vessel containing deuterium and tritium that permits its transfer as a gas in a nuclear weapon.

restricted data—All data concerning (1) design, manufacture, or utilization of atomic weapons, (2) production of special nuclear material, and (3) use of special nuclear material in the production of energy.

Safeguards Transporter (SGT)—A highly specialized trailer designed to safeguard nuclear weapons and special nuclear materials while in transit.

secondary—The second stage of a two-stage nuclear weapon that provides additional energy release in the form of fusion and is activated by energy from the primary.

security—An integrated system of activities, systems, programs, facilities, and policies to protect classified matter, unclassified controlled information, nuclear materials, nuclear weapons, nuclear weapon components, and DOE's and its contractors' facilities, property, and equipment.

security 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). Service life can include the terms "stockpile life," "deployed life," and "useful life."

significant finding investigation (SFI)—A formal investigation by a committee, chaired by an employee of a national security laboratory, to determine the cause and impact of a reported anomaly and to recommend corrective actions as appropriate.

special nuclear material (SNM)—Plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235. The Nuclear Regulatory Commission defines three categories of quantities of SNM according to the risk and potential for its use in the creation of a fissile explosive. Category I is the category of the greatest quantity and associated risk; Category II is moderate; Category III is the lowest.

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 assessment—Continuous, multi-layered evaluations of the safety, security, and military effectiveness of each U.S. nuclear weapon system making up the stockpile, conducted to evaluate the stockpile's status.

stockpile sustainment—The activities responsible for the day-to-day health of the stockpile, including surveillance, annual assessments, and routine maintenance, to ensure weapons remain safe, secure, and reliable for their projected lifecycle.

stockpile-to-target sequence—The order of events involved in removing a nuclear weapon from storage and assembling, testing, transporting, and delivering it to the target. The term also refers to a document that defines the logistical and employment concepts and related physical environments involved in delivering a nuclear weapon to a target.

subcritical experiment—An experiment specifically designed to obtain data on nuclear weapons for which less than a critical mass of fissionable material is present and, hence, no self-sustaining nuclear fission chain reaction can occur, consistent with the Comprehensive Nuclear Test Ban Treaty.

surety—The assurance that a nuclear weapon will operate safely, securely, and reliably if deliberately activated and that no accidents, incidents, or unauthorized detonations will occur. Factors contributing to that assurance include model validation for weapon performance based on experiments and simulations, material (e.g., military equipment and supplies), personnel, and execution of procedures.

surveillance—Activities that provide data for evaluation of the stockpile, giving confidence in the Nation's deterrent by demonstrating mission readiness and assessment of safety, security, and reliability standards. These activities may include laboratory and flight testing of systems, subsystems, and components (including those of weapons in the existing stockpile, newly produced weapons, or weapons being disassembled); inspection for unexpected wear or signs of material aging; and destructive or nondestructive testing.

sustainment—An NNSA program to modify and maintain a set of nuclear weapon systems (see stockpile sustainment). In the context of physical infrastructure that supports the nuclear security missions, sustainment refers to the set of activities over an asset's lifetime that provide for maintaining, operating, refurbishing, upgrading, and recapitalizing that asset until retirement and disposition.

technology maturation—Advancing laboratory-developed technology to the point where it can be adopted and used by U.S. industry.

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 a bad 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.

transuranic waste—Waste containing chemical elements heavier than uranium, often plutonium. It is primarily discarded equipment and soils contaminated with certain radioactive material.

tritium—A radioactive isotope of hydrogen whose nucleus contains two neutrons and one proton. It is produced in nuclear reactors by the action of neutrons on lithium nuclei.

uranium—A naturally occurring radioactive, metallic element (symbol: U) that is found in the earth as a mineral ore. It has three primary isotopes: uranium-238, -235, and -234. It is a strategic material, with several uses related to nuclear weapons and therefore is critical to national security.

uranium enrichment—The process of increasing the concentration of the uranium-235 isotope in a sample of uranium by separating it from uranium-238.

verification and validation (V&V)—Independent procedures that are used together for checking that a product, service, or system meets requirements and specifications, and that it fulfills its intended purpose. For example, in the context of software testing, verification provides evidence of the correctness of computer codes in solving pertinent equations, while validation assesses the adequacy of the physical models used to represent reality. V&V is also applied to nuclear weapons to ensure that they fulfil their intended function with sufficient precision to meet military and other specifications.

