Fiscal Year 2020

Stockpile Stewardship and Management Plan

Report to Congress

July 2019

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

Message from the NNSA Administrator

The Department of Energy's National Nuclear Security Administration (DOE/NNSA) was created to safeguard and support our Nation's security through the application of nuclear science. Since the days of the Manhattan Project, the highly talented men and women of the nuclear security enterprise have applied unique capabilities to promote U.S. security in the face of an ever-evolving global security environment. Nuclear deterrence has been, and remains, the cornerstone of our Nation's security posture. Providing the tools of deterrence to our military is the highest priority mission for DOE/NNSA.

DOE/NNSA's *Fiscal Year 2020 Stockpile Stewardship and Management Plan* (SSMP) describes plans to ensure the safety, security, and effectiveness of the U.S. nuclear weapons stockpile and to maintain the scientific and engineering tools, capabilities, and infrastructure that underpin the nuclear security enterprise. The SSMP is a companion document to the annual *Prevent, Counter, and Respond: A Strategic Plan to Reduce Global Nuclear Threats: FY 2020 – FY 2023* report to Congress, which outlines the equally vital missions of reducing the threats of nuclear proliferation and nuclear terrorism. In keeping with our commitments to Congress and the public, updated versions of these reports are published each year.

The fiscal year (FY) 2020 SSMP summarizes the activities being performed within DOE/NNSA's national laboratories, production facilities, and security sites in support of our national security missions. In particular, this report describes DOE/NNSA's plan to achieve the program requirements of: producing at least 80 plutonium pits per year by 2030; achieving the first production unit of the W80-4 warhead by FY 2025; and delivering the first production unit of the B61-12 gravity bomb and the W88 Alteration 370 warhead.

In FY 2019, DOE/NNSA completed production of the W76-1 Life Extension Program, began work on the W76-2 low yield ballistic missile warhead, and restarted design activities for the W78 replacement warhead (the W87-1). The nuclear security enterprise is at its busiest since the demands of the Cold War era.

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

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

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

Pursuant to statute, this FY 2020 SSMP is being provided to the following members of Congress:

The Honorable Richard Shelby
Chairman, Senate Committee on Appropriations

The Honorable Patrick Leahy
Vice Chairman, Senate Committee on Appropriations

The Honorable James Inhofe
Chairman, Senate Committee on Armed Services

The Honorable Jack Reed
Ranking Member, Senate Committee on Armed Services

The Honorable Lamar Alexander
Chairman, Subcommittee on Energy and Water Development
Senate Committee on Appropriations

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

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

The Honorable Martin Heinrich
Ranking Member, Subcommittee on Strategic Forces
Senate Committee on Armed Services

The Honorable Nita Lowey
Chairman, House Committee on Appropriations

The Honorable Kay Granger
Ranking Member, House Committee on Appropriations

The Honorable Adam Smith
Chairman, House Committee on Armed Services

The Honorable Mac Thornberry
Ranking Member, House Committee on Armed Services

The Honorable Marcy Kaptur
Chairman, Subcommittee on Energy and Water Development, and Related Agencies
House Committee on Appropriations

The Honorable Mike Simpson

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

The Honorable Jim Cooper

Chairman, Subcommittee on Strategic Forces
House Committee on Armed Services

The Honorable Michael Turner

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

Should you have any questions or need additional information, please contact Ms. Bridget Forcier, Office of the Chief Financial Officer, at (202) 586-0176; or Ms. Nora Khalil, NNSA Associate Administrator for External Affairs, at (202) 586-7332.

Sincerely,

Lisa E. Gordon-Hagerty
Under Secretary for Nuclear Security
Administrator, NNSA

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Message from the Secretary

National security is a fundamental mission of the Department of Energy (DOE). Maintaining a safe, secure, and effective U.S. nuclear stockpile is performed through the work of DOE's National Nuclear Security Administration (NNSA). This mission accounts for more than a third of the Department's discretionary budget. It comprises the developments made at the national security laboratories, production facilities, and security sites in science-based stockpile stewardship, advanced manufacturing, high performance computing, and other areas that benefit DOE and other departments and agencies throughout the Government.

DOE/NNSA has been working in close partnership with the Department of Defense (DoD) to implement the national security requirements laid out in the 2018 *Nuclear Posture Review*. Today's dynamic global threat environment includes an unprecedented range and mix of threats. The nuclear deterrent remains an essential element of our Nation's defense to protect our interests and those of our allies. The joint DOE and DoD efforts to implement the *Nuclear Posture Review* requirements will provide additional diversity in the attributes and flexibility of our deterrence options. This year's *Fiscal Year 2020 Stockpile Stewardship and Management Plan* (SSMP) continues to document our plans and progress on this critical initiative.

For the 23rd consecutive year, the science-based Stockpile Stewardship Program has allowed DOE and DoD to certify the safety, security, and effectiveness of the U.S. nuclear weapons stockpile to the President without the use of nuclear explosive testing. This impressive scientific achievement is enabled by DOE/NNSA's most valuable resource, its workforce. DOE/NNSA's ability to recruit, train, and retain the next generation of world-class scientists, engineers, and technicians is a major priority. Additionally, it is imperative that DOE/NNSA continues revitalization and modernization of its infrastructure to ensure the nuclear security enterprise can continue its work safely and effectively.

With continued congressional support for the program described in this SSMP, we will continue to meet our Nation's evolving nuclear security requirements while keeping the nuclear deterrent safe, secure, and effective.

Sincerely,

Rick Perry

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Executive Summary

This *Fiscal Year 2020 Stockpile Stewardship and Management Plan* (SSMP), including its classified Annex, describes the Department of Energy/National Nuclear Security Administration (DOE/NNSA) program for maintaining the safety, security, and effectiveness of the nuclear stockpile over the next 25 years. DOE/NNSA publishes the SSMP annually, either in full report form or as a summary, in response to statutory requirements, to support the President's Budget Request to Congress for Weapons Activities. This Fiscal Year (FY) 2020 SSMP is a full 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 2019–2042.*

This SSMP lays the foundation for meeting the nuclear deterrent objectives laid out in the *National Security Strategy* (White House 2017) and the 2018 *Nuclear Posture Review* (DoD 2018). Maintaining the range of flexible nuclear capabilities needed to ensure an effective nuclear deterrent can only be realized through enduring world-class science, technology, and engineering expertise and a responsive and resilient nuclear infrastructure.

Maintain the safety, security, and effectiveness of the Nation's nuclear deterrent:

With five warhead modernizations underway, DOE/NNSA is executing an unprecedented variety of complex component development and production work. Highlights of near-term and out-year mission milestones for the nuclear deterrent include:

- 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 by FY 2025, complete the life extension program (LEP) by 2031, and ensure alignment with the Department of Defense Long Range Standoff cruise missile replacement program.
- Deliver the W76-2 initial operational capability warheads to the Navy.
- Support fielding the Ground-Based Strategic Deterrent by FY 2030 and advance the W87-1 Modification Program (W78 Replacement) planning basis for warhead replacement modernization activities by 1 year.
- Sustain the B83-1 unit until a suitable replacement is identified.
- Continue execution of the Stockpile Responsiveness Program.
- Provide the enduring capability and capacity to produce plutonium pits at a rate of no fewer than 80 pits per year (ppy) by 2030 by expanding plutonium pit production capabilities.
- Assure a continuous and reliable supply of strategic materials for military needs, including plutonium, uranium, lithium, and tritium.

Accomplishments include:

- Completed 100 percent of the total production units of the W76-1 LEP, one of the two warheads associated with the Navy's submarine-launched ballistic missile. This LEP will add an additional 30 years of service life to the W76.

- The W88 Alt 370 program accelerated activities for the change-out of the high explosives (HE) in the W88, the other submarine-launched ballistic missile warhead.
- The B61-12 LEP, a nuclear gravity bomb for the Air Force, is currently in the production engineering phase and continues to meet its qualification test schedule; multiple flight tests were completed during the past year. Once completed, the LEP will add at least 20 years to the life of the system and consolidate four models of the B61 into a single variant.
- DOE/NNSA made significant progress on the W80-4 LEP and entered Phase 6.3 (Development Engineering) in February 2019.
- In alignment with the 2018 *Nuclear Posture Review*, DOE/NNSA advanced restart of the W87-1 Modification Program (W78 Replacement) to FY 2019 to support fielding the Air Force Ground-Based Strategic Deterrent by 2030. The program was reauthorized by the Nuclear Weapons Council to restart Feasibility Study and Design Options (Phase 6.2) in September 2018.

Strengthen key science, technology, and engineering capabilities:

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

Highlights of near-term and out-year mission milestones for science, technology, and engineering capabilities include:

- Advance the innovative experimental platforms, diagnostic equipment, and computational capabilities necessary to ensure stockpile safety, security, reliability, and effectiveness.
  - Achieve exascale computing and deliver a capable exascale machine by the early 2020s.
  - Develop an operational enhanced capability (advanced radiography and reactivity measurements) for subcritical experiments by the mid-2020s.
  - Ensure an enduring trusted supply of strategic radiation-hardened microsystems beyond 2025.
- Maintain state-of-the-art manufacturing technologies in support of production operations.
- Implement the Stockpile Responsiveness Program to fully exercise the workforce and capabilities of the nuclear security enterprise.
- Nurture Strategic Partnership Programs that support other customers' needs while advancing the long-term capabilities and workforces of the national laboratories.

Accomplishments include:

- The National Ignition Facility at Lawrence Livermore National Laboratory (LLNL) in Livermore, California and the Z pulsed power facility at Sandia National Laboratories (SNL) in Albuquerque, New Mexico once again pushed the envelope in the field of high energy density science with record performances for output. High energy density and inertial confinement fusion experiments support stockpile stewardship, as well as other national security applications and discovery science.

- The Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos National Laboratory (LANL) completed integrated hydrodynamic experiments that examined the effects of component aging and the changes proposed in the LEPs.
- The Joint Actinide Shock Physics Experimental Research (JASPER) gas gun at the Nevada National Security Site completed 18 experiments, including two with plutonium. Sixteen experiments on other special nuclear materials readied the platform for advanced diagnostics in support of upcoming plutonium experiments.
- The Microsystems Engineering, Science and Applications (MESA) Complex at SNL produced integrated circuits for the nuclear security enterprise, including circuits used in state-of-the-art diagnostic detectors.

> - *DOE/NNSA laboratories, plants, and sites took home 13 R&D 100 Awards, known as the "Oscars of Invention."*
> - *Over $65 million in grants were awarded to academic institutions across the Nation to support fundamental research relevant to DOE/NNSA's stockpile stewardship mission.*

- The Los Alamos Neutron Science Center (LANSCE) fielded 122 experiments critical to understanding nuclear weapons performance and an additional 546 experiments for other users, including other government organizations, universities, and industry (under proprietary user agreements). The proton radiography facility and the Lujan Center both executed shots in support of the B61-12 LEP and future stockpile options. The Weapons Neutron Research Facility measured nuclear criticality data, as well as radiochemical data from underground tests.
- The Sierra high performance computing system at LLNL has been accepted and is scheduled to move to full operations in FY 2019. With a speed of 119 petaFLOPS,[1] Sierra represents an almost-threefold performance increase over the previous supercomputer, Trinity at LANL, which will continue to serve the needs of the mission alongside Sierra.

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 our national security missions today and into the future. With the assistance and support of Congress, we will be able to reduce deferred maintenance and modernize the nuclear security enterprise.

Highlights of near-term and out-year mission milestones for nuclear security infrastructure include:

- Recapitalize existing infrastructure to implement a plan to produce no less than 80 ppy by 2030. The recommended strategy is a two-site solution:
  - Produce no fewer than 30 ppy at the Plutonium Facility (PF-4) at LANL in Los Alamos, New Mexico, beginning in 2026.
  - Repurpose the Mixed Oxide Fuel Fabrication Facility at the Savannah River Site near Aiken, South Carolina as part of the Savannah River Plutonium Processing Facility to produce at least 50 ppy by 2030.

[1] PetaFLOPS = one million billion or 10^{15} floating point operations per second.

- Phase out mission dependency on Building 9212 at the Y-12 National Security Complex (Y-12) in Oak Ridge, Tennessee and deliver the Uranium Processing Facility.
- Ensure long-term actinide chemistry and materials characterization and deliver the Chemistry and Metallurgy Research Replacement (CMRR) project.
- Modernize lithium and tritium facilities.
- Recapitalize the HE and nuclear weapons assembly infrastructure.
- Provide modern office and laboratory spaces to support the world-class workforce needed to maintain capabilities of the nuclear weapons stockpile.
- Reduce deferred maintenance and repair needs by not less than 30 percent by 2025.

Accomplishments include:

- The Uranium Processing Facility at Y-12 remained on track and on budget, facilitating the start of construction of the main buildings.
- Approved Critical Decision 4 (CD-4; Approve Start of Operations or Project Completion) at the High Explosive Pressing Facility at the Pantex Plant (Pantex) outside Amarillo, Texas. The High Explosive Pressing Facility will improve operational safety and security, thereby enhancing the quality and efficiency of HE production at Pantex.
- The John C. Drummond Center opened at Pantex, providing a modern work environment for more than 1,100 employees and replacing 52 Cold War-era facilities.
- Two critical subprojects for the CMRR project at LANL are on track to achieve CD-4 in FY 2022 on budget and schedule. The CMRR project will make it possible for mission-critical technical capabilities, such as analytical chemistry, materials characterization, and metallurgy research and development, to be relocated to modern laboratory facilities that meet or exceed current safety and environmental protection standards.
- Working with the Army Corps of Engineers, completed the 100-percent design phase for the Albuquerque Complex Project and broke ground on July 2, 2018. This is an important milestone on the path to a modern and efficient facility for over 1,200 DOE/NNSA employees in New Mexico.
- A groundbreaking was held at the Nevada National Security Site near Las Vegas, Nevada for the Mercury Modernization program. Mercury serves as the “base camp” for the Nevada National Security Site, housing facilities such as the operations command center, a fuel station, office buildings, and other support structures. The modernization effort will consolidate facilities into a smaller footprint, reduce energy costs, and provide a modern, sustainable infrastructure.

Challenges in Executing the Stockpile Stewardship and Management Plan

DOE/NNSA has made substantial progress on near-term priorities to ensure the stockpile remains safe, secure, and effective for as long as nuclear weapons exist. However, there remains a need for significant and sustained investments in critical elements over the coming decades to ensure that DOE/NNSA will be able to maintain a responsive and resilient enterprise into the 2030s and beyond.

While the service lives of existing warhead types are being extended through refurbishment, new capabilities will be necessary to avoid stockpile age-out, support LEPs, and prepare for future uncertainty. The following table reflects the mission growth since 2010 that is necessary to sustain the modern stockpile.

Mission Prior to 2010	*Current Mission*
Replacement components and materials harvested from retired weapons or domestic reserves	New capacity demands require reinstating production of components and materials
Plutonium pit requirements satisfied through reuse	Restoring plutonium pit production capability
Sufficient tritium reserve available	Increasing tritium production
Sufficient lithium resources available	Restarting lithium processing capabilities
Depleted uranium and binary capabilities not required	Re-establishing several uranium production capabilities
	Depleted uranium and binary capabilities necessary
	Developing domestic uranium enrichment capability

To ensure the capabilities to meet these mission requirements are both responsive and resilient will require significant and sustained investments over the coming decade to correct. There is no margin for further delay in modernizing NNSA's scientific, technical, and engineering capabilities and recapitalizing the infrastructure needed to produce strategic materials and components for U.S. nuclear weapons.

SSMP Structure

The overview in Chapter 1 provides background information that is useful for understanding the entire SSMP. The remainder of the document is organized programmatically and functionally. The appendices include additional information to aid in understanding the material covered, along with detailed information about each of DOE/NNSA's national security laboratories, nuclear weapons production facilities, and the Nevada National Security Site.

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Fiscal Year 2020 Stockpile Stewardship and Management Plan

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Legislative Language

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

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

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

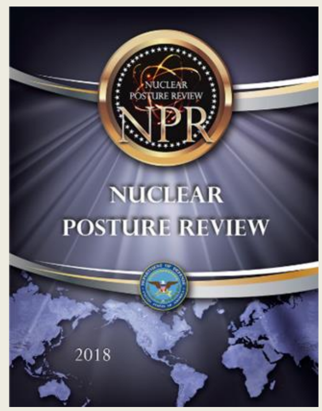
The *Fiscal Year 2020 Stockpile Stewardship and Management Plan* (SSMP) is a detailed report of DOE/NNSA's 25-year program of record to maintain the safety, security, and effectiveness of the nuclear stockpile and is primarily captured in this single, unclassified document. A classified Annex to the 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
Overview

The Department of Energy/National Nuclear Security Administration (DOE/NNSA) is tasked with carrying out the mission and authority drawn from the *Atomic Energy Act of 1954* (42 United States Code [U.S.C.] § 2011 *et seq.*) and, more specifically, the *National Nuclear Security Administration Act* (50 U.S.C. § 2401 *et seq*.), from which DOE/NNSA's core mission pillars are derived. NNSA's enduring missions remain vital to the national security of the United States and include maintaining the safety, security, and effectiveness of the nuclear weapons stockpile; reducing the threat of nuclear proliferation and nuclear terrorism around the world; and providing nuclear propulsion for the Navy's fleet of aircraft carriers and submarines.

DOE/NNSA continue to make essential contributions to U.S. and global national security now and into the future[1] with a talented and dedicated team that includes Federal, management and operating (M&O) partners, and other strategic partners within the U.S. interagency community.



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

This *Fiscal Year 2020 Stockpile Stewardship and Management Plan* (SSMP) is DOE/NNSA's 25-year strategic program of record for the nuclear weapons mission and was developed to be fully consistent with the 2018 *Nuclear Posture Review* and the *Nuclear Weapons Council's Strategic Plan for Fiscal Years (FY) 2019–2044* along with other guiding policy documents listed in Section 1.1. The annual SSMP has two primary purposes:

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

The FY 2020 SSMP includes budget information for the FY 2020 Future Years Nuclear Security Program (FYNSP), along with life extension program (LEP) schedules, preliminary infrastructure resource planning, and the long-term DOE/NNSA strategy through FY 2044 to ensure the Nation's nuclear deterrent.[2]

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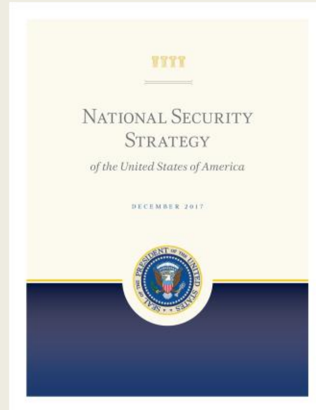
[1] Additional details are available in the *National Nuclear Security Administration Enterprise Strategic Vision*, December 2018.
[2] See 50 U.S.C. § 2453, Future-Years Nuclear Security Program, for a detailed description of the FYNSP.

1.1 Policy Framework Summary

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



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

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

Accomplishing this mission is complex and technically challenging. It requires long term planning of numerous, highly interconnected programs conducted at multiple sites, making use of cutting edge technological and manufacturing capabilities, and a workforce with unique expertise. DOE/NNSA works as one team to meet this critical nuclear mission. DOE/NNSA has to meet the current and near term needs of the stockpile and sustain the infrastructure and workforce that makes this work possible for the indefinite future. Doing so requires continual assessment of and improvement in our programs, processes and capabilities to overcome challenges. DOE/NNSA must address the gaps and shortfalls in critical infrastructure and in the manufacturing of warheads. DOE/NNSA must ensure the availability of expertise and modern advanced facilities across all sites, laboratories, and plants to qualify and certify the current and future stockpile. DOE/NNSA must also continually review and assess its enterprise-wide governance and management culture to ensure that the workforce and mission are effectively and responsibly managed.

The FY 2020 SSMP describes the current state of the strategic program of record for the nuclear weapons mission and the status of the workforce and supporting infrastructure. The *NNSA Nuclear Posture Review Implementation Plan Report to Congress* (2019) outlines the specific tasks necessary to further update the DOE/NNSA program of record to meet the national security responsibilities, strategic priorities, and policy directives detailed in the 2018 *Nuclear Posture Review*.

1.2 Summary of Strategic Environment and Nuclear Weapons Stockpile

The 2018 Nuclear Posture Review found that the current threat environment and an uncertain future necessitate a national commitment to maintain modern and effective nuclear forces and the infrastructure needed to support them. Sustaining and replacing existing nuclear capabilities is critical to preserving our ability to deter threats to the Nation.

The current strategic environment includes an unprecedented range and mix of threats that have resulted in increased uncertainty and risk. The United States must maintain a diverse set of nuclear capabilities that provide flexible and tailored deterrence options across the spectrum of adversaries, threats, and contexts. The nuclear triad (which includes capabilities at sea, on land, and by air) provides the diversity of platforms, weapons, and modes of operation necessary for the

United States to implement its deterrence strategies and achieve its objectives if deterrence fails. **Figure 1–1** shows examples of U.S. nuclear weapons and delivery platforms.