W76-1 LEP—A life extension program for the W76 submarine-launched ballistic missile warhead, delivered by a Navy Trident II.

W78—An intercontinental ballistic missile warhead, delivered by an Air Force Minute Man III LGM-30.

W80-4 LEP—A life extension program for the W80 warhead aboard a cruise missile, delivered by the Air Force B-52 bomber and future launch platforms.

W88—A submarine-launched ballistic missile warhead, delivered by a Navy Trident II.

W88 Alteration (Alt) 370—An Alt of the W88 warhead to replace the arming, fuzing, and firing components and to refresh the conventional high explosive main charge.

W87-1—An intercontinental ballistic missile warhead designed to replace the W78 and support the Air Force's ground-based strategic deterrent missile system planned to replace the Minuteman III.

warhead—The part of a missile, projectile, torpedo, rocket, or other munition that contains either the nuclear or thermonuclear system intended to inflict damage.

War Reserve—Nuclear weapons and nuclear weapon material intended for use in the event of war.

Weapons Activities—Sustaining, modernizing, and dismantling nuclear weapons; maintaining and modernizing production operations; and optimizing the scientific tools underpinning these efforts. The term also refers to the portion of the NNSA budget covering these activities.

Appendix G
Acronyms and Abbreviations

3D	three dimensional
AACE	American Association of Cost Engineering
ACRR	annular core research reactor
ACQ	Advanced Certification and Qualification
Alt	alteration
AoA	analysis of alternatives
ASC	Advanced Simulation and Computing
ASD	Advanced Sources and Detectors
ATDM	Advanced Technology Development and Mitigation
ATS	Advanced Technology System
BCR	Baseline Cost Report
BME	base metal electrode
CATS	Clearance Action Tracking System
CBI	Capabilities Based Investments
CD	Critical Decision
CHE	conventional high explosive
CMR	Chemistry and Metallurgy Research
CNS	Consolidated Nuclear Security, LLC
COCS	Common Occupational Classification System
COTS	commercial off-the-shelf
COVID-19	Coronavirus Disease 2019
CP	Challenge Problem
CSSE	Computational Systems and Software Environment
CSTART	Center for Security, Technology, Analysis, Response and Testing
CTCP	Counterterrorism and Counterproliferation Program
CUAS	counter unmanned aircraft systems
DARHT	Dual-Axis Radiographic Hydrodynamic Test
D&I	disassembly and inspection
DAF	Device Assembly Facility
DBT	design basis threat
DEIA	diversity, equity, inclusion, and accessibility
DM	deferred maintenance
DNS	Office of Defense Nuclear Security
DoD	Department of Defense
DOE	Department of Energy
DPF	Dense Plasma Focus
DPRK	Democratic People's Republic of Korea
EAS-3	El Capitan early access system-3
EC3E	Exascale Class Computer Cooling Equipment
ECP	Exascale Computing Project

ECSE	Enhanced Capabilities for Subcritical Experiments
FFRDC	Federally Funded Research and Development Centers
FITARA	Federal Information Technology Acquisition and Reform Act
FM&T	Federal Manufacturing and Technologies, LLC
FY	fiscal year
FYNSP	Future Years Nuclear Security Program
G2	DOE/NNSA Program Management Information System, Generation 2
GAO	Government Accountability Office
GBSD	ground-based strategic deterrent
GPP	General Plant Project
GTS	gas transfer system
HE	high explosives
HED	high energy density
HESE	High Explosives Science and Engineering
HEU	highly enriched uranium
HPC	high performance computing
HVAC	heating, ventilating, and air conditioning
ICF	Inertial Confinement Fusion
IDC	integrated design code
IHE	insensitive high explosive
IMI	Infrastructure Modernization Initiative
IT	Information Technology
JASPER	Joint Actinide Shock Physics Experimental Research
JTA	joint test assembly
JTD	Joint Technology Demonstrator
KCNSC	Kansas City National Security Campus
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LAP4	Los Alamos Plutonium Pit Production Project
LEP	life extension program
LEU	low-enriched uranium
LLC	limited life component
LLNL	Lawrence Livermore National Laboratory
LRSO	Long Range Standoff
M3	Material Management and Minimization
M&O	management and operating
MESA	Microsystems Engineering, Science and Applications
MFFF	Mixed Oxide Fuel Fabrication Facility
MgO	magnesium oxide
MGT	Mobile Guardian Transporter
MIE	major item of equipment
Mod	modification
MSIPP	Minority Serving Institution Partnership Program
MTE	major technical efforts
NATO	North Atlantic Treaty Organization
NCERC	National Criticality Experiments Research Center
NEPA	*National Environmental Policy Act*
NEST	Nuclear Emergency Support Team

NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
NPAC	Nonproliferation and Arms Control
NRC	Nuclear Regulatory Commission
NSCI	National Strategic Computing Initiative
OCIO	Office of the Chief Information Officer
OMB	Office of Management and Budget
OST	Office of Secure Transportation
Pantex	Pantex Plant
PF-4	Plutonium Facility
PIDAS	Perimeter Intrusion Detection and Assessment System
PPBE	Planning, Programming, Budgeting, and Evaluation
ppy	pits per year
R&D	research and development
RACR	Radiography/Assembly Capability Replacement
RASR	Research and Sounding Rocket
RCT	radiological control technician
RDT&E	research, development, test and evaluation
RPV	replacement plant value
SAR	Selected Acquisition Report
SCDS	Stewardship Capability Delivery System
SFI	significant finding investigation
SGT	Safeguards Transporter
SIRP	Security Infrastructure Revitalization Program
SLCM	Sea-Launched Cruise Missile
SNL	Sandia National Laboratories
SNM	special nuclear material
SRNL	Savannah River National Laboratory
SRPPF	Savannah River Plutonium Processing Facility
SRS	Savannah River Site
SRT&E	Stockpile Research, Technology, and Engineering
SRTE	Savannah River Tritium Enterprise
SSAA	Stewardship Science Academic Alliances
SSMP	Stockpile Stewardship and Management Plan
ST&E	science, technology, and engineering
STA	Secure Transportation Asset
STEM	science, technology, engineering, and mathematics
STS	stockpile-to-target sequence
TA	Technical Area
TABS	Thermally Activated Battery Simulator
TATB	triaminotrinitrobenzene
TCR	Test Capability Revitalization
TPBAR	tritium-producing burnable absorber rod
Triad	Triad National Security, LLC
TRL	technology readiness level
TVA	Tennessee Valley Authority
U1a	U1a Complex

U.S.	United States
U.S. Code	United States Code
USSTRATCOM	U.S. Strategic Command
WBN1	Watts Barr Nuclear Unit 1
WBN2	Watts Barr Nuclear Unit 2
WDCR	Weapon Design and Cost Report
WDD	Weapons Dismantlement and Disposition
WR	War Reserve
Y-12	Y-12 National Security Complex
Z	Z pulsed power facility

Appendix H
List of Figures and Tables

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A Report to Congress

Fiscal Year 2022 Stockpile Stewardship and Management Plan

March 2022

U.S. Department of Energy
National Nuclear Security Administration
1000 Independence Avenue, SW
Washington, DC 20585