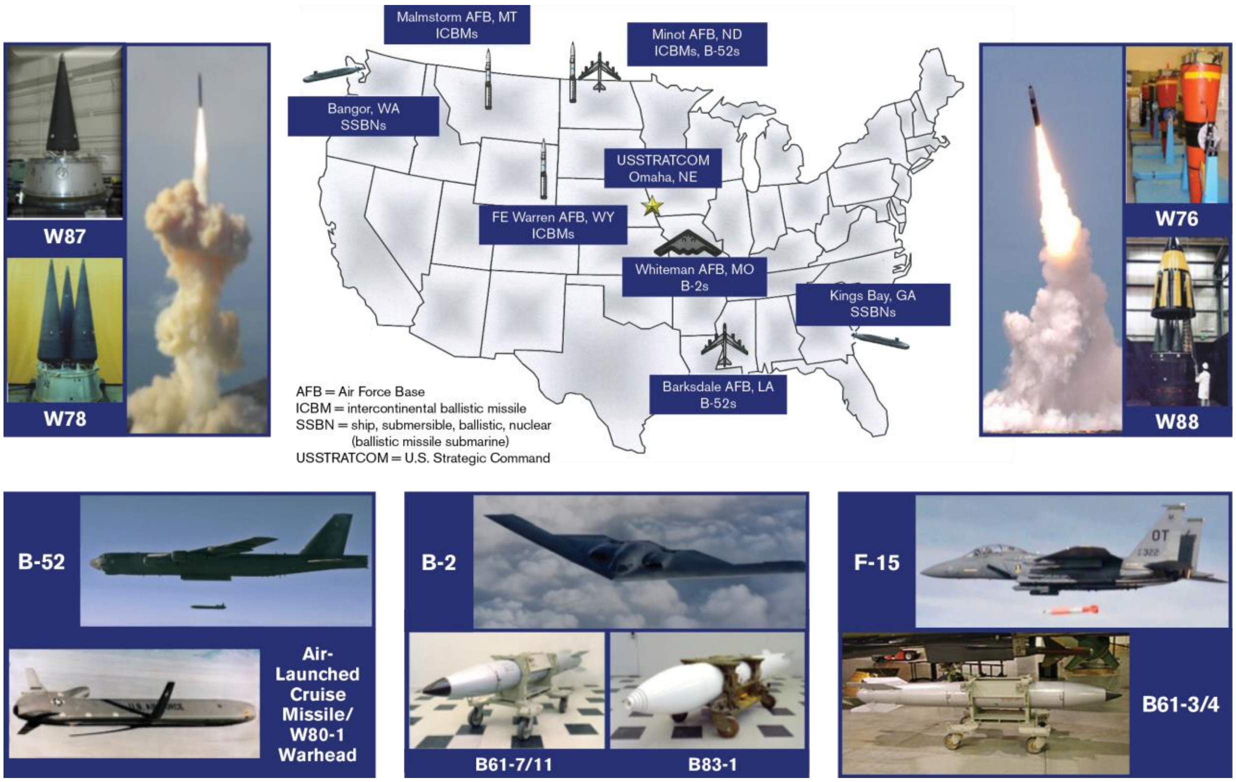
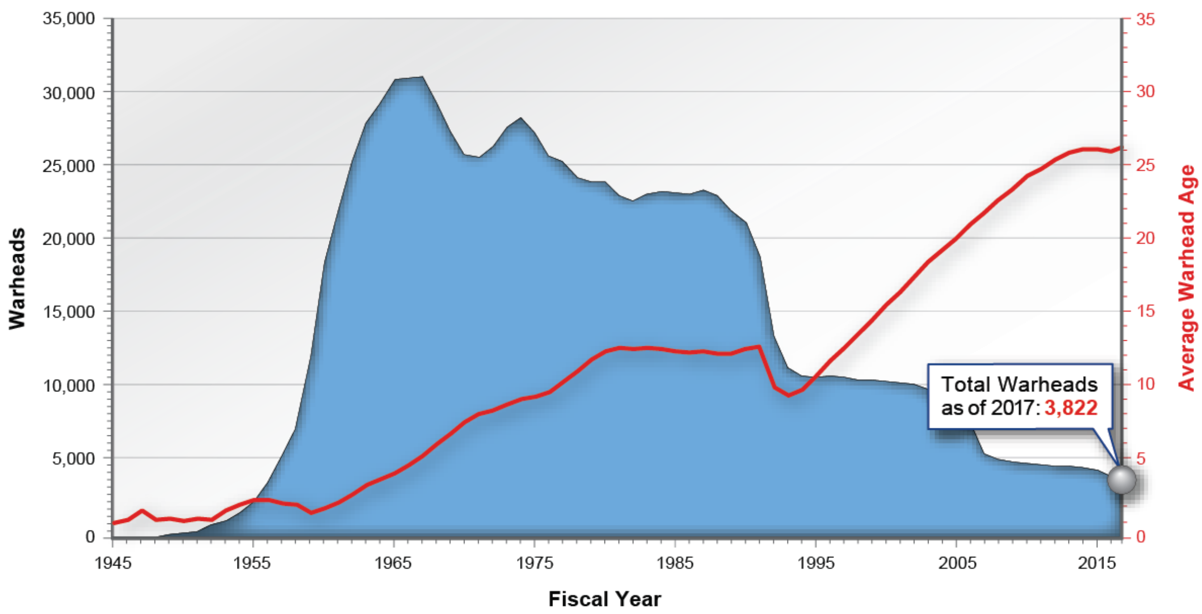


Figure 1–1. Examples of U.S. nuclear weapons and delivery systems

The size and composition of the nuclear stockpile has evolved as a consequence of the changing global security environment and U.S. national security needs. The average age of weapons in the stockpile remains high. Many weapons are well past their original design life and require specific actions to assess their condition, perform routine maintenance to ensure operability, and extend weapon lifetimes. The evolution in the size and age of the nuclear weapons stockpile is illustrated in **Figure 1–2**.

The current stockpile consists of active and technical/geopolitical hedge weapons that are necessary to meet military requirements. Retired weapons are not included in the count of stockpile weapons. **Table 1–1** reflects the major characteristics of the Nation's current 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 includes specific technical details about the stockpile by warhead type.



Note: NNSA closely tracks the age of each component within every nuclear weapon in the Nation's stockpile as part of ensuring safety, security, and reliability. The age of each weapon is taken from the day that final assembly at the Pantex Plant is completed. The age of each weapon is reset to "zero" following a major modernization, such as a life extension, after which the weapon is certified by the national security laboratories for an additional 20-30 years, depending on the weapon type and modernization conducted. The database that tracks this information, and the information itself, is classified. 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, 1945–2017

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

Warheads—Strategic Ballistic Missile Platforms					
Type [a]	***Description***	***Delivery System***	***Laboratories***	***Mission***	***Military***
W78	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LANL/SNL	Surface to surface	Air Force
W87	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LLNL/SNL	Surface to surface	Air Force
W76-0/1/2	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
W88	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
Bombs—Aircraft Platforms					
B61-3/4	Non-strategic bomb	F-15, F-16, certified NATO aircraft	LANL/SNL	Air to surface	Air Force/Select NATO forces
B61-7	Strategic bomb	B-52 and 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" for the W76) represents the modification associated with the respective weapon.

1.3 Partnership with the Department of Defense

DOE/NNSA and DoD work collaboratively to maintain and modernize the delivery systems and stockpile. DoD generates military requirements for the nuclear delivery platforms, while NNSA generates safety and security requirements and oversees the assessment, design development, production, test, and research programs that respond to DoD requirements. These complementary efforts are coordinated through the congressionally mandated Nuclear Weapons Council. The Council is a joint DoD-DOE/NNSA activity established by 10 U.S.C. § 179, as amended, and chaired by the DoD Under Secretary of Acquisition and Sustainment to facilitate cooperation and coordination, reach consensus, and establish priorities between the two Departments in fulfilling stockpile management responsibilities. The Council is also the focal point for routine interagency activities to maintain the stockpile.

1.3.1 Stockpile Strategy

The 2018 *Nuclear Posture Review* calls for a tailored approach to maintain deterrence across a spectrum of adversaries, threats, and contexts. Increased demand for diversity and flexibility of platforms, weapons, and modes of operation has reinforced the necessity to continue sustaining and modernizing the enduring stockpile.

As detailed in the *NNSA Nuclear Posture Review Implementation Plan (2019)*, DOE/NNSA is committed to the execution of policy direction provided by the 2018 *Nuclear Posture Review*. While its impact to most modernization programs was minimal, the 2018 *Nuclear Posture Review* did notably modify and add to the program of record. To meet the emerging requirements of U.S. strategy, the United States will enhance the flexibility and range of its tailored deterrence options in a variety of ways:

- **B83-1 Retention.** The 2018 *Nuclear Posture Review* recommended retaining the B83-1 gravity bomb past its planned retirement date to support military needs until a suitable capability replacement is identified. On August 28, 2018, the Nuclear Weapons Council authorized this retention. NNSA completed the planning, scheduling, and budgeting required to maintain the B83-1 through the Nuclear Weapons Council-determined retirement date.
- **Low-Yield Ballistic Missile Warhead.** The 2018 *Nuclear Posture Review* recommended modifying a small number of existing submarine-launched ballistic missile warheads to provide a low-yield ballistic missile option. The low-yield ballistic missile warhead is a modification (Mod) of the existing W76-1 weapon system and is designated as the W76-2 by naming convention. The W76-2 provides a low-yield option capable of overcoming adversary air defenses. See Section 2.5.2 for details.

Major Goals of Weapons Activities

- *Complete W76-1 production in FY 2019.*
- *Cease programmatic operations at the Chemistry and Metallurgy Research facility at LANL.*
- *Deliver the B61-12 gravity bomb.*
- *Deliver the W88 Alt 370 (with refresh of the conventional high explosives).*
- *Synchronize NNSA's W80-4 life extension with DoD's Long Range Standoff cruise missile program and complete the life extension program by 2031.*
- *Provide the enduring capability and capacity to produce plutonium pits at a rate of no fewer than 80 pits per year by 2030.*
- *Phase out mission dependency on Building 9212 at Y-12 by the end of 2025.*
- *Provide experimental and computational capabilities to support annual assessment and certification of the stockpile.*
- *Enhance the predictive capability to certify and assess the stockpile via theory, modeling, and experimental validation using advanced scientific tools.*

- **Define the Capability to Effectively Engage and Defeat Hardened and Deeply Buried Targets.** The 2018 *Nuclear Posture Review* identified the need to hold hardened and underground targets at risk. The Nuclear Weapons Council established a joint NNSA/DoD Hard and Deeply Buried Target Defeat Team, coordinated through the DoD Assistant Secretary of Defense for Nuclear Chemical and Biological Defense Programs/Office of Nuclear Matters, to determine future options for defeating such targets.
- **Pursue a Sea-Launched Cruise Missile.** As recommended in the 2018 *Nuclear Posture Review*, development of a nuclear-armed sea-launched cruise missile enhances the flexibility and diversity of U.S. nuclear capabilities to help address an ever-changing geopolitical environment. Feasibility studies of this capability are being coordinated by a joint DoD-DOE working group led by DoD's Office of Nuclear Matters.
- **Advance the W78 Replacement (W87-1).** The 2018 *Nuclear Posture Review* called for advancing the W78 warhead replacement program by 1 year, to FY 2019, to support fielding it on the Ground-Based Strategic Deterrent by 2030. On August 28, 2018, the Nuclear Weapons Council provided the Air Force with authorization to restart modification activities for the W87-1 in a MK21 aeroshell. NNSA has restarted the program in Phase 6.2 (Feasibility Study).

The United States must continue the 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 W76-2 Mod
- Completing the B61-12 LEP
- Completing the W88 Alteration (Alt) 370
- Synchronizing NNSA's W80-4 life extension with DoD's Long Range Standoff (LRSO) cruise missile program and completing the W80-4 LEP by FY 2031
- Replacing the W78 with the W87-1 to meet DoD and DOE/NNSA requirements for performance, safety, and security
- Exploring future ballistic missile warhead options to meet the required military characteristics based on the threats and vulnerabilities of potential adversaries, including the possibility of common reentry systems for Air Force and Navy systems

1.4 The Nuclear Security Enterprise

DOE/NNSA's Nuclear Security Enterprise, illustrated in **Figure 1–3**, consists of NNSA Headquarters (located in Washington, DC; Germantown, Maryland; and Albuquerque, New Mexico); NNSA field offices; three national security laboratories (two of which have production missions); four nuclear weapons production facilities; and the Nevada National Security Site. The highly-trained workforce consists of approximately 2,172 Federal civilians, approximately 43,000 contractor employees at NNSA's M&O sites, assigned members of the military, and non-M&O personnel (i.e., support service contractors or post-doctoral students).[3] (More detailed descriptions of the workforce and each M&O site can be found in Chapter 7, "Sustaining the Workforce," and Appendix D, "Workforce and Site-Specific Information.")

[3] These numbers do not include Naval Reactors.

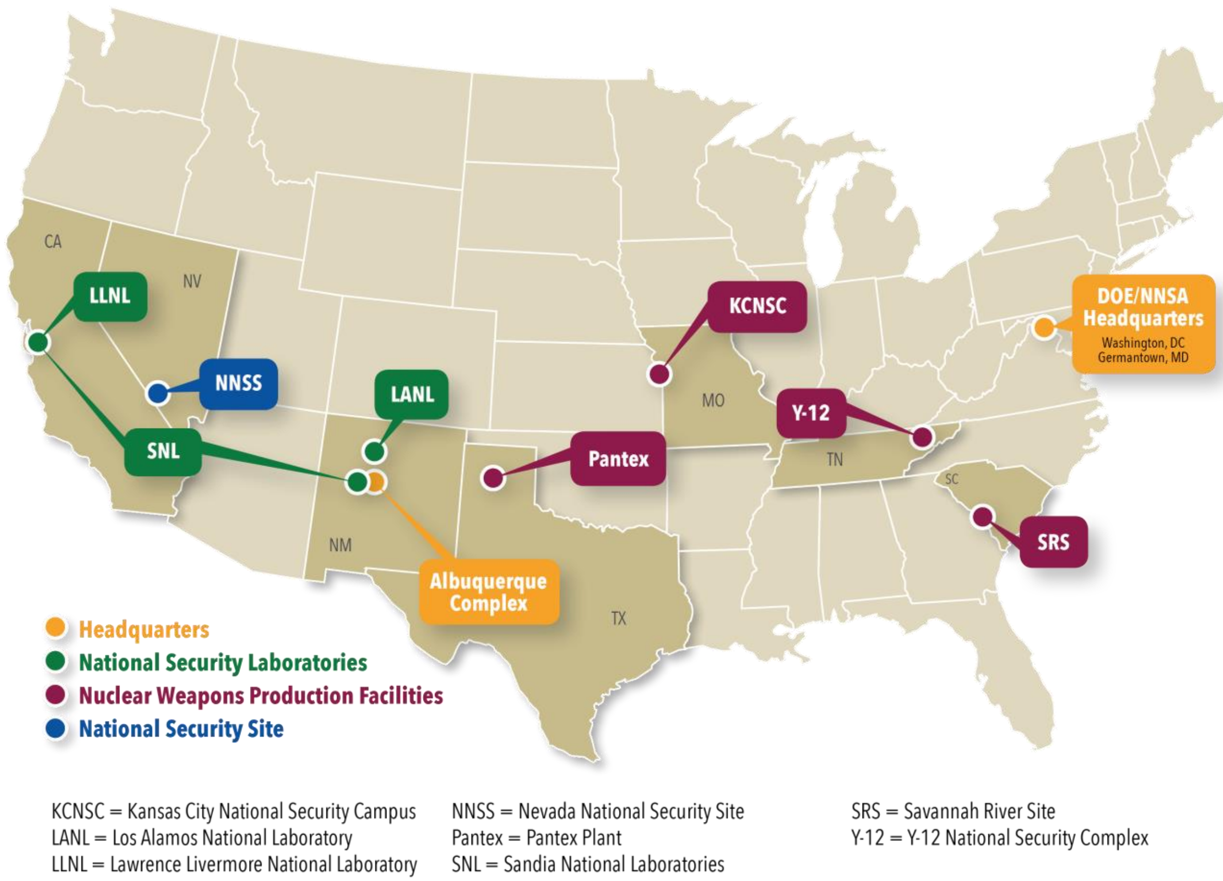


Figure 1–3. The DOE/NNSA nuclear security enterprise

NNSA Headquarters implements the overall nuclear weapons strategy in collaboration with its M&O partners and oversees and coordinates activities to ensure these are accomplished in an efficient, fiscally responsible manner. Information is available in other chapters about other capabilities funded by the Weapons Activities programs. See Chapter 4, "Physical Infrastructure;" Chapter 5, "Secure Transportation Asset;" and Chapter 6, "Security."

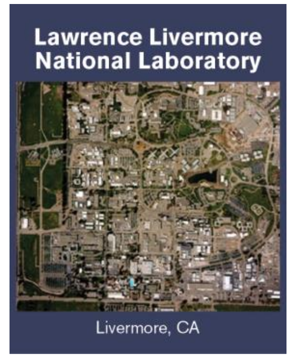
1.4.1 National Security Laboratories

The primary mission of DOE/NNSA's national security laboratories is to develop and sustain nuclear weapons design, simulation, modeling, and experimental capabilities and competencies to ensure confidence in the stockpile without nuclear explosive testing. All three laboratories are managed and operated by Federally Funded Research and Development Centers.[4] They engage in long-term research, development, test and evaluation (RDT&E) activities for primary nuclear weapon missions and apply science, engineering, and technology to solve other national security challenges. Other DOE national laboratories also support the Weapons Activities and Defense Nuclear Nonproliferation programs.

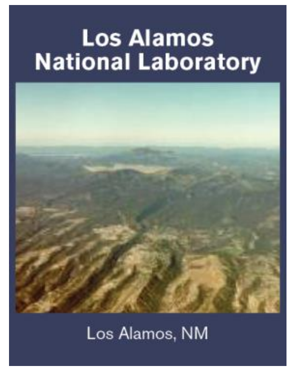
[4] Federally Funded Research and Development Centers (FFRDCs) are unique contractor entities that are sponsored and funded by the U.S. Government to meet special long-term research or development needs that cannot be met as effectively by existing government or other contractor resources. Various Federal government agencies contract with 43 different FFRDCs currently. Most own their own facilities, while the national security laboratories are sited in government-owned facilities. All FFRDCs are often characterized by their commitment to the public interest, objectivity, independence, and long-term focus.

The three national security laboratories are Lawrence Livermore National Laboratory (LLNL) in Livermore, California; Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico; and Sandia National Laboratories (SNL) in both Albuquerque, New Mexico, and Livermore, California.[5] All three laboratories also support nuclear counterterrorism, counterproliferation, and nonproliferation.

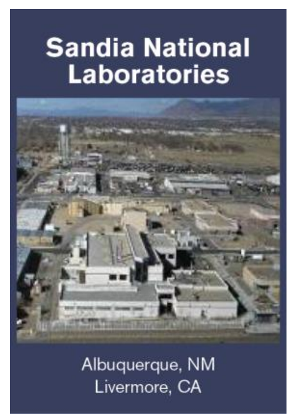
Lawrence Livermore National Laboratory. LLNL is one of two national security laboratories for the design of nuclear components of weapons. LLNL is responsible for nuclear design activities for the legacy B83, W80, and W87 systems and for the W87-1 Modification Program and the W80-4 cruise missile warhead LEP. Other LLNL core capabilities include high performance computing, high energy density physics, plutonium research and development (R&D), hydrodynamic and weapons engineering environmental tests, advanced manufacturing and materials science, tritium target development and fabrication, and high explosives (HE) R&D.



Los Alamos National Laboratory. LANL is the other national security laboratory whose FFRDC is responsible for designing the nuclear components of weapons. LANL is responsible for nuclear design and engineering of the legacy B61, W76, W78, and W88 systems and for the W76-1, W76-2, B61-12, and W88 Alt 370 modernization programs. LANL also provides plutonium operations for R&D and pit manufacturing capabilities. LANL's other core missions include advanced radiography, tritium, and HE R&D; detonator, radioisotope thermoelectric generator power supply, and other non-nuclear component production and testing; and special nuclear material accountability, storage, protection, handling, and disposition.



Sandia National Laboratories. SNL is the national security laboratory responsible for systems engineering and integration of nuclear weapons and for designing, developing, qualifying, sustaining, and retiring the non-nuclear components of nuclear weapons, which represent the vast majority of the components that comprise these weapons. SNL ensures (1) internal systems integration of all non-nuclear systems and components, (2) integration between the non-nuclear and nuclear portions of weapons, and (3) integration of weapons with their delivery systems. SNL's other core missions include production of neutron generators; radiation-hardened microelectronics; other non-nuclear components; and engineering, design, and technical systems integration for the NNSA Office of Secure Transportation.



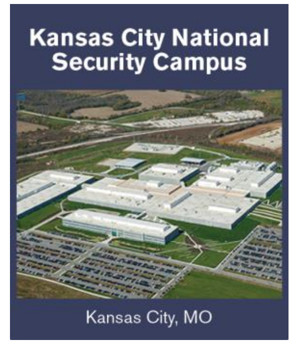
1.4.2 Nuclear Weapons Production Facilities

A range of activities that support the stockpile are conducted at DOE/NNSA's four nuclear weapons production facilities.[6] The Kansas City National Security Campus (KCNSC) in Kansas City, Missouri, produces non-nuclear components. The Pantex Plant (Pantex) in Amarillo, Texas, manufactures and tests HE components and assembles, disassembles, and refurbishes stockpile weapons and components. The Y-12 National Security Complex (Y-12) in Oak Ridge, Tennessee, manufactures uranium components and dismantles and stores highly enriched uranium (HEU). The Savannah River Site (SRS) in Aiken,

[5] DOE's Savannah River National Laboratory conducts research and development in support of tritium processing and gas transfer system design and certification activities.
[6] Some production capabilities also exist at LANL and SNL.

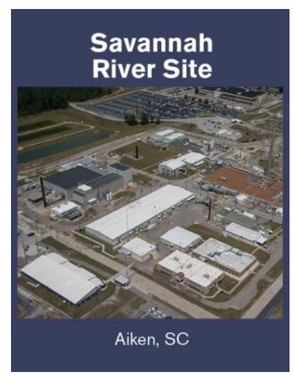
South Carolina, extracts, recycles, and loads tritium into gas transfer systems (GTSs). These nuclear weapons production facilities perform other activities, including uranium and plutonium processing, to meet DOE/NNSA's nonproliferation goals and counterterrorism activities.

Kansas City National Security Campus. KCNSC is focused on procurement, production, and life-cycle support of non-nuclear weapons components for the Nation's nuclear stockpile, including electronic, mechanical, and engineered materials components. In partnership with the national laboratories to transition weapon modernization concepts through design and development and into production and sustainment, the site is responsible for over 80 percent of the components across all active and emerging nuclear stockpile systems. KCNSC consists of a 1.5-million square foot main facility and two satellite office facilities in Kansas City, Missouri, which are primarily focused on the Nuclear Weapons Programs mission. The site supports Nuclear Nonproliferation, Emergency Management, and Counterterrorism missions, as well as a Global Security mission that involves development and delivery of field-ready engineering solutions for other government agencies' national security missions. Facilities in Albuquerque, New Mexico, primarily focus on the development, manufacture, and delivery of products and services for the Office of Secure Transportation and products to support the nuclear weapons stockpile.

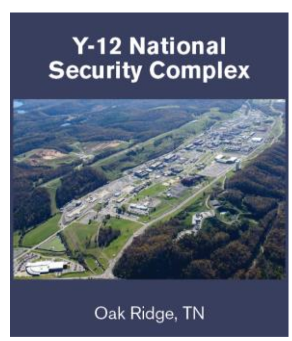


Pantex Plant. Pantex manufactures and tests HE components; assembles, disassembles, refurbishes, repairs, maintains, and surveils stockpile weapons and components; fabricates joint test assemblies and performs postmortems; assembles and disassembles test beds; conducts interim staging and storage of components from dismantled weapons; and performs pit requalification, reuse, surveillance, and packaging.

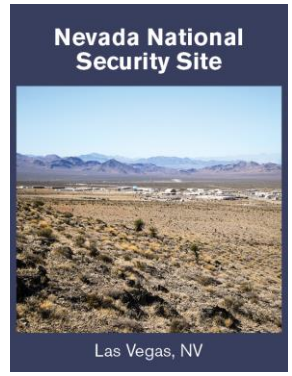
Savannah River Site. SRS is NNSA's Tritium Center of Excellence and the primary location for NNSA's tritium operations. The tritium facilities use unique separation and extraction systems developed by Savannah River National Laboratory to supply the radioactive hydrogen gas for nuclear weapons. That activity, which is an integral part of the Nation's nuclear defense, has been central to the SRS mission for more than 60 years. SRS's primary activities include extracting tritium from irradiated target rods, separating and recycling the gas from field returns, managing the tritium inventory for the stockpile, loading tritium and deuterium into GTSs, performing surveillance of GTSs to support stockpile certification, and recovering helium-3.



Y-12 National Security Complex. Y-12 is the Uranium Center of Excellence for the nuclear security enterprise. Y-12 manufactures uranium and other components for nuclear weapons. Y-12 also dismantles, stores, and performs test and evaluation of these components for surveillance purposes. Y-12 is the main storage facility for Category I/II quantities of HEU and supplies HEU for naval reactors.



1.4.3 Nevada National Security Site



The Nevada National Security Site provides facilities, infrastructure, and personnel to the national security laboratories 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 the only location where HE-driven plutonium experiments can be conducted at weapon scale using weapon-relevant amounts of special nuclear material. Other missions include developing and deploying state-of-the-art diagnostics and instruments, analyzing data, storing programmatic materials, conducting criticality experiments, and supporting nuclear counterterrorism and counterproliferation, and nonproliferation activities.

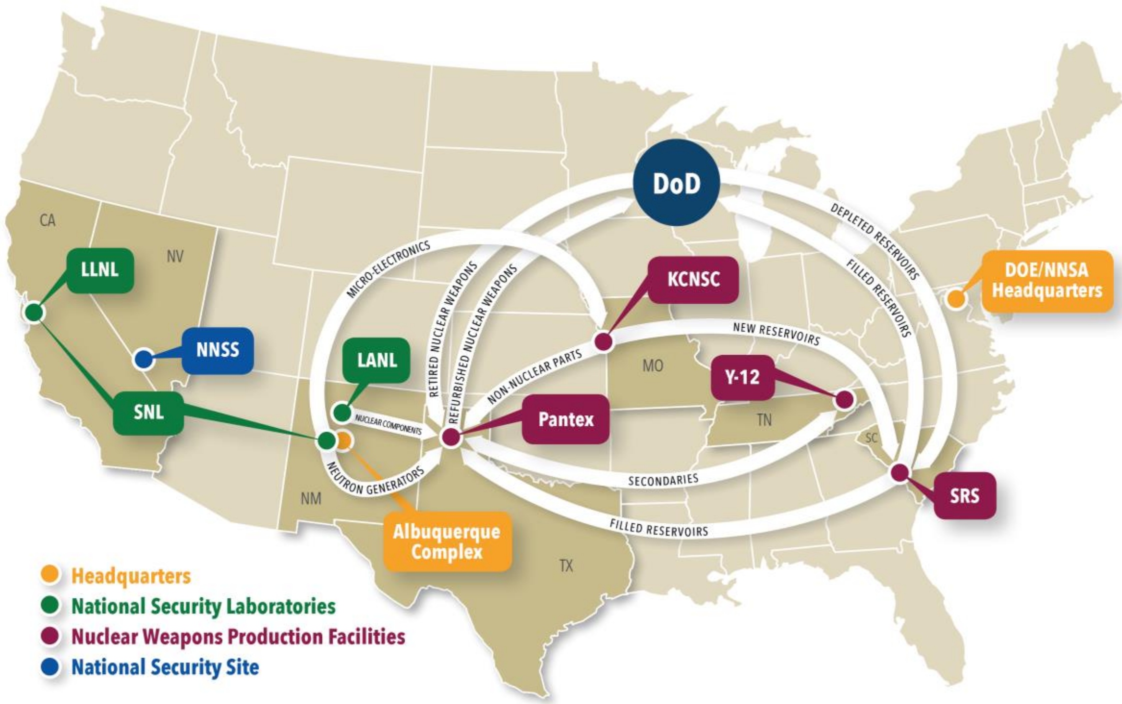
1.4.4 Capabilities That Support the Nuclear Security Mission

DOE/NNSA and DoD together deliver the capabilities needed to ensure an effective nuclear deterrent that will provide the Nation with the ability to adapt and respond to a dynamic security environment, emerging strategic challenges, and geopolitical and technological surprises. Underpinning this responsibility for the deterrent is the technical expertise resident at DOE/NNSA's national laboratories, production sites, the Nevada National Security Site, and within the nuclear weapons infrastructure.

The expert workforce and advanced capabilities necessary to maintain the Nation's nuclear deterrent are found at DOE/NNSA's eight nuclear security enterprise sites. Each of these sites contribute in complementary ways to ensure the Nation has the full range of capabilities needed to maintain the safety, security, reliability, and effectiveness of the nuclear weapons stockpile. A list of the Weapons Activities capabilities is defined in Appendix B. The *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Plan Summary* describes the Weapons Activities capabilities that support the nuclear security enterprise in detail. **Figure 1–4** depicts the interrelationship of the important nuclear weapons-related product flow between the sites.

1.4.5 Highlights of Ongoing Nuclear Security Enterprise Changes Affecting Multiple Locations

To meet the requirement to achieve no fewer than 80 pits per year (ppy) by 2030, the preferred alternative calls for NNSA to expand its pit production capabilities by simultaneously maximizing pit production activities at LANL and adding a second pit production site by repurposing the former Mixed Oxide Fuel Fabrication Facility at SRS. This proposed dual-site approach, with at least 50 ppy produced at SRS and at least 30 ppy at LANL, manages the cost, schedule, and risk of such a vital undertaking. This approach also improves the resiliency, flexibility, and redundancy of the nuclear security enterprise by eliminating reliance on a single production site and assures a production capability for the next 50 years and beyond. LANL will remain a consolidated Center of Excellence for plutonium research, development, and manufacturing activities.



DoD = Department of Defense
KCNSC = Kansas City National Security Campus
LANL = Los Alamos National Laboratory
LLNL = Lawrence Livermore National Laboratory
NNSS = Nevada National Security Site
Pantex = Pantex Plant
SNL = Sandia National Laboratories
SRS = Savannah River Site
Y-12 = Y-12 National Security Complex

Figure 1–4. Site nuclear weapon product flow

1.5 Overall Strategy, Objectives, and Prioritization of Weapons Activities

DOE/NNSA and DoD implement the Nation's objectives to maintain strategic stability with other major nuclear powers, deter potential adversaries, and reassure allies and partners as to the national security commitments of the United States. DOE/NNSA priorities are to sustain and maintain the stockpile while balancing infrastructure and RDT&E investments to meet technical and national security challenges in the near and long term.

> *"Our nuclear deterrent is nearing a crossroads. To date, we have preserved this deterrent by extending the life span of legacy nuclear forces and infrastructure—in many cases for decades beyond what was originally intended. But these systems will not remain viable indefinitely. In fact, we are now at a point where we must concurrently modernize the entire nuclear triad and the infrastructure that enables its effectiveness."*
>
> *Vice Chairman, Joint Chiefs of Staff, General Paul Selva, 2017*

There are three major strategies to sustain and maintain the stockpile:

- Assess and certify the stockpile annually through science-based stockpile stewardship, including assessing whether the safety and reliability of the future nuclear stockpile can be assured in the absence of underground nuclear testing, and as a safeguard, maintain a nuclear test capability.
- Extend the life of select nuclear warheads through modernizations by replacing obsolete technology while enhancing stockpile safety and security and meeting military requirements, treaties, and other international obligations.

- Ensure the capabilities to support the nuclear stockpile near and long term.
  - Address aging infrastructure and equipment obsolescence by making strategic investments aligned with integrated, risk-informed, data-driven prioritization plans that sustain and advance weapon activity capabilities. Make facility and infrastructure investments that target reduction of safety, security, and programmatic risks and dispose of excess facilities at the eight M&O partner sites.
  - Augment the Stockpile Stewardship and Stockpile Management Programs with an effective Stockpile Responsiveness Program[7] to provide a greater breadth of opportunities that exercise key capabilities and skills across the entire nuclear weapon life cycle while maintaining the capability to design, develop, and produce nuclear warheads with new or different military capabilities if required in the future. Exercising these capabilities also provides a mechanism to preserve and transfer knowledge across the workforce.
  - DOE/NNSA is investing in advanced manufacturing technologies to reduce development and production costs, improve design and development cycle time, and protect against product and manufacturing obsolescence. Advanced manufacturing will also enable novel design opportunities and increase in-house production of nuclear weapon components.
  - To better assure supply chain protection and viability, DOE/NNSA has implemented several initiatives through the Nuclear Enterprise Assurance program to address threats to critical products and processes. The program focuses on restricting information, enhancing and sustaining designs, establishing robust secure manufacturing and testing processes, and augmenting supply chain management to protect against malicious hardware or software entering nuclear security enterprise products (see Annex for additional information).
  - NNSA partners with the DOE Office of Science on the DOE Exascale Computing Initiative to ensure that future high performance computing architectures will support modeling and simulation requirements of the nuclear security enterprise. In addition, NNSA is planning strategic investments in several experimental capabilities to collect higher-fidelity data to validate modeling and simulation capabilities into the future.

1.6 Challenges in Executing the Stockpile Stewardship and Management Plan

> *"Recapitalizing the nuclear weapons complex of laboratories and plants is also long past due; it is vital we ensure the capability to design, produce, assess, and maintain these weapons for as long as they are required."*
>
> *2018 Nuclear Posture Review*

The DOE/NNSA nuclear security enterprise requires major recapitalization to ensure the deterrent remains modern, robust, flexible, resilient, responsive, and appropriately tailored to deter 21st century threats. Responding to the 2018 *Nuclear Posture Review* will require an analysis of capabilities and capacities to determine the improvements necessary for the nuclear security enterprise to support additional weapon modernization programs. DOE/NNSA must build a more modern enterprise, as more than half of NNSA's facilities are over 40 years old. The demands of the LEPs and the Stockpile Stewardship Program have stressed the aging infrastructure, even before considering the needs generated by the 2018 *Nuclear Posture Review.* Without infrastructure modernization, the risk to NNSA's

[7] For additional information, see the DOE/NNSA February 2018 report to Congress, *Stockpile Responsiveness*.

missions will increase. Science, technology, and engineering; infrastructure; and workforce needs are discussed further in Chapters 3, 4, 7, and 9.

Four key challenges must be addressed:

- The current stockpile program of record represents a continued increase in scope, including restarting production operations that have been dormant for decades and increasing overall production rates of many components. NNSA is restoring capabilities and enhancing capacity at the production plants to address needs as the current LEPs and Alts enter the production phase. Planning is underway to determine the long-term capacity and capability needs to avoid stockpile age-out, support LEPs, and prepare for future uncertainty.
- The increased number of concurrent system builds require maturing new deterrence options with shortened development cycles; advancing the ability to predict weapon performance in configurations that were not tested underground; and evaluating the impact of new materials and processes, the reuse of aging components in future systems, and enhancing production throughput. The nuclear weapons stockpile requires updated technologies that require investment in new processes, technologies, and tools to produce, qualify, and certify warheads in accordance with stringent stockpile specifications and requirements.
- Trustworthiness of the nuclear weapons supply chain must be sustained to protect against potential sabotage, malicious introduction of an unwanted function, or subversion of a function without detection. DOE/NNSA's radiation-hardened silicon microelectronics capability, the Microsystems Engineering, Science and Applications (MESA) Complex at SNL, relies on tools and capabilities that are no longer supported by manufacturers. DOE/NNSA is installing new tooling and planning recapitalization efforts to extend the life of the MESA facilities. DOE/NNSA is also engaging with DoD and the Massachusetts Institute of Technology's Lincoln Laboratory to establish R&D efforts that could also serve as a production capability.
- The DOE/NNSA nuclear security enterprise has many retirement-eligible employees who are expected to leave the workforce in the near future (**Figure 1–5**). To prepare for these high numbers of retirements, aggressive programs are necessary to recruit 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.

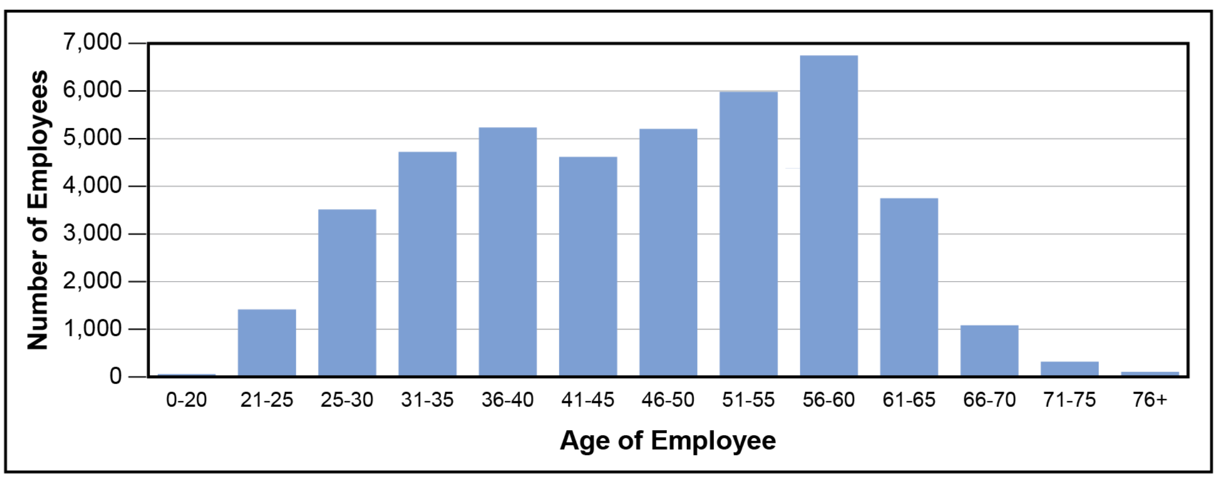


Figure 1–5. Nuclear security enterprise headcount distribution by age (as of September 30, 2018)

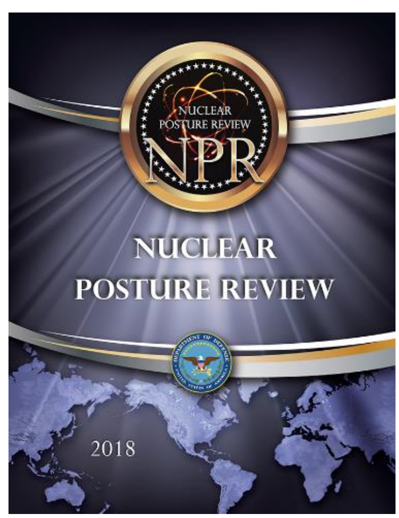
Chapter 2
Stockpile Management

Stockpile management encompasses the Directed Stockpile Work (DSW) Program, along with technology maturation programs that support the stockpile. Stockpile management activities are undertaken to directly sustain or support the stockpile or to understand and report on its status. These activities include maintenance, surveillance, significant finding investigations (SFIs), reliability reporting, annual assessment, provision of required materials and technologies (for warhead components and production of those components), life extension, and dismantlement and disposition. Activities that can be reasonably attributed to specific warheads are funded by individual warhead budget lines in the Stockpile Systems or life extension program (LEP) budget lines. Activities that are not warhead-specific are funded by Stockpile Services budget lines or funding lines specifically for the activity, such as Advanced Manufacturing Development, Strategic Materials, and Weapons Dismantlement and Disposition. Subsequent sections of Chapter 2 describe each of these activities in more detail but they can be related to each other in the following manner.

Stockpile Management Accomplishments

- *Completed Cycle 23 of the annual assessment process.*
- *Completed W76-1 last production unit.*
- *Completed W76-2 first production unit.*
- *Qualified and sold the first additively manufactured component to War Reserve production stores.*
- *Qualified CoLOSSIS II at Pantex.*
- *Delivered a substantial subset of first production units of B61-12 and W88 Alt 370 weapon components early or on time at KCNSC.*

The stockpile undergoes annual assessments, while surveillance and maintenance occur on a scheduled basis throughout a weapon's lifetime. While conducting surveillance, assessment, or maintenance, an issue of interest may arise and give cause to conduct an SFI to determine the issue's potential impact on warhead performance and safety. The results of the SFI may lead to a corrective action, an alteration (Alt), or modification (Mod) to a weapon system (conducted as part of maintenance), or the issue may be resolved without any changes to the stockpile. At some point in their life cycle, warheads, if they are to remain in the stockpile, need to undergo life extension to comprehensively address aging issues and modernize the warheads to meet updated policy requirements for safety and security. Conducting these life extensions (and other warhead component changes as part of maintenance) requires modern technologies, production capabilities, and special materials.



This update reflects the current approved program of record consistent with Presidential direction and congressional authorizations and appropriations. Last year, DoD issued the 2018 *Nuclear Posture Review* (February 2018), which reiterated the importance of ongoing modernization efforts and initiated new efforts to address increasing geopolitical threats. One new effort was a low-yield ballistic missile warhead (W76-2). With congressional authorization, DOE/NNSA successfully completed a W76-2 first production unit in February 2019. In FY 2019, DOE/NNSA also restarted the W87-1 Modification Program (formerly known as the W78 warhead replacement) 1 year earlier than previously planned. Other *Nuclear Posture Review* recommendations, such as pursuing a sea-launched cruise missile and identifying a replacement for the B83-1 strategic bomb, are in the beginning stages of review. Sustaining the current stockpile, continuing ongoing modernization efforts, and responding to new initiatives places heavy demands on the nuclear security enterprise. Efficient and effective stockpile management ensures the United States is able to maintain and certify a safe, secure, and effective nuclear arsenal now and in the future and requires comprehensive planning to ensure that all stockpile elements fit cohesively into an integrated system.

2.1 Maintenance

Stockpile maintenance includes three areas of focus:

- Limited life components (LLCs) such as gas transfer systems (GTSs), power sources, and neutron generators require periodic replacement to sustain system functionality.
- Alts, such as changing the type of LLC, incorporation of surety features, and other changes to respond to emerging issues that do not rise to the level of a major Alt or LEP, are addressed on a priority basis, depending on stockpile impact. Surety provides a level of confidence that a system will operate exactly as planned under both expected and unexpected circumstances. Each weapon system that is retained in the stockpile long term will incorporate an Integrated Surety Architecture.
- Minor repairs to individual weapons as a result of transportation and handling.

> NUCLEAR POSTURE REVIEW NPR
>
> **Sustain the Triad:**
> *"Eliminating any leg of the triad would greatly ease adversary attack planning and allow an adversary to concentrate resources and attention on defeating the remaining two legs. Therefore, we will sustain our legacy triad systems until the planned replacement programs are deployed."*

Figure 2–1 shows some of the sustainment elements required to maintain the current stockpile. This includes LLCs such as neutron generators, GTSs, joint test assemblies (JTAs), and Integrated Surety Architecture. LLCs will be discussed further in Section 2.1.1; JTAs are discussed in Section 2.2.

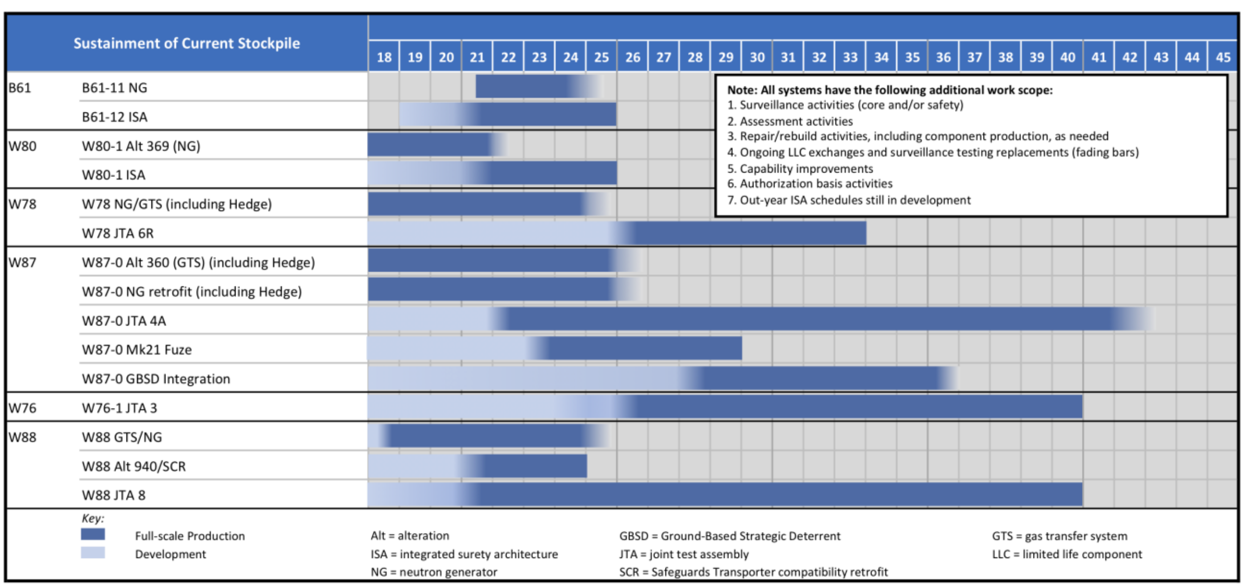


Figure 2–1. Sustainment of current stockpile

2.1.1 Limited Life Components

Weapons contain LLCs that require periodic replacement to sustain system functionality. Age-related changes affecting these components are predictable and well understood, and surveillance is conducted to ensure the components continue to meet performance requirements throughout their stockpile life. Periodic LLC exchanges replace these components throughout a weapon's lifetime. DOE/NNSA produces LLCs, while DOE/NNSA and DoD jointly manage component delivery and installation of replacements on a planned schedule.

2.1.1.1 Gas Transfer Systems

GTSs are designed, produced, filled, and delivered to DoD for existing weapon systems. SNL and LANL are the design agencies; KCNSC produces the systems; and SRS fills them. Modern GTS designs have extended LLC intervals and have increased the weapon performance margin, thereby improving maintenance efficiency and enhancing weapon safety and reliability. SNL and LANL conduct development hardware function testing to validate performance characteristics and to provide tritium research and development (R&D) to inform GTS designs supporting the current and future stockpile. The Savannah River National Laboratory at SRS works closely with SNL and LANL to evaluate new GTS designs and verify that GTSs can be loaded in the production facilities and meet weapons systems performance characteristics. In parallel with R&D efforts, SRS maintains production facilities for tritium-loading operations, GTS surveillance, and tritium recovery from end-of-life GTSs.

2.1.1.2 Challenges and Strategies

Table 2–1 provides a high-level summary of challenges related to GTSs and the strategies to address them.

Table 2–1. Summary of gas transfer systems challenges and strategies

Challenges	Strategies
Formal risk analyses indicate that deterioration of infrastructure and programmatic equipment threaten the continuity of SRS efforts in both production and R&D. DOE/NNSA faces infrastructure challenges in aging facilities in addition to evolving requirements that affect facility modifications.	SRS will maintain both production and R&D capabilities by (1) refurbishing or constructing R&D facilities separate from the production infrastructure, (2) recapitalizing the existing process equipment and infrastructure, and (3) fully replacing some production facilities through line-item construction.
The increasing GTS workload associated with multiple upcoming LEPs and Alts is increasing the demand on technical staff and production and infrastructure capabilities at SRS and KCNSC.	To address capacity needs, SRS will modify the process and infrastructure equipment in multiple facilities and has requested additional staff for some production and infrastructure areas. KCNSC is executing a plan to increase capacity by replacing or adding additional multi-axis machines to improve efficiencies and provide additional cleared personnel on multiple shifts.

2.1.1.3 Power Sources

Current and future planned nuclear weapons and life-extended warheads require compact, high-powered, highly variable power sources that have long-term reliability. Requirements for size, weight, active life, responsiveness, and output are unique to nuclear weapon applications. This capability supports other national security mission needs that require advanced power sources to meet stringent requirements that are not available from commercial vendors. This capability also includes prototyping and parts development, and 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.

2.1.1.4 Challenges and Strategies

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

Table 2–2. Summary of power sources challenges and strategies

Challenges	*Strategies*
Instabilities in the supplier base put the primary production capability at risk, and facility inadequacies put SNL's research, development, test and evaluation and production capabilities at an elevated risk of not meeting the mission.	Modern infrastructure is required to meet the long-term, full life-cycle requirements for power source capabilities. DOE/NNSA has initiated a project to determine mission needs and analyze alternatives to ensure capabilities are sustained.
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 this 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.	

2.1.1.5 Neutron Generators

Neutron generators are highly complex LLCs that provide neutrons at specific times and rates to initiate weapon function. SNL's 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.

2.1.1.6 Challenges and Strategies

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

Table 2–3. Summary of neutron generators challenges and strategies

Challenges	*Strategies*
Aging facilities, infrastructure, and equipment 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 and cleanliness. Formal planning is ongoing to establish long-term capabilities that will ensure that mission deliverables are met while allowing consolidation, increased flexibility, and expanded capabilities. These improvements include clean room enhancements, advanced manufacturing, increased use of automation, and streamlined safety and security management.

2.1.2 Other Alterations

Weapon Alts are required to improve the safety, security, and reliability of nuclear weapons. While major Alts (such as the W88 Alt 370) are covered under Section 2.5, "Modernizing the Stockpile," other Alts are routinely incorporated into nuclear weapons to respond to emerging issues, including issues identified during surveillance activities. Weapon systems that will remain in the stockpile will incorporate an Integrated Surety Architecture. Other Alts are scheduled on a priority basis, depending on their impact to the nuclear weapons stockpile.

2.1.3 B83-1 Sustainment

2.1.3.1 Overview

The B83-1 gravity bomb holds a variety of protected targets at risk. The 2018 *Nuclear Posture Review* directed sustainment of the B83-1 past its current planned retirement date until a suitable replacement is identified. In coordination with DoD through Nuclear Weapons Council authorization, DOE/NNSA is sustaining the B83-1 beyond its original retirement date. Currently, no Alts are anticipated during the extended sustainment period.

2.1.3.2 Current Status

The B83-1 is executing sustainment activities, including surveillance and weapon assessments. DOE/NNSA is working with the design and production agencies to ensure requirements are met in accordance with the Nuclear Weapons Council authorization to sustain the B83-1 through the program of record. Design analysis considerations help determine how to sustain the system without alteration.

2.1.3.3 Challenges and Strategies

Table 2–4 provides a high-level summary of B83-1 sustainment challenges and the strategies to address them.

Table 2–4. Summary of B83-1 Sustainment challenges and strategies

Challenges	*Strategies*
Maintain sufficient hardware quantities for surveillance.	Evaluate hardware and provisioning needs to achieve program of record requirements.
Conduct the required volume of system-level and component surveillance testing.	Conduct surveillance planning activities and maintain directive documents in accordance with program of record objectives.
Margins are increasingly challenged by LLC exchange extensions.	Conduct analysis of operational trade space to enable system sustainment without alterations to inform system sustainment decisions and assess potential impacts.

2.2 Surveillance

DOE/NNSA's surveillance activities provide data to evaluate the safety, security, reliability, and performance of the stockpile in support of annual assessments. The cumulative body of surveillance data supports decisions regarding weapon life extensions, Alts, Mods, repairs, and rebuilds. The Surveillance program has six goals:

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

The Surveillance Enterprise leverages of the Stockpile Evaluation program and the Enhanced Surveillance subprogram. These two program elements work closely together to execute the surveillance enterprise requirements and develop new surveillance capabilities at the system, component, and material levels. The Stockpile Evaluation program conducts surveillance evaluations of weapons, assemblies, and components for both the existing stockpile (i.e., weapon returns from DoD) and new production (i.e., Retrofit Evaluation System Test units). Anomalies, when discovered, are assessed through SFIs.

The Enhanced Surveillance subprogram develops the diagnostics, processes, models, and other tools needed by the Stockpile Evaluation Program to improve the ability to predict and detect initial or age-related defects, assess reliability, and estimate component and system lifetimes.

DOE/NNSA conducts stockpile evaluation through weapon disassembly and inspection (D&I), stockpile flight testing, stockpile laboratory testing, component testing and material evaluation, and test equipment. The number of disassemblies, inspections, and major component tests completed in FY 2018 and baselined for FY 2019 are delineated in **Table 2–5**.

Table 2–5. FY 2018 actual and FY 2019 baselined major Directed Stockpile Work stockpile evaluation activities (as of January 8, 2019)

	D&Is		*JTA Flights*		*Test Bed Evals*		*Pit NDEs*		*Pit D-Tests*		*CSA NDEs*		*CSA D-Tests*		*GTS Tests*		*HE D-Tests*		*DCA Tests*		*Program Totals*	
	Fiscal Years																					
Warheads	18	19	18	19	18	19	18	19	18	19	18	19	18	19	18	19	18	19	18	19	18	19
B61	9	7	5	5	4	4	16	27	1	2	11	12	4	2	4	8	0	4	17	19	71	90
W76-0	4	4	2	0	0	0	4	0	0	2	4	4	1	1	6	11	4	4	6	4	31	30
W76-1	30	28	6	3	22	18	37	51	1	3	14	23	1	5	6	17	6	5	19	17	142	170
W78	8	10	4	1	7	1	18	27	0	2	19	13	2	2	4	6	4	4	6	8	72	74
W80-1	19	13	4	3	10	5	61	32	3	2	1	0	1	1	4	12	4	5	28	0	135	73
B83-1	2	2	1	1	1	1	11	11	2	6	1	0	1	1	3	3	1	1	0	4	23	30
W84	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	1	9	3
W87-0	9	9	1	3	7	5	13	13	0	2	2	0	1	1	2	9	1	1	4	4	40	47
W88	7	6	4	3	7	0	14	14	0	1	2	0	2	1	10	14	3	4	0	8	49	51
TOTALS	89	80	27	19	58	34	174	175	7	20	54	52	13	14	39	80	31	29	80	65	572	568

CSA = canned subassembly
D&I = disassembly and inspection
DCA = detonator cable assembly
D-tests = destructive tests
GTS = gas transfer system
HE = high explosive
JTA = joint test assembly
NDE = nondestructive evaluation

The numbers of major surveillance evaluations completed in FY 2018 and projected by the program of record for FY 2019 through FY 2024 are delineated in **Table 2–6**. The national security laboratories, in conjunction with DOE/NNSA and the nuclear weapons production facilities, continually refine these planning requirements based on new surveillance information, deployment of new diagnostics, annual assessment findings, and analysis of historical information using modern assessment methodologies and computational tools.

Table 2–6. Major surveillance evaluations completed in FY 2018 and the program of record for FY 2019 through FY 2024 (as of January 8, 2019)

Major Activity	*FY 2018 Actual*	*Approved Baseline FY 2019 - FY 2024*						*FY 2019 - FY 2024 Total*
		FY 2019	*FY 2020*	*FY 2021*	*FY 2022*	*FY 2023*	*FY 2024*	
D&Is	89	80	91	87	77	83	74	492
JTA Flights	27	19	25	28	25	26	27	150
Test Bed Evals	58	34	49	79	62	53	49	326
Pit NDEs	174	175	202	225	217	222	162	1203
Pit D-Tests	7	20	15	18	19	17	19	108
CSA NDEs	54	52	40	47	38	47	42	266
CSA D-Tests	13	14	20	21	19	20	18	112
GTS Tests	39	80	103	76	57	57	66	439
HE D-Tests	31	29	44	39	38	36	33	219
DCA Tests	80	65	74	96	96	75	91	497
TOTALS	572	568	663	716	648	636	581	3812

CSA = canned subassembly
D&I = disassembly and inspection
DCA = detonator cable assembly
D-tests = destructive tests
FY = fiscal year
GTS = gas transfer system
HE = high explosive
JTA = joint test assembly
NDE = nondestructive evaluation

2.2.1 Surveillance Challenges and Strategies

Table 2–7 provides a high-level summary of Surveillance program challenges and the strategies to address them.

Table 2–7. Summary of Surveillance program challenges and strategies

Challenges	*Strategies*
Potential shortfalls with pit and canned subassembly testing due to capacity limitations and a historical test backlog.	DOE/NNSA is working to improve efficiency by conducting highest-priority testing and delaying or eliminating lower-priority testing.
Aging surveillance capabilities and capacities across the enterprise (e.g., test equipment).	Ongoing formal planning is being conducted to establish surveillance capabilities and capacities to ensure that mission deliverables are being met while enabling a flexible, tailorable, and a more responsive Stockpile Evaluation Program.

The Stockpile Evaluation program contains the following elements: weapon D&I, stockpile flight testing, stockpile laboratory testing, component testing and material evaluation, test equipment, and anomaly investigation. Adjunct activities include reliability and annual assessments. These elements will be discussed in the following subsections.

2.2.2 Disassembly and Inspection

Weapons sampled from the production lines or returned from DoD are inspected during disassembly. Weapon disassembly is conducted in a controlled manner to identify any abnormal conditions and preserve the components for subsequent evaluations. Visual inspections of, for example, color changes, cracking, or flaking during D&I can also provide state-of-health information.

2.2.3 System Flight Testing

A subset of weapons that have undergone D&I are reassembled into JTA configurations to represent the original build to the extent possible. Non-nuclear components from these systems are used directly, along with surrogate parts for the nuclear components. For example, plutonium and highly enriched uranium (HEU) are replaced with either surrogate materials and/or instrumentation. Some JTAs contain extensive telemetry instrumentation to provide detailed information on component and subsystem performance during flight environments. The JTA units are delivered to and flown by the DoD operational command responsible for the 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.

2.2.4 System Laboratory Testing

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, polymers, glasses, plastics, ceramics, foams, electronics, optical, and explosives). This surveillance process enables detection and evaluation of the onset of aging, trends, and anomalous changes at the component or material level.

2.2.5 Component Testing

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 evaluation techniques (e.g., radiography, ultrasonic testing, electrical testing, and dimensional measurements) and destructive evaluation techniques (e.g., disassembly and coring of pits and canned subassemblies (CSAs), live firing of detonators and high explosive (HE) samples, as well as chemical assessments).

2.2.6 Test 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 simulate a weapon employment scenario. Second, the testers simultaneously collect data on the performance of components and subsystems. 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.

2.2.7 Anomaly Investigative Process

When anomalies arise that could significantly affect weapon safety, security, reliability, or performance, surveillance data are taken and then assessed to determine whether observations are serious enough to open an SFI for specific weapon or component issues. SFIs are also opened for anomalies discovered anywhere in the stockpile when unexpected phenomena are observed. Such occurrences are investigated by the design agency responsible for the anomalous component. Investigations can include modeling of historical data, focused materials experiments, research and studies, major system test replication (i.e., hydro tests), 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. 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.

2.2.8 Weapon Reliability

Nuclear weapon reliability is the probability that a designated weapon can deliver the specified nuclear yield at the target, assuming all required DoD inputs are correct. The stockpile also undergoes an annual weapon reliability assessment, which is compiled into the Weapon Reliability Report. This report communicates to DoD the major aspects (yield and reliability) for the military effectiveness of the stockpile. The Weapon Reliability Report is the principal DOE/NNSA report on reliability for U.S. Strategic Command (USSTRATCOM), which uses it for overall strategic planning actions and targeting.

2.2.9 Annual Assessment

The directors of the three DOE/NNSA national security laboratories and the Commander of USSTRATCOM provide a written annual assessment on the state of each warhead type in the nuclear weapons stockpile. The annual stockpile assessment review process is not an annual recertification of the warheads in the stockpile. It is an assessment of each warhead's existing certification basis considering information generated by the Stockpile Stewardship Program in the past year. Each annual assessment builds on continuing experience with each weapon system and incorporates new information from stockpile maintenance, surveillance, experiments, simulations, and other sources to enhance the technical basis of each weapon type.

The annual stockpile assessment process evaluates the safety, security, and effectiveness of weapons based on physics and engineering analyses, experiments, and computer simulations. Assessments may also evaluate the effect of aging on performance and quantify performance thresholds, uncertainties, and margins. These evaluations rely on all available sources of information on each weapon type, including surveillance, non-nuclear hydrodynamic tests, subcritical experiments, materials evaluation, modeling and simulation, and aging and lifetime evaluation techniques.

The overall assessment philosophy and approach involves quantification of weapon characteristics and rigorous review of the results and certification basis by teams of weapons scientists and engineers. The laboratory teams responsible for each weapon type and its assessment include individuals with extensive weapons experience and access to both historical and new data. The assessments and conclusions in the Annual Assessment Reports are reviewed by independent peers, Red Teams (subject matter experts appointed by each laboratory's director), program managers, senior laboratory management, and the Laboratory Directors. Specific results related to the stockpile systems are provided in the latest *Report on Stockpile Assessments*.

2.3 Crosscutting Programs

Crosscutting programs support multiple aspects of stockpile management, including surveillance activities and provisioning materials and components for stockpile maintenance and modernization. Program activities include production support for manufacturing and engineering operations, provisioning of products and services for multi-weapon system surveillance, maturation of advanced and exploratory weapons technologies, demonstration and deployment of advanced manufacturing processes, and provisioning of energetic materials and radiation-hardened microelectronics.

2.3.1 Production Support

The Production Support Program is a DSW Program that funds multi-system, manufacturing-based activities that provide individual site production capabilities and capacity for the LEPs, LLC production, weapon surveillance, and weapon assembly and disassembly operations. The Production Support Program also enables the modernization of production capabilities to improve efficiency and ensure that manufacturing operations meet future requirements. This includes maintenance/calibration services for manufacturing operations to meet DoD War Reserve requirements.

Collectively, these activities directly support execution of systems engineering concepts and production integration. The Production Support Program provides DSW with the capability to conduct life extension work, stockpile surveillance, dismantlement work, neutron generator production, and detonator cable assembly production.

2.3.1.1 Accomplishments

- Analytical laboratories continued to grow their workforce in support of more than 8,000 work orders and 50,000 analytical tests. Inspected more than 153,000 piece parts at over 90 vendors
- Conducted required maintenance and calibration actions on process equipment to ensure the required availability to meet production deliverables
- Onboarded new commodity vendors in cables, tooling, materials, and machined parts and implemented supplier improvement plans for key existing partners in all commodity teams
- Completed installation of the new measurement and test equipment management tool
- Provided multi-system operations, maintenance, and laboratory support to meet LLC exchange production delivery and GTS surveillance deliverables
- The neutron generator enterprise met its production build and shipment goals in FY 2018 in accordance with the Neutron Generator Implementation Program Plan and the LLC Production Control Document (the Neutron Generator Implementation Program Plan and LLC Production Control Document are both part of Production Support's yearly deliverables)
- The Electronic Neutron Generator (ELNG) Product Realization Team successfully completed the qualification testing of the B83, legacy B61, and B61-12 ELNGs; these are the first ELNGs produced at SNL. ELNGs in the current stockpile were produced at the Pinellas Plant
- Continued execution of the Manufacturing Modernization Project, a multi-year project to transition to digital product acceptance

2.3.1.2 Status

The Production Support Program assists missions at seven national security sites and its portfolio is subdivided into seven major functional elements: Engineering Operations; Manufacturing Operations; Quality Supervision and Control; Tool, Gage, and Equipment Services; Purchasing; Shipping; and Materials Management and Electronic Product Flow.

The Production Support Program currently provides the manufacturing capabilities (e.g., engineering, manufacturing, quality assurance) and capacity for LEP production, enduring stockpile weapon assembly, weapon disassembly, weapon safety and surveillance testing, and reliability testing that are required to meet directive and DoD delivery schedules. It also supports manufacturing investments for detonator and detonator cable assembly production and the neutron generator enterprise. Detonator production is expanding to encompass eight product lines, and the neutron generator line maintains five product lines using new equipment to enable higher yield rates, increased maintenance/calibration services, and improved shop floor efficiency. Expanding engineering and quality assurance processes for B61-12 LEP non-nuclear component production is also captured under the Production Support Program. Continued work on the Manufacturing Modernization Project continues to support digital product production and acceptance, specifically completing the upgrade of the detonator manufacturing line (scheduled to be complete in FY 2021). The program also began implementing electronic work instruction processes and procedures for the visual factory shop floor, and migrating from a paper-based product life-cycle management system to electronic media.

2.3.1.3 Challenges and Strategies

Table 2–8 provides a high-level summary of the Production Support Program's challenges and the strategies to address them.

Table 2–8. Summary of Production Support Program challenges and strategies

Challenges	*Strategies*
Demands on the program continue to increase as the enterprise strives to have manufacturing capabilities and capacity in place to meet LEP production schedules.	Ensure facilities and equipment are maintained and calibrated to support schedules.
The Manufacturing Modernization project faces challenges due to changes and upgrades in the plutonium manufacturing requirements versus capability.	Work with LANL and the Plutonium Sustainment Program to ensure Manufacturing Modernization project deployment is aligned with product lines with mature capabilities.

2.3.2 Management, Technology, and Production

The Management, Technology, and Production (MTP) Program's work scope is a multi-system, production-based program that promotes nuclear security enterprise integration and enhances efficiency. MTP activities provide the products, components, and/or services for multi-weapon system surveillance (laboratory/flight test data collection and analysis); weapons reliability reporting to DoD; DSW requirements tracking and execution; management and operation; and stockpile planning. The MTP Program funds plant and laboratory personnel to sustain the stockpile through activities related to surveillance; weapons response process improvements; engineering authorizations; safety assessments; use control technologies; containers; base spares; studies and assessments for nuclear operation safety; production of weapon components for use in multiple weapons systems; and transportation/handling gear for use in multiple weapons systems. The MTP Program also includes activities that benefit the nuclear security enterprise mission, as differentiated from Production Support activities, which support internal site-specific production missions.

2.3.2.1 Accomplishments

- Delivered the Weapons Reliability Report to DoD, an annual requirement for the program
- Responded to and informed DOE/NNSA requests for 2018 *Nuclear Posture Review* planning using Enterprise Modeling and Analysis Consortium support teams
- Completed each Weapon Response scope on schedule using a combination of analysis, testing, and expert knowledge
- Completed a series of tests in support of nuclear safety R&D deflagration/detonation studies
- Continued establishing the Cold Hearth Melting capability to support recycling, refinement, and alloying of scrap uranium-niobium alloy

- Completed a 2-year product data management system redeployment effort to improve audit readiness, sustainability, and extensibility and support increased throughput of product definition release
- Completed the first production release of the logistics, accountability, planning, and scheduling solution on September 21, 2018 (this phase of the solution allows DOE/NNSA to author, manage, and coordinate the directive schedules for DSW across the nuclear security enterprise)
- Enhanced the Livermore Independent Diagnostic Scoring System by imitating new design on radar rafts and on the recorder board used for neutron data capture (upgraded system rafts with new components)

2.3.2.2 Status

The MTP Program's portfolio maintains base production capability at six national security sites. MTP is subdivided into the elements of General Management Support, Product Realization Integrated Digital Enterprise (PRIDE), Weapons Training and Military Liaison, Studies and Initiatives, Surveillance, Support for External Production Missions, Production of New Non-Weapon Specific Base Spares, Maintenance of Existing Non-Weapon Specific Base Spares, and Assessments and Studies. Other activities involve planning, integration and program management, ensuring a viable workforce, and weapon component testing and production.

The program includes 10 critical activities:

- Executing stockpile sustainment activities
- Providing products, components, and/or services for multi-weapon surveillance
- Weapons reliability reporting to DoD
- Accounting for weapon logistics and accountability
- Processing special materials (including depleted uranium processing)
- Stockpile planning
- Developing the surveillance testers (stronglink, environmental testing equipment, and centrifuges) required to support LEP testing requirements and the multi-system weapon response and external production resources needed to conduct nuclear safety studies to ensure uninterrupted nuclear explosive operations at production plants
- Conducting use control studies and equipment procurements to align with nuclear weapon first production units and enduring stockpile refresh opportunities
- Sustaining efforts to re-establish a special nuclear material manufacturing capability and capacity at Y-12 and upgrading flight testing support and related equipment at the Tonopah Test Range
- Ensuring that all Weapons Evaluation Test Laboratory surveillance activities are executed in accordance with the baseline plans

The program is also currently funding models-based environment investments to enable DOE/NNSA to exchange classified three-dimensional (3D) product definition via common computer-aided design and drafting architecture from weapon component sourcing to quality inspection.

2.3.2.3 Challenges and Strategies

Table 2–9 provides a high-level summary of MTP Program challenges and the strategies to address them.

Table 2–9. Summary of Management, Technology, and Production Program challenges and strategies

Challenges	*Strategies*
Preparing for model-based enterprise and the use of models as the authorized design basis without a return to explosive nuclear testing.	Pilot projects have been funded to identify and address implementation issues.
Recapitalizing aging equipment and infrastructure at the Tonopah Test Range to support increased demand for surveillance flight testing.	Funding increased to support requirements.
Increased usage of the Weapons Evaluation Test Laboratory capabilities to support LEP qualification stressing availability of test assets for surveillance testing.	Working issues and requirement through the capital acquisition process.
Enhance product realization data management and collaboration tools.	Work scope defined in DSW Program Execution Plan.

2.3.3 Weapon Technology Development

The primary mission of the Weapon Technology Development program is to perform advanced and exploratory R&D and systems engineering to ensure viable technology options for modernization and enhancement of the nuclear weapons stockpile. Currently, it takes 5 to 7 years to mature technologies for integration into system architectures and provide options to address current and future stockpile needs. The focus of the R&D programmatic scope is to improve existing capabilities, provide solutions for addressing capability gaps and shortfalls, evolve capabilities to meet emerging threats and changing policy, and use improved technologies and methods to reduce development times and life-cycle costs. These efforts, funded via the DSW R&D Certification and Safety and R&D Support Programs, are organized under the focus areas of Technology Development and Integration, Technology Demonstrators, and Weapon Technology Development Support.

The Technology Development and Integration scope, funded through R&D Certification and Safety, focuses on R&D, engineering, and integration of technologies that improve capabilities in the areas of safety, security, and effectiveness with the intended application to multiple weapon systems in the enduring and future stockpile. This work is accomplished through early development of components to replace aging technologies; nuclear safety assessments and studies; systems engineering; system requirements; new engineering models and algorithms; and design studies with the objective of sufficiently advancing technologies to be adopted for future applications. Technology Demonstrators, also resourced via R&D Certification and Safety, conduct scaled demonstrations of technologies anticipated for insertion into the stockpile. The Weapon Technology Development program provides support to the administrative and organizational infrastructure that provides stockpile studies and programmatic work for multiple systems. This support includes program management activities, flight test diagnostic capabilities, updates of R&D and engineering tools, quality assurance, Nuclear Enterprise Assurance Program support activities, and operations and maintenance of Joint Integrated Lifecycle Surety capabilities, funded under R&D Support.

There are five primary goals of the Weapon Technology Development program:

- Develop and mature agile, affordable, and assured technologies
- Demonstrate new technologies within subsystem or system contexts in relevant environments
- Identify and address stockpile capability gaps, shortfalls, issues, and risks
- Produce viable responses to address emerging threats and avoid technological surprise
- Employ tailored systems engineering to develop, demonstrate, and integrate capabilities into future system architectures

2.3.3.1 Accomplishments

- The High Operational Tempo Sounding Rocket Flight Test, or HOT SHOT, program successfully launched its first research rocket from the Pacific Missile Range Facility in Kauai, Hawaii. HOT SHOT provides a test platform with a high-risk tolerance for new technologies that can duplicate many of the combined launch environments needed to qualify components, technologies, and subsystems. These activities support DOE/NNSA's goal to accelerate development cycles and shorten the duration of future weapons modernization programs. The first flight validated analyses of mechanical responses in a combined environment, explored the dynamic performance of additively manufactured structures, and matured a digital data architecture for future weapons and tools for real-time data acquisition.
- The Research and Sounding Rocket project was also piloted, serving as a feed-in structure to the HOT SHOT program. This project provides a portfolio of low-cost, high-frequency, preliminary flight vehicle test beds to evaluate and prove-in early technology development work, new instrumentation options, and advanced modeling and simulation codes. The high tempo and quick turnaround nature of these flights enables creation and validation of the necessary mode of operations for subsequent flight tests. Six flight tests were conducted during FY 2018 in collaboration with rocket programs at the University of Oklahoma and Oklahoma State University, creating relevant multi-dimensional environments for a variety of experiments and payloads.
- Accelerated technology maturation of the neutron generator monitor application-specific integrated circuits (ASICs), which allowed insertion to JTA units for additional programs. The new ASIC provides several technical enhancements, including increased and decreased neutron generator monitor circuit mass.
- Successfully advanced the system readiness level for the Joint Technology Demonstrator (JTD) project through the System Technical Review 2 and successful completion of Gate 2 review. Conducted subsystem-level builds and demonstrations of the electrical system functional test bed with positive results.
- Initiated the Air Force and DOE/NNSA Demonstrator Initiative and conducted a customer requirements review that established the technical basis for multiple flight tests in FY 2022.

2.3.3.2 Status

The Weapon Technology Development program is poised to continue advancing technology options for down-select by future weapon systems, particularly for the next insertion opportunities (i.e., W87-1 and the Next Navy Warhead). The program is currently maturing non-nuclear components and systems architectures and demonstrating technologies in relevant environments to de-risk technology options. Weapon Technology Development supports technology R&D in multiple major technical areas, including neutron generators; safety mechanisms; sensors; energetics; power sources; systems engineering for nuclear explosive packages; mounts; arming, fuzing, and firing (AF&F) subsystems and all internal components; detonators; material science; and GTSs. There are eight major ongoing activities:

- Advancing development of hardware, materials, equipment, and processes, and demonstrating technology or manufacturing readiness levels sufficiently to transition to a program of record
- Developing cost-efficient technology solutions to enhance the safety, security, reliability, and performance of the stockpile
- Increasing technology development activities for high-energy, low-sensitivity energetic components for future systems

- Developing and testing conformal thermal batteries, launch accelerometers, and replacement inertial sensor technologies
- Executing JTD activities in collaboration with the United Kingdom (UK) to explore technology applications in a systems context
- Continuing to develop and use the capability to demonstrate technologies in a system or subsystem context in relevant environments using low-cost, high-frequency demonstrators
- Maturing foundation bus technology for transformation of capabilities supporting future systems
- Continuing to plan multiple flight experiments necessary to de-risk technologies

The Weapon Technology Development program will continue efforts to ensure the availability of technology options and system architectures for future systems. The program is seeking support from other DOE/NNSA offices to enhance the sounding rocket flight testing infrastructure at the Kauai Test Facility. This program will provide real-time flight performance data for model validation and accelerated qualification.

2.3.3.3 Challenges and Strategies

Table 2–10 provides a high-level summary of Weapon Technology Development program challenges and the strategies to address them.

Table 2–10. Summary of Weapon Technology Development program challenges and strategies

Challenges	*Strategies*
Conduct and complete technology maturation activities as planned to support future weapons programs.	Identify high-priority technologies in coordination with the end user and maintain frequent communication with relevant partners. Leverage resources from the UK, as authorized under the Mutual Defense Agreement, and other NNSA programs.
Develop high-quality insensitive high explosives raw materials to meet the requirements of future systems	Collaborate with Stockpile Services to continue work as planned. Continue development of alternative insensitive high explosive formulations based on new molecules.
Effectively communicate Joint Technology Demonstrator (JTD) milestones, accomplishments, issues, and intentions to senior leadership.	Ensure that all JTD participants are properly trained and informed of relevant national priorities. Conduct quarterly updates with DOE/NNSA and continue to work with UK partners to ensure senior management is informed of JTD outcomes.
Transitioning technology findings and benefits to LEP process.	Negotiate early and continually with weapon program managers to ensure that interface requirement agreements are developed and approved and the benefits are well understood.

2.3.4 Advanced Manufacturing Development

The Advanced Manufacturing Development Program develops, demonstrates, and deploys next-generation production processes and manufacturing tools so that future weapons are agile and assured. Advanced manufacturing methods are essential to achieving the efficiency and agility required for production of the future stockpile. Laboratory and plant management and operating (M&O) Centers of Excellence have been established to coordinate, explore, and exercise transformative manufacturing approaches to support stockpile responsiveness as legacy methods may no longer be reproducible. R&D of these methods and assessment of their impacts on nuclear explosive package performance are key elements of the program and are supported by elements of the Advanced Simulation and Computing, Science, Technology Maturation, and Stockpile Responsiveness Programs.

The Advanced Manufacturing Development Program has three subprograms: Component Manufacturing Development, which focuses on modernizing manufacturing technology and process development; Additive Manufacturing, which focuses on technology also known as 3D printing; and Process Technology Development, which currently supports uranium processing technologies. The Additive Manufacturing subprogram has a broad impact on DOE/NNSA's mission by enabling new and novel design alternatives (including designs that cannot be manufactured by traditional methods), simplifying component production, accelerating design iteration and production development schedules, and reducing costs. Analyzing the behavior of materials and components made with this advanced technology is challenging because behavior must be characterized over a range of scales from microscale to mesoscale and validated by testing.

2.3.4.1 Component Manufacturing Development

The Component Manufacturing Development subprogram seeks to develop the innovative manufacturing processes necessary to replace sunset technologies, upgrade existing technologies, and introduce future enabling technologies across the nuclear security enterprise in support of maintaining the safety, security, and effectiveness of the stockpile. This subprogram is responsible for developing the proofs of concept for manufacturing processes and validating that those processes meet component design requirements with initial prototype builds. The subprogram coordinates with other programs to ensure proper transition of the technology. These efforts are system-agnostic and prioritized to ensure the critical mission need is addressed. The Component Manufacturing Development subprogram focuses on the successful transition of technologies from design agency to production agency.

The four Component Manufacturing Development subprogram focus areas are described below.

Advanced Production Development. Draws on exploratory manufacturing research across the laboratories and plants to inform decisions on process improvements. This focus area is intended to improve current capabilities through the development of new techniques for manufacturing specific materials and production processes.

Manufacturing Process Integration. Facilitates introduction of new manufacturing techniques into production lines to ensure the materials and components produced by novel manufacturing processes meet design requirements and are on a well-defined path for insertion into a weapon system or production line.

Manufacturing Diagnostic Development. Enables new manufacturing processes by developing process monitoring and control diagnostics to observe and study novel production methods and materials. These diagnostics provide a path to qualification and certification for manufacturing processes and ensure the integrity of the nuclear weapons supply chain.

Material Obsolescence and Sunset Processes. Pursues alternatives for obsolete or hazardous materials and aging production processes and includes new approaches designed to better conserve materials that are scarce or challenging to produce. These alternative approaches must be developed and deployed before aging issues or material shortages affect the status of LEPs, Alts, or Mods.

Top Priorities in the Component Manufacturing Development subprogram:

- Directly affect the agility and responsiveness of DOE/NNSA's manufacturing infrastructure
- Focus on innovative technologies in time for insertion in the W87-1 while continuing to advance technology for later systems [this focus is in response to a key lesson learned from previous LEPs;

that technology needs to be sufficiently mature prior to the weapon program entering Phase 6.3 (Development and Engineering)].

- Facilitate the sites replacement of conventional polymer processes with additive manufacturing processes by 2023 (benefits include seeing a process step reduction from 11 to 3 major steps, reducing production footprint from 10,000 square feet to 1,000 square feet, and increasing part yield from 70 percent to over 95 percent, all resulting in reduced material wastes and maintaining schedule and cost confidence for future weapon programs)
- Replace specific hazardous and obsolete processes by Phase 6.3 (FY 2023) of the W87-1 Modification Program (benefits include reducing process steps from 16 to 4 major steps, reducing cost per part from $238,000 to $100,000, and increasing part yield from 5 percent to over 50 percent)
- Develop a suite of technologies to mitigate material supply chain risks, address quality considerations, and integrate schedule and cost confidence levels into processes for current and future programs of record
- Create an integrated digital manufacturing network at each of the production sites, leveraging ongoing activities in Laboratory and Plant Direct Research and Development programs, as well as Advanced Simulation and Computing on artificial intelligence/big data/machine learning
- Leverage industry advancements to integrate their manufacturing machines into our aging and obsolete production lines; manage large manufacturing data sets generated from modern manufacturing processes; and automate processes where a strong business case exists

Accomplishments

- Developed the first small batch of additively manufactured chip slapper detonators, reducing the process development time by 50 percent and exceeding product quality expectations
- Transitioned product acceptance testers to assure readiness in meeting production capacity for the B61-12 LEP, W88 Alt 370, and MK21 Fuze Programs
- Increased new neutron generator tooling output by 25 percent in FY 2017 at less than half the cost and time compared to traditional manufacturing methods
- Transitioned ASIC production control software from fabrication factory works to a system called the Electronic Production Control System (the system automates tracking of ASICs through the production process, which will reduce human error in recording the information, and will result in an estimated cost avoidance of approximately $17.6 million, to be realized over the Future Years Nuclear Security Program)

Status

- Component Manufacturing Development portfolio projects are intended to directly affect the agility and responsiveness of DOE/NNSA's manufacturing infrastructure (the subprogram will mature innovative, cost-saving technologies in time for insertion in the W87-1 with investments specifically targeting a handful of critical production needs that must be in place for the W87-1 to be successful)
- Component Manufacturing Development will continue to target high-value, long-term technologies that will be available to systems after the W87-1

Challenges and Strategies

Table 2–11 provides a high-level summary of Component Manufacturing Development subprogram challenges and the strategies to address them.

Table 2–11. Summary of Component Manufacturing Development subprogram challenges and strategies

Challenges	*Strategies*
Multiple Component Manufacturing Development-funded projects will transfer to the Strategic Materials Program over the next 5 to 10 years.	Coordinate with the strategic materials programs to develop a life-cycle management strategy to reduce future material supply chain risks.

2.3.4.2 Additive Manufacturing

The Additive Manufacturing subprogram capitalizes on 3D printing of polymers and metals for stockpile applications to shorten production schedules and design cycles. These time reductions for design and production will ultimately lead to lower life-cycle costs and enable production of components with qualities that are not possible using current manufacturing technologies. This subprogram focuses on innovative and revolutionary processes that have not yet been demonstrated in a relevant production environment, using multi-site collaborations to share results quickly and speed development. Additive manufacturing reduces risks to program schedules and avoids costs traditionally associated with subcontracting work to outside vendors in direct support of the nuclear security enterprise. Additive manufacturing plays an integral role in supporting the nuclear security mission through rapid prototyping, JTA component production, tooling, and polymer pad and cushion production.

The Additive Manufacturing subprogram mission scope addresses four focus areas:

- Initial Capabilities: Establish advanced and exploratory additive manufacturing capabilities
- Prototype Production: Produce additive manufacturing prototypes that demonstrate the range of their benefits
- Science-Based Manufacturing: Develop methods that meet design and qualification requirements
- Accelerated Qualification and Certification: Accelerate qualification and certification of additively manufactured parts, enabling insertion into the stockpile

The Additive Manufacturing subprogram focuses on longer-term investments that reduce the cost of design-to-manufacture iterations. These specific processes require fully characterizing additively manufactured materials and capabilities and then producing methodologies that enable qualification and certification. Additive manufacturing also offers tremendous performance advantages in comparison to legacy manufacturing processes by promoting better and faster design cycles, lower production costs, and faster development and production cycles.

Accomplishments

- Developed Direct Ink Write technology for cushions and pads to Technology Readiness Level 5
- The nuclear security enterprise produced its first additively manufactured War Reserve component in 2018
- Developed a stainless-steel powder bed additive manufacturing process that enables current and future programs to use additively manufactured GTS mass mocks and trainers (in comparison to traditional methods, this process results in a 50 percent shorter manufacturing cycle time and a cost avoidance of $793,000 per part)

- Upgraded the arming and fuzing production line to increase process efficiency and reduce material waste streams (this will benefit current and future major modernization programs during production)
- Acquired a patent at LLNL for additive manufacturing of energetic materials in FY 2019, demonstrating DOE/NNSA's leadership in this field and enabling technological advancement across the nuclear security enterprise
- Printed an HE booster into a main charge cavity and proved initiation, demonstrating an attractive alternative approach to conventional manufacturing

Status

- Since 2013, KCNSC has printed over 63,000 tools, fixtures, and molds that help reduce schedule risk and have resulted more than $124 million in cost avoidance
- An estimated 10 percent of all tools, fixtures, and molds in the enterprise and an estimated 90 percent of prototype tools and fixtures are additively manufactured

Challenges and Strategies

Table 2–12 provides a high-level summary of Additive Manufacturing subprogram challenges and the strategies to address them.

Table 2–12. Summary of Additive Manufacturing subprogram challenges and strategies

Challenges	*Strategies*
Meet the need to accelerate the development of a large array of manufacturing capabilities to support the W87-1 Modification Program is required.	To support the W87-1 Modification Program, the subprogram will additively manufacture components; replace hazardous materials and related processes; develop manufacturing processes to support advanced arming, fuzing, and firing designs; and develop a process to manufacture new gas transfer system reservoir materials.

2.3.4.3 Process Technology Development

The Process Technology Development subprogram supports development, demonstration, and use of new production technologies to enhance manufacturing capabilities for nuclear weapon materials. Funding will be used to deploy new technologies with the potential to shorten production schedules, reduce risks, enhance personnel safety, or reach optimal maturity levels in time to support mission needs.

At present, this subprogram focuses on uranium processing technologies and, more specifically, on acquiring major items of equipment for Y-12 by 2025. These include a calciner project, direct chip melt installation, and an electrorefiner project. These major items of equipment will relocate uranium processing capabilities into existing facilities at Y-12 to support phasing out mission dependency on Building 9212. Additional information about uranium can be found in Sections 2.4.2 through 2.4.5.

2.3.5 Radiation-Hardened Microelectronics

The electronics in nuclear warheads must function reliably in a range of operational environments. These environments include radiation sources ranging from cosmic rays to intrinsic radiation within the weapon and from hostile sources. A trusted supply of these strategic radiation-hardened advanced microelectronics performs critical, sensing AF&F functions to meet current program requirements, and supports R&D to maintain the safety, security, and effectiveness of the Nation's nuclear deterrent in a diverse threat environment.

2.3.5.1 Accomplishments

- The Electronic Production Control System was developed and used to track ASIC parts through all production steps (this system implementation decreased product acceptance times from weeks to 2 days, while reducing quality documentation record errors using barcode scanning technology coupled with automated generation of electronic Log Record Books; this automation eliminates the need to perform manual data entry tasks)
- The Microsystems Engineering, Science and Applications (MESA) complex delivered a record 26,000 microfabricated parts to DOE/NNSA for the B61-12, W88 Alt 370, and Mk21 Fuze Programs (this is the largest ASIC production run in SNL history and includes components with new capabilities)
- The Silicon Fabrication Facility completed all planned life-of-program production and safety stock wafer fabrication for the modernization programs and delivered over 6,000 War Reserve parts to DOE/NNSA in support of baseline first production unit dates for the B61-12, W88 Alt 370, Mk21 Fuze, and W80-4

2.3.5.2 Status

The MESA fabrication facilities at SNL produce custom, strategic, radiation-hardened microelectronics for nuclear weapons and space-based nuclear detonation detection systems. The Nation's trusted, strategic radiation-hardened microelectronics development and manufacturing capability must be sustained beyond 2025 to support stockpile modernization as directed in the 2018 *Nuclear Posture Review*. DOE/NNSA uses collocated R&D and production to support rapid design, manufacturing, packaging, and testing of strategic radiation-hardened microelectronics that function properly when exposed to intense radiation environments.

2.3.5.3 Challenges and Strategies

Table 2–13 provides a high-level summary of radiation-hardened microelectronics challenges and the strategies to address them.

Table 2–13. Summary of Radiation-Hardened Microelectronics challenges and strategies

Challenges	Strategies
Competing requirements among the Alt/LEP programs must be balanced while continuing the development and sustainment of the engineering and science-based microelectronics capabilities required to accomplish the Nation's nuclear weapon missions.	Prioritizing Alt/LEP support and microelectronics fabrication capabilities to achieve investment balance to enable delivery of the program of record.
Silicon Fabrication Facility infrastructure and aging and unsupported equipment likely will require upgrades and replacements to sustain this capability through 2040.	DOE/NNSA is working with SNL to address highest-risk infrastructure needs. SNL has already begun a 6- to 8-inch tool conversion to support production for future programs of record.
MESA Microsystems Fabrication Facility capabilities, which deliver strategic radiation-hardened semiconductor devices, need to be sustained over the next decade to meet nuclear weapon requirements. The fragility and capability limits of the MESA facility places risk on DOE/NNSA design and production efforts.	DOE/NNSA is addressing the strategic radiation-hardened microelectronics capability options through an Extended Life Program to sustain the capability through 2040 and beyond.

2.4 Strategic Components and Materials

DOE/NNSA is focused on manufacturing nuclear weapons components of strategic interest that need to be replaced. These key components, including primaries, secondaries, and radiation cases, are critical to weapon performance, and their manufacture is tightly controlled. Production of these components and the materials needed to construct them was reduced or stopped during the 1990s when they were no longer required. Conducting LEPs and a greater emphasis on a responsive manufacturing infrastructure now require restoring or increasing the capacity of these material and component capabilities, necessitating new methods and approaches to provide sufficient throughput and efficiency. These strategic components require the availability of materials and subcomponent streams that are managed by DOE/NNSA and need to be tightly coordinated with component production. The facilities and operations required to process the materials and then fabricate and assemble the components have been grouped into seven material classes:

- Plutonium
- HEU
- Depleted Uranium
- Domestic Uranium Enrichment
- Tritium
- Lithium
- Energetic Materials

Material process flows and the recovery of material from dismantlement and disposition activities are coordinated by the Material Recycle and Recovery (MRR) and Storage programs.

2.4.1 Plutonium

The United States no longer has the capability to produce new primaries for nuclear weapons, including plutonium subcomponents such as pits, at the rate needed. Specifically, the United States has not manufactured a War Reserve pit since 2012 and has not had the ability to manufacture more than 10 pits per year (ppy) for over two decades, since the Rocky Flats Plant closed. The 2018 *Nuclear Posture Review* includes a requirement for a responsive nuclear weapons infrastructure that provides "the enduring capability and capacity to produce plutonium pits at a rate of no fewer than 80 ppy by 2030." In May 2018, the DOE/NNSA Administrator provided Congress with DOE/NNSA's recommended alternative to produce no fewer than 80 ppy by 2030; as required by the *National Defense Authorization Act for Fiscal Year 2019*. This recommended alternative was endorsed by the chair of the Nuclear Weapons Council. DOE/NNSA's recommended alternative to meet pit production requirements is twofold:

- Repurpose the former Mixed Oxide Fuel Fabrication Facility (MFFF) at SRS to produce 50 War Reserve ppy by 2030 (see Section 2.4.1.2)
- Concurrently, DOE/NNSA will continue to invest in LANL to produce 30 War Reserve ppy beginning in 2026; as practicable, DOE/NNSA will assess opportunities for LANL to produce above that quantity

This two-pronged alternative is the optimal path forward to meet pit production requirements while managing the risks and costs associated with increasing production rates and maintaining existing plutonium operations at LANL.

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 equipment and facilities for R&D activities. Manufacture and surveillance of plutonium components, as well as experiments and analysis of plutonium, currently occur at LANL's Plutonium Facility (PF-4). DOE/NNSA also leverages additional capabilities and expertise at SNL, LLNL, Pantex, and the Nevada National Security Site to support defense-related plutonium missions.

The largest portion of the U.S. weapons-usable plutonium inventory is in the form of retired pits. DOE/NNSA continues to repurpose and reconfigure nuclear material bays to stage pits at Pantex until a long-term staging facility is available. LANL and LLNL continue to manage annual pit surveillance at LANL, LLNL, Pantex, and the Nevada National Security Site. DOE/NNSA continues to invest in additional pit nondestructive evaluation throughput capacity. The Confined Large Optical Scintillator Screen and Imaging System (CoLOSSIS) II and the Laser Gas Sampling Station II in FY 2018 are examples of steps to improve the efficiency and affordability of surveillance activities. This data collection and analysis 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.

Almost all plutonium processing for the nuclear weapons program (e.g., recovery, characterization, component fabrication, nondestructive analysis, and surveillance) and basic and applied research on plutonium are conducted in LANL's PF-4. PF-4 is the only DOE/NNSA facility authorized to produce pits for the enduring stockpile. DOE/NNSA continues to invest in PF-4 to establish an enduring 30 ppy production capability by FY 2026 and to maintain LANL as the Nation's Plutonium Center of Excellence for R&D.

2.4.1.1 Accomplishments

- Fabricated five Development W87-like pits to support a transition to the process prove-in phase
- Continued investments to replace end-of-life pit production equipment required to manufacture the first War Reserve pit in FY 2023
- Conducted preconceptual design activities for pit production at SRS

2.4.1.2 Status

DOE/NNSA continues to invest in LANL capabilities to meet pit production requirements and is developing design documentation to create a pit production capability at SRS. On October 10, 2018, DOE/NNSA began transition activities. MFFF has been renamed to the Savannah River Plutonium Processing Facility (SRPPF), and a conceptual design will be used to develop CD-1 (Approve Alternative Selection and Cost Range) for the Deputy Secretary's final review and decision.

DOE/NNSA is recapitalizing facilities and equipment (i.e., acquiring, installing, configuring, and authorizing equipment for operation) to replace an aging base capability to manufacture and certify pits. Through a series of Technical Area 55 (TA-55) Reinvestment Projects (TRP I, TRP II, and TRP III), DOE/NNSA is addressing PF-4's aging infrastructure and systems. The Chemistry and Metallurgy Research Replacement (CMRR) project maintains continuity in analytical chemistry and materials characterization capabilities by transitioning these activities from the Cold War-era Chemistry and Metallurgy Research (CMR) facility to newer facilities. Risk reduction activities through the MRR program regarding material-at-risk are continuing in CMR through significant removal of the nuclear material inventory currently housed in the legacy facility. The first two CMRR subprojects have approved baselines and are on schedule to be completed in 2022. The Plutonium Pit Production Project was created during the FY 2019 appropriations process and includes the unbaselined scope of the CMRR project, which is associated with expanding analytical chemistry and materials characterization, and pit manufacturing equipment installation to produce a minimum of 30 ppy.

FY 2020 goals and milestones include:

- Fabricate five process prove-in pits
- Continued investments in pit production equipment required a minimum of 30 ppy production capability
- Complete the conceptual design and CD-1 (Approve Alternative Selection and Cost Range) for SRPPF

2.4.1.3 Challenges and Strategies

Table 2–14 provides a high-level summary of Plutonium Program challenges and the strategies to address them.

Table 2–14. Summary of Plutonium Program challenges and strategies

Challenges	*Strategies*
DOE/NNSA must increase pit production over the next decade to meet a capacity of no fewer than 80 pits per year (ppy) by 2030. The current schedule includes a War Reserve first production unit in FY 2023, building to a production capability of 10, 20, and at a minimum, 30 War Reserve ppy in 2024, 2025, and 2026, respectively, at LANL, and 30 ppy thereafter. Concurrently, DOE/NNSA is repurposing facilities at SRS to provide no fewer than an additional 50 War Reserve ppy capability by 2030. Meeting these deliverables remains a challenge as DOE/NNSA continues to re-optimize existing available space, replace end-of-life manufacturing equipment, and invest in additional manufacturing equipment, associated facilities, and staff. DOE/NNSA also faces space challenges caused by the need to store retired pits and the deteriorating condition of aging Cold War-era infrastructure.	Continue to invest in PF-4 to establish a minimum 30 ppy production capability at LANL by FY 2026 and maintain LANL as DOE/NNSA's Plutonium Center of Excellence for Research and Development. Continue to execute project development activities related to building a pit production capability at SRS. Execute Savannah River Plutonium Processing Facility project in time to support production milestones. Address LANL plutonium infrastructure challenges through construction such as the CMRR project. Modernize waste processing and treatment facilities through recapitalization and line-item projects such as the TA-55 Reinvestment Project and the Radiological Liquid Waste Treatment Facility Project.
Maintain subject matter expertise at the national laboratories in base R&D capabilities to support plutonium production.	Continue two-way communication between the nuclear weapons production facilities and the national security laboratories. The laboratories will determine a path forward to provide the expertise necessary to meet production needs and recommend improvements that can be applied to plutonium production.

2.4.2 Uranium

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

2.4.3 Highly Enriched Uranium

HEU is uranium in which the concentration of the fissile isotope, uranium-235, is increased to 20 percent or greater.

2.4.3.1 Accomplishments

- Initiated planning and prioritization efforts to phase-out mission dependency on Building 9212
- Increased the reliability of existing uranium capabilities in casting sustainment and machining sustainment investments
- Removed enriched uranium material from Area 5 to achieve the Y-12 de-inventory milestone and continued enabling efforts to establish and maintain target working inventory levels
- Installed radiography capability in Building 9201-2E
- Achieved Performance Baseline and Start of Construction (CD-2/3) for all seven Uranium Processing Facility subprojects
- Achieved CD-2/3 for the Y-12 Electrorefiner project

2.4.3.2 Status

Y-12 is home to the Nation's primary uranium processing and storage infrastructure. LANL and LLNL both house uranium R&D capabilities, and Y-12 also has a development laboratory that supports uranium activities. Y-12's Building 9212 contains the most hazardous enriched uranium operations. At more than 70 years of age, Building 9212 does not meet modern nuclear safety and security standards. DOE/NNSA is phasing out mission dependency on Building 9212 through a series of enriched uranium capability relocations into existing facilities at Y-12, as well as the Uranium Processing Facility, when completed. To successfully execute this transition, new technologies will be deployed and existing processes will be simplified or eliminated to increase the overall safety and efficiency of enriched uranium operations. During this transition period, efforts to reduce the material-at-risk will continue through the material recycle and recovery.

Infrastructure investment in Buildings 9215 and 9204-2E is integral to the overall strategy. These two buildings were constructed in the 1950s and late 1960s, respectively, and their construction predates many of the modern safety standards applicable to nuclear facilities. The infrastructure and programmatic equipment in both buildings are degrading due to age and condition, and replacement facilities are not planned for several decades. Both the machining operations in Building 9215 and the assembly and disassembly operations in Building 9204-2E must safely continue with high reliability through the 2040s. The Plant Laboratory, Building 9995, provides chemical analysis for the entire site. Building 9995 was built in the 1950s to support operations in Building 9212. The infrastructure and analytical chemistry capabilities in Building 9995 also require additional investments to continue to support the mission.

The Uranium Processing Facility will provide new floor space for the high-hazard, high-security operations in Building 9212 that are not suitable to relocate to existing facilities. Completion and startup of the Uranium Processing Facility, along with completion and operation of the Process Technology Development Program's Y-12 Electrorefiner and Calciner Projects, will enable DOE/NNSA to fully phase out mission dependency on Building 9212.

FY 2020 goals and milestones include:

- Complete construction of the Uranium Processing Facility substation
- Complete design package and begin installation for the Decontamination, Sort, and Segregate facility

2.4.3.3 Challenges and Strategies

Table 2–15 provides a high-level summary of Uranium Program challenges and the strategies to address them.

Table 2–15. Summary of Uranium Program challenges and strategies

Challenges	*Strategies*
Transition enriched uranium capabilities into existing and new-build facilities to phase out mission dependency on Building 9212. This will shut down Building 9212's production processes, drain and isolate systems, and facilitate post-operations cleanout of the facility in accordance with the Building 9212 Exit Strategy. DOE/NNSA must maintain operations in Building 9212 while the Uranium Processing Facility is under construction and make investments to extend the operational life of enduring enriched uranium facilities where key processes will be relocated and facilities on which the uranium strategy is dependent, such as the Plant Laboratory in Building 9995.	Implement the Building 9212 Exit Strategy. Execute key technology transitions and process relocations by the end of 2022, including direct chip melt in Building 9215, electrorefining in Building 9215, and calciner in Building 9212. Maintain direct communications with Y-12, LANL, and LLNL to support accomplishment of the overall mission while closely tracking the progress of construction and relocation activities. Advance technologies currently planned for deployment in the field and those technologies required to meet future mission needs (including technologies to reduce production footprints).
DOE/NNSA faces challenges in maintaining subject matter expertise at the national security laboratories in base R&D capabilities and production support as a result of retirements combined with industry competition for a small pool of highly skilled, technical employees.	Continue two-way communications between the nuclear weapon production facilities and the national security laboratories. The laboratories are exploring a viable path forward to provide the expertise necessary to meet production needs and recommend improvements that can be applied to highly enriched uranium production.
Extend the operational lifetime of existing enriched uranium processing facilities (Buildings 9215 and 9204-2E and the Plant Laboratory in Building 9995).	Sustain existing enriched uranium capabilities through enhanced equipment maintenance and the purchase of critical spare parts to improve the availability and reliability of production systems. Execute planned investments in electrical modernization in Buildings 9204-2E and 9215.
Many of the uranium processes currently performed in Building 9212 cannot be transferred to another operating facility and must be replaced.	Execute the Uranium Processing Facility project to provide new floor space for the high-hazard, high-security operations in Building 9212 that are not suitable to relocate to existing facilities.

2.4.4 Depleted Uranium

Depleted uranium is a by-product of the enrichment process that has a lower ratio of uranium-235 to uranium-238 than naturally occurring uranium. DOE/NNSA has a long-term requirement for high-purity depleted uranium feedstock to meet national security needs. The capability to produce, process, and handle depleted uranium supports a number of key missions within the nuclear security enterprise, from providing parts for LEPs to downblending HEU to LEU.

2.4.4.1 Accomplishments

- With DOE Office of Environmental Management's Paducah-Portsmouth Project Office (PPPO), began initial design of a potential depleted uranium hexafluoride (DUF_6) to depleted uranium tetrafluoride (DUF_4) conversion line and initiated cost and schedule development
- Began establishing an interface mechanism between PPPO and a Phase 2 (DUF_4 to metal) conversion capability

- Collaborated with DoD to document mutual interest in depleted uranium supply and outline efforts to reduce operational risk
- Began working initial feasibility and estimated cost of procurement/cost avoidance for DoD through completion of a depleted uranium recycle pilot project

2.4.4.2 Status

DOE/NNSA is currently exhausting usable inventories of high-purity depleted uranium metal feedstock used for weapons production. DOE has a large quantity of depleted uranium in the form of DUF_6 stored in cylinders at its sites in Portsmouth, Ohio, and Paducah, Kentucky. Currently, DOE/NNSA does not have the capability to convert DUF_6 to DUF_4. DOE/NNSA evaluated various options for re-establishment of the capability to convert DUF_6 to DUF_4 and is working with DOE's Office of Environmental Management on the potential installation and operation of equipment at the Portsmouth DUF_6 Conversion Facility to convert DUF_6 to DUF_4 to meet nuclear stockpile requirements. The MRR program began efforts to re-establish the depleted uranium feedstock capability in FY 2019, including initiation of design work for the construction of a DUF_6 to DUF_4 conversion line at the Portsmouth site.

Y-12 uses an alloying process, along with a set of wrought and machining capabilities, to produce binary alloy components for use in national security applications. The process is less efficient than other possible production capabilities and relies on an aging infrastructure. Y-12 also uses casting, machining, inspection, and certification capabilities to deliver components and subassemblies for use in nuclear weapons production. DOE/NNSA has begun the process of developing technologies intended to phase out the wrought process, including direct casting.

FY 2020 goals and milestones include:

- Begin component procurement and potential installation at PPPO
- Leverage efforts with DoD to sustain phase 2 vendor production capabilities

2.4.4.3 Challenges and Strategies

Table 2–16 provides a high-level summary of Depleted Uranium Program challenges and the strategies to address them.

Table 2–16. Summary of Depleted Uranium Program challenges and strategies

Challenges	*Strategies*
Commercial capabilities do not exist to convert DUF_6 to DUF_4. Conversion of DUF_6 to DUF_4 is needed to support depleted uranium metal production, which is required to meet future mission needs. DOE/NNSA projects a shortfall of depleted uranium between FY 2029 and FY 2031.	Continue advancing technologies currently planned for deployment in the field and those technologies required to meet future mission needs. Investigate alternate processes and technology improvements that can increase the efficiency of traditional manufacturing processes. DOE/NNSA is working toward re-establishing the capability to convert DUF_6 to DUF_4 at the Portsmouth site. Re-establishment efforts will begin in FY 2019 (see Section 2.4.8, Material Recycle and Recovery and Storage).
DoD and NNSA depend on a limited vendor base for depleted uranium metal production.	Increase supply and more closely interface with DoD. DOE/NNSA is exploring the capability for recycling depleted uranium resulting from processing of by-products and waste. This effort has the potential to provide an alternate source for a small portion of the demand. DOE/NNSA is working with DoD counterparts to establish a clear understanding of the shared need for this material.

2.4.5 Domestic Uranium Enrichment

Enriched uranium contains higher concentrations of the fissile uranium-235 isotope than natural uranium and is required at varied enrichment levels for national security and medical isotope production. A domestic uranium enrichment capability will provide a reliable supply of enriched uranium to support a variety of U.S. missions, including support for tritium production, nonproliferation, and the Naval Reactors Program.

2.4.5.1 Accomplishments

- Continued execution of an Analysis of Alternatives (AoA) to identify and evaluate solutions to the LEU mission need
- Completed design and began testing of a small centrifuge design at Oak Ridge National Laboratory
- Began execution of the Downblend Offering for Tritium campaign to extend the need date for delivery of LEU fuel for tritium production to 2041

2.4.5.2 Status

The U.S. Government currently has no uranium enrichment capability. While commercial LEU sources exist, their use has domestic peaceful use restrictions, leading to these sources to be "encumbered." Mission needs for enriched uranium are currently fulfilled via the United States' remaining HEU stockpile, which is a finite, currently irreplaceable source. DOE/NNSA is funding centrifuge R&D efforts for potential deployment in an enrichment facility. DOE/NNSA is conducting an AoA for a domestic uranium enrichment capability. The AoA is planned to conclude in 2019. In October 2018, DOE/NNSA initiated another campaign to downblend excess HEU from its stockpiles to provide unobligated LEU fuel in support of its tritium production mission. This campaign extends the need date for delivery of unobligated LEU fuel for tritium production out until 2041.

DOE/NNSA is pursuing a three-pronged strategy to provide a reliable supply of unobligated and unencumbered enriched uranium:

- **Downblend HEU to LEU to extend the tritium fuel need date to 2041.** DOE/NNSA has identified existing unobligated and unencumbered material to power the Tennessee Valley Authority (TVA) reactors through 2041. 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 the mission need (CD-0) for this capability in December 2016. If the AoA adds construction of an enrichment capability, conceptual design work for a pilot plant will begin in 2020. Successful operation of a pilot plant will inform design, construction, and operation decisions for a full-scale uranium enrichment facility.

FY 2020 goals and milestones include:

- Complete testing of Oak Ridge National Laboratory small centrifuge design
- Complete AoA and recommend a solution to the LEU mission need
- Begin conceptual design for a centrifuge pilot plant, depending on the outcome of the AoA
- Continue execution of the Downblend Offering for Tritium Program to extend the need date for delivery of LEU fuel for tritium production to 2041

2.4.5.3 Challenges and Strategies

Table 2–17 provides a high-level summary of Domestic Uranium Enrichment Program challenges and the strategies to address them.

Table 2–17. Summary of Domestic Uranium Enrichment Program challenges and strategies

Challenges	***Strategies***
U.S. policy requires enriched uranium for defense missions, such as tritium production, to be free from domestic peaceful use restrictions (unencumbered) and from foreign peaceful use obligations (unobligated). Because the U.S. Government does not currently possess a uranium enrichment capability using U.S. technology and stocks of the HEU used to meet defense needs are finite, construction of an enrichment facility will be necessary.	Execute acquisition strategy to re-establish a domestic uranium enrichment capability. Continue R&D of two domestic centrifuge technologies.
DOE/NNSA has a near-term need for unobligated LEU for its tritium mission.	Continue downblending of excess HEU to produce unobligated LEU fuel.

2.4.6 Tritium

Tritium, which has a short radioactive half-life, is a critical material necessary for the functioning of nuclear weapons in the stockpile. As discussed in the Section 2.1.1.1, tritium is used in weapons to meet weapon system military characteristics, increase system margins, and ensure weapon system reliability. GTSs store the tritium to be delivered to the primary during weapon activation. Tritium inventories are maintained to meet this and other national security needs. Two sources of tritium support and maintain this inventory: (1) material recycle and recovery of tritium, primarily from GTS reservoirs, and (2) production by irradiation of lithium targets in reactors and extraction of tritium from these targets at SRS.

2.4.6.1 Accomplishments

- Commenced irradiation of 1,584 tritium-producing burnable absorber rod (TPBARs) in the TVA Watts Bar Nuclear Plant Unit 1’s (WBN1) Cycle 16
- Submitted a License Amendment Request to the Nuclear Regulatory Commission for tritium production at Watts Bar Nuclear Plant Unit 2 (WBN2) to begin in early FY 2021
- Awarded a long-term transportation services contract

2.4.6.2 Status

Tritium Production

DOE/NNSA has the capability to meet planned workload and mission deliverables. As indicated below, tritium production is ramping up and on schedule to meet requirements. The tritium production goal independently certified by the Nuclear Weapons Council in 2015, as requested by Congress, increased tritium production capabilities from 1,700 grams to 2,800 grams per two 18-month reactor cycles of production at TVA by 2027. This increased production requirement necessitated the use of two reactors. WBN1 has been in tritium production since 2003 and is one cycle away from achieving the maximum licensed TPBAR irradiation rate of up to 1,792 TPBARs per 18-month reactor cycle.

Irradiating 1,792 TPBARs in each of two reactors has a 98 percent confidence level of producing 2,800 grams per the 18-month cycle. Planned reactor production can be adjusted once full operations have been demonstrated. A license amendment request for tritium production in WBN2 was approved in May 2019 by the Nuclear Regulatory Commission.

Tritium Processing at SRS

After being irradiated, TPBARs are transported to the Tritium Extraction Facility at SRS, where tritium is extracted by heating the rods. The processes to produce and extract tritium use unique and specialized equipment. For tritium that is recycled, the GTSs are unloaded of their contents and the tritium and helium-3 are recovered and recycled as part of the process of maintaining tritium inventories.

Functions necessary to sustain this inventory include processing, storing, purifying, separating hydrogen isotopes, waste gas processing, and producing tritium. Associated functions include loading and unloading GTS reservoirs, shipping and receiving bulk tritium shipping containers, disposing of helium-3, and supporting functions that maintain capabilities. Much of this work is currently housed in the H-Area Old Manufacturing facility. 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 meet program deliverables. A plan to maintain and recapitalize the facilities to meet processing requirements and other delivery schedules is currently in development. The plan focuses on both the need to maintain the facilities themselves and the need to ensure the supply chain, which includes unique vendors and tritium R&D capabilities, is maintained.

This includes maintaining the supply chain from Pacific Northwest National Laboratory's tritium R&D capabilities, to the TVA reactors, to SRS's extraction capabilities and capacities.

There are eight FY 2019–2020 goals and milestones:

- Fabricate and deliver 1,792 TPBARs for WBN1's Cycle 17
- Complete irradiation of 1,584 TPBARs for WBN1's Cycle 16
- Fabricate and deliver approximately 1,000 TPBARs for WBN2's Cycle 4
- Complete three shipments to SRS's Tritium Extraction Facility
- Complete one waste shipment of TPBAR baseplates
- Complete post-irradiation of TPBARs at the Pacific Northwest National Laboratory
- Extract 1,200 TPBARs at the Tritium Extraction Facility
- Begin the CD-1 (Approve Alternative Selection and Cost Range) process for the Tritium Finishing Facility

2.4.6.3 Challenges and Strategies

Table 2–18 provides a high-level summary of Tritium Program challenges and the strategies to address them.

Table 2–18. Summary of Tritium Program challenges and strategies

Challenges	*Strategies*
Tritium processing and extraction capabilities need to be maintained/sustained while meeting mission deliverables.	Develop a comprehensive recapitalization plan to maintain capabilities while ensuring the continuity of tritium processing and extraction operations, such as the isotope separation column and storage bed replacement.
Availability of unique equipment and qualified vendors to deal with low molecular weight materials, such as hydrogen isotopes.	Work to strengthen the commercial supply chains and manage the associated risks, assess procurement processes to aid in retaining the tritium supplier base, and develop the ability to refurbish and replace unique equipment.
Retention and development of specialized staff.	Work to establish pathways with local educational institutions for training and hiring personnel while exploring and developing new strategies for training and retaining experienced staff.
The gas transfer system loading systems require recapitalization to provide the anticipated loading capacities and accommodate the expanded demand generated by the 2018 *Nuclear Posture Review*. The strategy includes complex system designs and concurrent production of multiple weapon systems.	Implement modifications to the loading process equipment in multiple SRS facilities by FY 2020 to support the mission and avert this issue.
DOE/NNSA plans to produce 2,800 grams of tritium per cycle at TVA reactors by 2027. The overall program is considered to pose moderate risk related to suppliers.	Work to maximize tritium production as tritium-producing burnable absorber rod production increases. Monitor programmatic risk to ensure the supply chains are sustainable.
The Watts Bar Nuclear Plant Units 1 and 2 licenses will be at the 60- and 40-year renewal points, respectively, in 2055.	Monitor the nuclear energy industry to determine whether the commercial light water reactor program is still a feasible alternative past 2055. Studies over the next several years will monitor emerging technologies to determine whether better alternatives for tritium production are feasible, particularly post 2055. While there are a range of options, strategies will depend on where the commercial nuclear industry stands at that time. Many factors will be monitored as decision points are approached.

2.4.7 Lithium

DOE/NNSA uses lithium to manufacture nuclear weapon components and supplies lithium to the Department of Homeland Security, the DOE Office of Science, and others.

2.4.7.1 Accomplishments

- Met Defense Programs deliverables for lithium material supply
- Completed installation and qualification of the Small Scale Wet Chemistry Facility
- Advanced the technology readiness levels of future lithium process technologies

2.4.7.2 Status

DOE/NNSA created the 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

(1) sustaining the current Manhattan Project-era infrastructure and equipment until transition to the Lithium Processing Facility, (2) increasing the usable supply of lithium by dismantling and recycling lithium components using small-scale technologies to purify and convert lithium, and (3) designing and constructing the Lithium Processing Facility to house lithium processing capabilities by 2030.

DOE/NNSA has also updated the Lithium Strategy Document and developed the Lithium Technology Maturation Plan. DOE/NNSA is maturing technologies for insertion into the Lithium Processing Facility that will make lithium purification and processing safer and more efficient. DOE/NNSA is preparing for CD-1 (Approve Alternative Selection and Cost Range) for the Lithium Processing Facility in 2019. CD-4 (Approve Start of Operations or Project Completion) is scheduled for 2027.

FY 2019 – FY 2020 goals and milestones include:

- Approve CD-1 and begin detailed design work for the Lithium Processing Facility
- Complete installation and qualification of Small Scale Wet Chemistry
- Install and qualify legacy processing capability restart projects
- Continue advancement of the technology readiness levels for process technologies in support of insertion into the Lithium Processing Facility

2.4.7.3 Challenges and Strategies

Table 2–19 provides a high-level summary of Lithium Program challenges and the strategies to address them.

Table 2–19. Summary of Lithium Program challenges and strategies

Challenges	Strategies
The United States no longer maintains full lithium purification capabilities and relies on recycling as its primary source of lithium for weapon systems. At 75 years old, the current lithium facility at Y-12 is one of the oldest operating facilities in the nuclear security enterprise. Until the new Lithium Processing Facility is operational, much of the risk to lithium sustainment is associated with the age and degradation of the existing facility.	Continue using the legacy lithium facility and equipment to meet near-term stockpile needs while implementing a lithium strategy and establishing the Lithium Processing Facility to address long-term capability requirements. Identified inventories that can serve as a source for recycled lithium for future LEP use. Began re-establishing a small purification capability and restarting some legacy processing capabilities to supplement recycling activities. Develop and mature new purification and process technologies to make current and future processes more efficient. Restart the support equipment to convert some weapons quality raw materials into weapons materials. Develop and mature lithium process technologies to introduce efficiencies into the current process and prepare for insertion of these new technologies into the Lithium Processing Facility.
The lithium strategy also depends on the ability of Weapons Dismantlement and Disposition to dismantle weapons systems to provide the lithium materials needed for LEPs.	Restart a small purification capability and legacy processing capabilities in the legacy lithium facility to provide additional feedstock material. Deploy a new material recycle cleaning station to provide additional capacity. Authorized a specification change by the design laboratories that increases the available inventory of material suitable for recycle for weapons production.

2.4.8 Energetic Materials

A safe, secure, and effective nuclear deterrent requires energetic materials such as HE, pyrotechnics, and propellants. DOE/NNSA ensures nuclear weapon sustainment and modernization program requirements for these critical materials are met through investment in development and production capabilities, safe and secure facilities, effective logistics, and a reliable supplier base. DOE/NNSA's energetic materials and associated components are highly specialized and must meet rigorous quality and performance requirements.

Energetic materials are an enduring requirement for each weapon system in the stockpile. The existing stockpile, planned LEPs and major Alts, LLC exchanges, and future modernization programs will continue to have a heavy demand for energetics. Due to the integrated nature of HE and energetic materials with the specific components and systems, development and production funding is typically tied directly to the component and system. The nuclear security enterprise must maintain reliable production; science, technology, and engineering (ST&E) capabilities; integrated infrastructure; and the necessary logistics (handling, storage, and delivery) for raw materials and final War Reserve products.

Energetic materials are used in many aspects of nuclear weapons and are integral to the design and performance of components. Changes to these components can induce changes to the performance requirements of the energetic material.

DOE/NNSA organizes its energetic materials efforts to meet weapon delivery schedules and address challenges through implementation of the DOE/NNSA Defense Programs Strategic Plan for Energetic Materials. The energetic materials mission covers three main efforts:

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

DOE/NNSA mission priorities ensure that energetic materials and products are available to meet production base and capability objectives and other commitments in the 2017 *National Security Strategy of the United States of America* and the 2018 *Nuclear Posture Review*:

- Meet full rate weapon production, component production, surveillance, and assessment requirements
- Develop viable solutions to meet the needs of current and future modernization efforts
- Research novel and existing energetics and to ensure the stockpile mission's success
- Continue modernization of design agency ST&E, adding capacity for growing programs and further enabling both design agency and production agency efficiency and throughput
- Foster and enhance relationships with commercial entities and vendors, and develop long-term strategic partnerships that ensure the sustainability of the DOE/NNSA complex's production
- Promote novel R&D to gather unprecedented data to validate predictive models for annual assessments and certification and implement artificial intelligence strategies to parse data

2.4.8.1 Accomplishments

- Coordinated with DoD for use of the DX (highest national priority) rating through the Defense Priorities and Allocations System for procurements pertaining to the authorized DoD DX-rated systems
- Completed 100 percent design of the High Explosive Science and Engineering facility at Pantex
- Completed Critical Decision 0 (CD-0; Approve Mission Need) for the High Explosive Synthesis, Formulation, and Production Facility at Pantex
- Began planning for other HE infrastructure investments, including Energetic Materials Characterization CD-0 and start of an AoA in FY 2019
- Began activities to establish the SNL Internal Production for Explosive Components capability starting in FY 2019
- Completed complex-wide site visits for the Government Accountability Office audit on the management of HE capabilities started in FY 2018, with the final report anticipated in late FY 2019
- Qualified War Reserve conventional high explosive (CHE) in the High Explosive Pressing Facility
- Produced the first lot of a plastic-bonded explosive, with newly produced and legacy raw materials to meet performance specifications from the Holston Army Ammunition Plant since 2005
- Re-established synthesis formulation of key insensitive high explosive (IHE) material components to be used in future LEPs
- Re-established the synthesis of War Reserve materials at Pantex for SNL neutron generator production
- Produced kilogram-quantities of IHE, with a novel process, demonstrating the ability to manufacture life-of-program quantities for the future systems
- Reconstituted DOE/NNSA's capability to make detonator materials, applying advanced data analytics and synchrotron x-ray data from the Advanced Photon Source to identify performance changes with age and develop lifetime models for detonators

2.4.8.2 Status

In May 2018, Defense Programs designated the Director, Stockpile Services Division, within the Office of Nuclear Weapons Stockpile, as the Defense Programs Enterprise Manager for Energetic Materials. This led to the Defense Programs Strategic Plan for Energetic Materials in December 2018 and the establishment of the DOE/NNSA Energetics Coordinating Committee. Specific targets to enhance the goals and objectives of the Defense Programs energetics enterprise are outlined in the DOE/NNSA Strategic Plan for Energetic Materials.

2.4.8.3 Challenges and Strategies

Table 2–20 provides a high-level summary of Energetic Materials challenges and the strategies to address them.

Table 2–20. Summary of Energetic Materials challenges and strategies

Challenges	*Strategies*
Demand for energetic material	Exercise initiatives within the Defense Programs Strategic Plan for Energetic Materials and maintain a strong R&D capability within the national laboratories.
Supplier base	Exercise suppliers to maintain proficiency on a more frequent schedule between procurements and continue technical exchanges.
Material requirements	Document the detailed processes and specifications necessary to ensure energetic materials meet performance requirements.
Inventory consumption and replenishment	Institute a more routine process to continuously exercise synthesis and formulation of energetic materials.
Infrastructure and equipment	Coordination with Infrastructure and Operations and the Programmatic Recapitalization Working Group to improve energetic readiness.
Governance of energetics supply	Affirm the role of the Enterprise Manager for Energetic Materials as designated by DOE/NNSA leadership with both internal Defense Programs offices and external partners.

2.4.9 Material Recycle and Recovery and Storage

The MRR and Storage programs coordinate material process flows and the recovery of material from dismantlement and disposition activities.

With materials recycled from assembly operations, LLCs, weapons dismantlement, and other production operations, the MRR program provides vital quantities of strategic materials feedstock by purifying the materials (e.g., plutonium, uranium, and tritium) and recovering the intrinsic value of each (usable quantities of the material without impurities) to sustain the Nation's nuclear deterrent. The MRR program processes and dispositions by-products from purification and recovery activities to ensure the supply chains are maintained in a healthy state and strategic material value is optimally recovered. The MRR program is also responsible for re-establishing a depleted uranium feedstock capability to support Defense Programs' enduring requirements.

The Storage program manages materials storage and staging by sustaining capability health, managing inventory logistics for nuclear and non-nuclear materials, conducting component and container surveillance activities for pits, and storing dismantled warhead components and materials. The Storage program is also responsible for leveraging capabilities across the enterprise to provide a more responsive storage and staging capability base. These capabilities fully support programmatic and 2018 *Nuclear Posture Review* requirements, and include developing comprehensive system/material health assessments to ensure a strong supply chain.

2.4.9.1 Accomplishments

- Initiated efforts to re-establish the capability to convert DUF_6 to DUF_4 through capability improvements at the Portsmouth site, including beginning design and developing the cost and schedule of the potential conversion line (see Section 2.4.4, Depleted Uranium, for more detail)
- Began establishing an interface mechanism between PPPO and the Phase 2 (DUF_4 to metal) conversion capability (see Section 2.4.4, Depleted Uranium, for more detail)
- Continued meeting MRR program production and planning goals for recovery and recycle of tritium from returned reservoirs and began execution of a recapitalization plan to support the SRS tritium enterprise

- Met first trimester goals ahead of schedule for the production of enriched uranium (purified metal and metal supply for casting) and reduced material-at-risk from briquettes at Y-12
- Continued reducing operational risk in PF-4 through material-at-risk reduction and transuranic waste management and material disposition in support of exiting CMR at LANL
- Executed Pantex surveillance activities per the baseline plan
- Developed and began implementing storage/supply chain comprehensive health metrics at Y-12 and LANL
- Continued Confinement Vessel Disposition Project cleanout activities for vessel nine
- Continued working on CMR exit strategy documentation regarding material disposition
- Began an initial risk-ranked listing of at-risk materials

2.4.9.2 Status

DOE/NNSA's MRR program oversees these activities:

- De-inventorying LANL's CMR and PF-4 vault facilities to reduce material-at-risk, as well as continuing processing of by-products and disposing of transuranic wastes
- Recovering and recycling plutonium at LANL to support mission needs
- Re-establishing the capability to deliver high-purity depleted uranium feedstock and strengthening the interface with DoD to better sustain this commodity
- Recovering and recycling enriched uranium to provide feedstock (e.g., purified enriched uranium metal, characterized metal supply for casting) and dispositioning low-equity by-products at Y-12
- Recovering, recycling, and purifying tritium after LLC unloading/extractions to enable loading the gas into GTSs at SRS
- Recovering helium-3 by-product from tritium purification for other national security needs in collaboration with the DOE Office of Science

DOE/NNSA's Storage program oversees these activities:

- Sustaining storage capability and storage health for enriched uranium, depleted uranium, and lithium at Y-12
- Optimizing the PF-4 vault at LANL following de-inventory efforts, as well as standardizing containers (the new SAVY 5-quart-size canister) to extend design life and reduce operational risk
- Increasing the responsiveness of staging capabilities across the nuclear security enterprise by optimizing storage and staging capacity at the Nevada National Security Site
- Increasing storage capacity and performing surveillance of pits and containers at Pantex
- Supporting the capability to comply with DOE Order 410.2, *Management of Nuclear Materials*
- Using the interface between the site storage programs to optimize efficiency and continuous improvement

FY 2020 goals and milestones include:

- Complete CMR de-inventory at LANL to support the CMR exit strategy
- Continue efforts to re-establish a high-purity depleted uranium feedstock supply capability, including beginning component procurement and potential installation at PPPO and leveraging efforts with DoD to sustain Phase 2 vendor production capabilities
- Meet stockpile needs for recycle and recovery of tritium and enriched uranium
- Continue reducing risk in PF-4 through material-at-risk reduction and transuranic waste management at LANL to support the plutonium sustainment mission
- Execute the Pantex surveillance mission and continue conversion of additional bays for staging
- Develop a comprehensive macro supply chain health assessment for enriched uranium and plutonium

2.4.9.3 Challenges and Strategies

Table 2–21 provides a high-level summary of MRR and Storage program challenges and the strategies to address them.

Table 2–21. Summary of Material Recycle and Recovery and Storage program challenges and strategies

Challenges	*Strategies*
Storage/staging capacity is a constraint across the nuclear security enterprise.	Provide responsive storage/staging capabilities across the nuclear security enterprise (e.g., LANL, Y-12, Pantex, Nevada National Security Site): – Work off inventory and optimize the footprint in the PF-4 vault to support pit production at LANL. – Complete the capability responsiveness project at the Nevada National Security Site to support pit production surge capacity or other high-value DOE/NNSA priorities. – Complete rack reconfiguration project at the Highly Enriched Uranium Materials Facility to increase capability responsiveness at Y-12. – Implement comprehensive system health assessments for storage and staging capabilities across all storage sites. Continue repurposing and reconfiguring nuclear material bays to stage plutonium pits to provide short-term capacity improvements until a long-term staging facility is available. Manage transuranic waste at LANL per the laboratory's strategic plan until the Waste Isolation Pilot Plant is fully operational.
Recapitalization efforts are needed to sustain processing and storage capabilities.	Implement recapitalization plans to sustain processing and storage facilities, including hydride storage for tritium operations at SRS, and reduce dependence on Building 9212 at Y-12. The Nevada National Security Site currently has a project underway to increase the responsiveness of staging capabilities in support of nuclear security enterprise priorities.
The staging capacity at Pantex is projected to become more constrained within the next decade as more weapons are dismantled, creating additional operational inefficiencies involving required movements of these items.	Increase pit staging capacity through additional capacity projects to optimize footprints until the Material Staging Facility is operational.

2.5 Modernizing the Stockpile

DOE/NNSA supports the 2018 *Nuclear Posture* Review and is aligned with the Nuclear Weapons Council's Strategic Plan for Fiscal Years 2019-2044. DOE/NNSA is modernizing the stockpile through a planned program of life extensions, Mods, and Alts that are supported by a robust set of ST&E activities. DOE/NNSA's program of record supports the 2018 *Nuclear Posture Review* with the additions of the low-yield ballistic missile (W76-2), extension of the B83 retirement date, and a study of a sea-launched cruise missile to ensure a viable U.S. nuclear weapon deterrent to address 21st century threats. This program of record is illustrated in **Figure 2–2**.[1] The Navy will explore the feasibility of fielding the W87-1 on a Navy delivery platform. This long-term vision of the stockpile seeks to build flexibility for the Nation to enable rapid response to unforeseen contingencies while incorporating features and technologies that enhance safety and security, as appropriate and practicable. The schedule shown in Figure 2–2 is subject to change upon completion of the FY 2020-2045 Requirements and Planning Document.

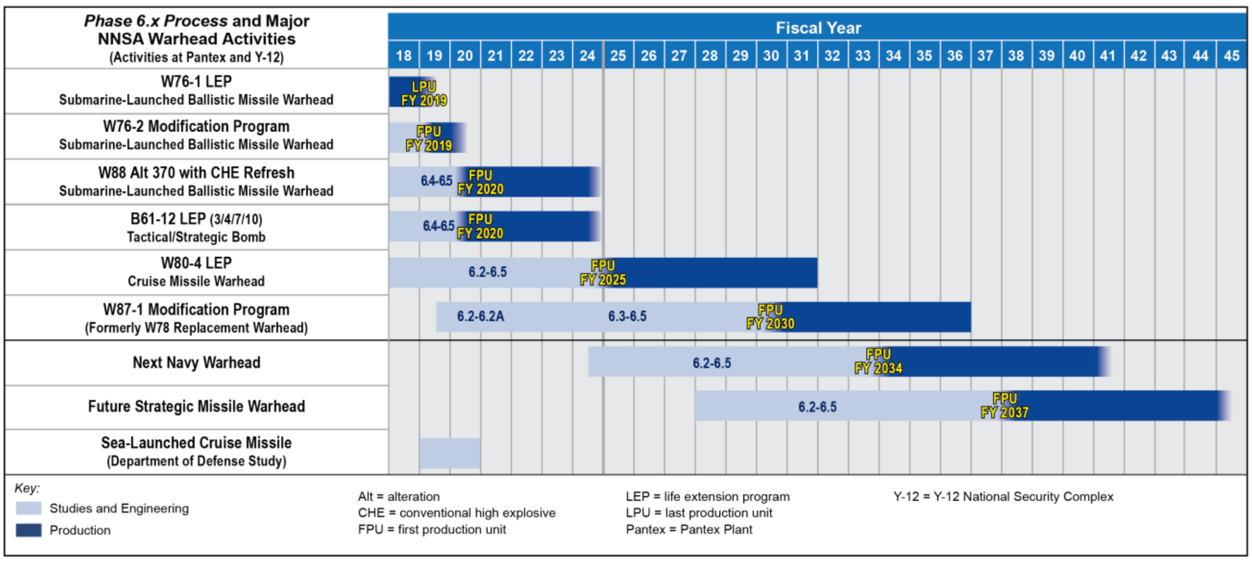


Figure 2–2. NNSA warhead activities[2]

2.5.1 The Strategy

NNSA's warhead modernization strategy envisions a modern, flexible, and resilient future stockpile by pursuing modest supplements to the stockpile to deter adversaries from limited nuclear employment, assure allies, and provide options to meet U.S. objectives should deterrence fail. With this strategy, NNSA will consider flexibility-enabling design strategies and features that promote future system modernizations to be accomplished at lower costs and with greater speed. The Nation will be postured to respond to the adversaries' capabilities, stockpile aging, and shortfalls in U.S. hedge capabilities.

[1] The Next Navy Warhead, Future Strategic Missile Warhead, and Sea-Launched Cruise Missile programs are still notional, require further coordination between DoD and NNSA, and are not established programs of record.

[2] This schedule is under revision, see Sections 2.5.3 (W88 Alt 370) and 2.5.4 (B61-12 LEP).

2.5.2 W76-2 Modification Program

DOE/NNSA is supporting the low-yield ballistic missile from the 2018 *Nuclear Posture Review* through the W76-2 Modification Program. DOE/NNSA has received authorization through the Nuclear Weapons Council to proceed forward to the engineering development phase (and any subsequent phase) to modify or develop a low-yield nuclear warhead for submarine-launched ballistic missiles. DOE/NNSA also received congressional authorization through the *John S. McCain National Defense Authorization Act for FY 2019* (P.L. 115-232) and an appropriation through the *Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019* (P.L. 115-244).

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

2.5.2.1 Accomplishments

- Completed production of the W76-2's first production unit in February 2019

2.5.2.2 Status

DOE/NNSA's laboratories and plants performed program planning activities related to scope, schedule, cost, and risk elements similar to activities typically accomplished during Phases 6.1 and 6.2/2A. These activities were completed in preparation for receipt of Nuclear Weapons Council authorization to proceed to the engineering development phase and subsequent phases. The DOE/NNSA laboratories and plants executed a compressed Phase 6.3 through 6.5 process and achieved the warhead first production unit in February 2019.

2.5.2.3 Challenges and Strategies

Table 2–22 provides a high-level summary of W76-2 Modification Program challenges and the strategies to address them.

Table 2–22. Summary of W76-2 Modification Program challenges and strategies

Challenges	*Strategies*
New hazard analysis information requires modification to weapon response information that necessitate timely response.	Identify, analyze, and disposition new hazard analysis information.
The logistics of the large volume of program documents required for release pose constraints on organizational resources that are not staffed to handle the increased volume.	Prioritize and plan the release of documents to avoid overwhelming the document release system.

Weapon response information is developed by the DOE/NNSA laboratories to determine the response of the weapon during assembly and disassembly operations based on hazard scenarios identified by Pantex. Given the scope of the W76-2 Modification Program, the project team is relying on existing weapon response information from the W76-1 warhead to bound and characterize the weapon response information related to the W76-2 warhead. To mitigate the risk of extended pauses to nuclear explosive operations, the team is identifying and analyzing potential impacts to the operation to ensure production activities are conducted safely. The volume of program documents (i.e., requirements documents, engineering drawings, product specifications, etc.) required for program execution is vast and requires a planned strategy to ensure the document release system is not overwhelmed. Document release must be properly timed to ensure approval and availability for implementation prior to the start of program gate reviews, design reviews, and follow-on production to the warhead first production unit.

2.5.3 W88 Alteration 370 Program

The W88 Alt 370 Program includes a new AF&F assembly and a CHE refresh to replace the main HE charges, a new lightning arrestor connector, trainers, flight test assemblies, and associated handling gear to maintain the W88 warhead in the existing nuclear weapons stockpile. The late addition of the CHE refresh required acceleration and compression of the design and development activities in the late stages of Phase 6.3. This action was required to align with the original W88 Alt 370 Program scope by Phase 6.4 (Production Engineering). The W88 Alt 370 conversion is scheduled concurrently with the LLC exchanges of the GTSs and neutron generators.

2.5.3.1 Accomplishments

- Completed Commander Evaluation Test (CET-1) qualification flight test (June 2018)
- Completed AF&F Final Design Review (December 2017)
- Completed System Final Design Review (January 2018)
- Fabricated process prove-in pre-production functional hardware at the component, subsystem, and AF&F level for final qualification and validation
- Delivered trainer kits
- Completed LANL 3675 and 3676 hydrodynamic tests
- Completed on-time first production unit of nuclear major components: Penguin (October 2017), long tube subassembly (April 2018), taper tapes (April 2018), aft retainer ring (April 2018), and locator (August 2018)
- Completed on-time first production unit of non-nuclear major components: magnetically coupled stronglink (June 2018), launch accelerometer (June 2018), and electrical contact stronglink (July 2018)
- Wrote Joint Configuration Management Plan with B61-12
- Conducted seven annual site assessments and closed the corrective actions
- SNL, KCNSC, and multiple DOE/NNSA organizations piloted Earned Value Management reporting in a joint effort with the Navy
- Delivered all hardware units for the Demonstration and Shakedown Operation (DASO) 29 flight tests

2.5.3.2 Status

The W88 Alt 370 Program is now in Phase 6.4. The follow-on CET-1, DASO flight tests, and critical system-level and AF&F tests will be completed in FY 2019. The System Final Design Review was completed in the second quarter of FY 2018; all components are in the final stages of production evaluation and qualification and 12/33 non-nuclear and nuclear components. Pantex will be authorized for nuclear explosive operations by the fourth quarter of FY 2019.

DOE/NNSA completed a high-fidelity cost estimate (the Baseline Cost Report) in FY 2017. The report estimate is $2.6 billion, which is approximately $255 million (or 11 percent) higher than the estimate in the FY 2015 Selected Acquisition Report. The increased costs primarily resulted from increased testing and qualification plus planning margins for treating technical risks, accompanied by some offsetting reduction in the scope associated with the nuclear components. This estimate represents the program baseline and is reflected in the FY 2017 Selected Acquisition Report.

At the time of publication, there is an unresolved technical issue related to the qualification of electrical components used in non-nuclear assemblies which is expected to delay the first production unit date for the W88 Alt 370. DOE/NNSA is pursuing additional testing and screening to determine the path forward for continued use of the affected components and the impacts the production schedule are still being assessed. DOE/NNSA is working to minimize any delays and is closely coordinating with the Navy.

2.5.3.3 Challenges and Strategies

Table 2–23 provides a high-level summary of W88 Alt 370 Program challenges and the strategies to address them.

Table 2–23. Summary of W88 Alt 370 Program challenges and strategies

Challenges	*Strategies*
The W88 Alt 370 Program faces a continued risk of late component design changes in Phase 6.4 Production engineering. As the program is an integrated effort with shared technology between the Air Force and Navy, changes and/or delays to one program may directly impact the progress of another.	DOE/NNSA closely aligns efforts on the W88 Alt 370 Program with those of its DoD partners to manage design changes and minimize production impacts. This close collaboration ensures scope, schedule, and cost decisions are aligned with strategic-level priorities.

2.5.4 B61-12 Life Extension Program

The B61 gravity bomb is the oldest nuclear weapon in the stockpile. 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 both nuclear and non-nuclear components and incorporates component reuse where possible. With the addition of an Air Force-procured tail-kit assembly, the B61-12 LEP will consolidate and replace the B61-3, -4, -7, and -10 bomb variants, which will reduce the overall number of gravity bombs.

2.5.4.1 Accomplishments

- Successfully completed the first high-fidelity system flight test utilizing HE with a mock pit to assess with the Air Force F-15 in March 2018
- Conducted the fifth System Hydrodynamic Test Shot E in March 2018
- Successfully completed the first B-2A (System 2) qualification drop in June 2018
- Completed all component Final Design Reviews
- Completed the System-Level Final Design Review in September 2018
- Delivered trainer hardware to support a first Type 5B first production unit at Pantex
- Completed on-time first production units of nuclear major components: detonator preload assembly (January 2018), Lucas (May 2018), and pressure pads (August 2018)
- Completed on-time first production unit of non-nuclear major components: intent stronglink (July 2018), trajectory stronglink (July 2018), rolamite (July 2018), lightning arrestor connector (July 2018), and switch (July 2018)

2.5.4.2 Status

The Program continues in Phase 6.4, which is the final development phase prior to production of War Reserve units. The B61-12 LEP has completed Final Design Reviews of major components to allow the DOE/NNSA nuclear weapons production facilities to begin final process prove-in of the production processes. Qualification of component production processes, including certified tooling and testers, is scheduled to continue in FY 2019. This qualification will enable the nuclear weapons production facilities to begin shipment of first production units for components to Pantex in FY 2019. System qualification of the B61-12 continues on schedule with the completion of over 45 system tests since the start of Phase 6.4, including 11 qualification flight test releases using B-2, F-15, and F-16 aircraft at the Tonopah Test Range. Certification activities that ensure the weapon meets DoD requirements, including joint qualification testing, will continue as the program moves into Phase 6.5.

The B61-12 LEP is proceeding within the cost documented in the October 2016 Baseline Cost Report, which estimated the program costs at $7.605 billion (then-year dollars). The B61-12 LEP is continuing to leverage other DOE/NNSA programs for multi-system production process improvements. The costs of these related programs are estimated to be $648 million. The overall program cost is $8.253 billion, which is within 1.1 percent of the initial baseline Selected Acquisition Report that was provided to Congress in FY 2013.

Similar to the W88 Alt 370, the B61-12 LEP is experiencing an unresolved technical issue related to the qualification of electrical components used in non-nuclear assemblies which is expected to delay the first production unit date. Further testing is required to ascertain the impacts and whether a change in Initial Operational Capability dates are necessary. A decision on first production unit and Initial Operational Capability dates is being jointly coordinated with the Air Force.

2.5.4.3 Challenges and Strategies

Table 2–24 provides a high-level summary of B61-12 LEP challenges and the strategies to address them.

Table 2–24. Summary of B61-12 Life Extension Program challenges and strategies

Challenges	*Strategies*
B61-12 LEP single point failures associated with critical manufacturing processes and capabilities.	The B61-12 LEP maintains a rigorous risk management program as part of the Risk and Opportunities Management Plan to identify critical equipment and process single point failures that could impact production. The Federal program office works closely with the impacted production site(s) to assure the identified production risks have strong mitigation strategies and assure implementation proceeds as planned. As appropriate, the Federal program office deploys B61-12 contingency funds and/or works with other DOE/NNSA organizations to fund equipment mitigation and documents the resulting agreements in B61-12 Interface Requirements Agreements.
Improving component manufacturability, minimizing design changes, and assuring components' schedules maintain appropriate lead-time to Pantex.	The B61-12 LEP deployed new change control and configuration management tools in FY 2018 to tighten design change requests, establish new approval thresholds, and require more comprehensive impact assessments to assure that design changes, if implemented, are necessary and do not impact production schedules. The Federal program office improved tracking and monitoring of component producibility issues and jointly approved recovery plans to assure component first production units continue to support the system first production unit at Pantex.
Coordination of B61-12 and Air Force systems integration schedules	The B61-12 LEP works closely with the Air Force Nuclear Weapons Center to update and maintain the Joint Integrated Master Schedule, documenting handoffs and commitments among DOE/NNSA, the tail-kit Assembly, and Aircraft program offices. The B61-12 LEP Federal program office is an executive member in the B61-12 Project Officers Group and participates in the Project Officers Group subgroups that are responsible for All-Up-Round integration, shipment, aircraft nuclear certification activities, and fielding logistics to achieve an on-time initial operational capability at Air Force bases.

2.5.5 W80-4 Life Extension Program

The AGM-86 air-launched cruise missile is now more than 25 years past its design life and faces continuously improving adversary air defense systems. The air-launched cruise missile carries the W80-1 warhead, which is also well past its planned life span. Replacing the air-launched cruise missile is the mission of the Long Range Standoff (LRSO) cruise missile program; extending the life span of the W80-1 is the objective of the W80-4 LEP. These two synchronized programs will ensure the bomber force's capability to deliver stand-off weapons that can penetrate and survive advanced integrated air defense systems.

2.5.5.1 Accomplishments

- Conducted Component Feasibility and Cost Gates for all active Product Realization Teams
- Conducted Component Requirements Reviews for active Product Realization Teams, with a few exceptions, including those Product Realization Teams related to the JTA
- Delivered Fit Check Units (FCU-1) to the Air Force to verify the mechanical interface between the W80-4 warhead and LRSO cruise missile
- Conducted Technology Maturation and Risk Reduction Phase Kickoff meetings with LRSO cruise missile program contractors
- Conducted various technical integration meetings with cruise missile program contractors to ensure technical alignment of the W80-4 warhead and LRSO cruise missile
- Developed and updated the Missile to Warhead-Interface Control Document, stockpile-to-target sequence, and military characteristics with the W80-4 Project Officers Group
- Entered Phase 6.3, Development Engineering, in February 2019
- Conducted the System Cost Gate
- Developed W80-4 Weapon Design and Cost Report and completed reconciliation with the NNSA Office of Cost Estimating and Program Evaluation
- Developed the W80-4 Major Impact Report

2.5.5.2 Status

The W80-4 LEP entered Phase 6.3 (Development Engineering) in FY 2019, where the design will continue to be refined. DOE/NNSA will continue working closely with DoD. The primary Phase 6.3 deliverables are the baseline design, which will advance production engineering processes; the preliminary Design Review and Acceptance Group Review, which will indicate DoD acceptance of the baseline design and its associated plan for certification; generation of the Baseline Cost Report; and Nuclear Weapons Council approval of the military characteristics and stockpile-to-target sequence. The program completed Phase 6.2A activities, completing development of the Weapon Design and Cost Report and its reconciliation with the Office of Cost Estimating and Program Evaluation's Independent Cost Estimate, the NNSA Program Plan, the Joint Integrated Project Plan, the Phase 6.2A Report, and the System Cost Gate Review.

The W80-4 LEP Federal program office, coordinating with the M&O partners, standardized Earned Value Management System practices and schedules across the sites by implementing a state-of-the-art Empower software tool to expedite Earned Value Management System data analysis.

The W80-4 LEP Federal program office compared cost and uncertainty risk analysis data compiled by the M&O sites with similar data from the B61-12 LEP and W88 Alt 370, validating its program cost and schedule projections.

The W80-4 LEP experienced a loss of $120 million in productivity due to delays associated with Continuing Resolutions from FY 2016-2018. As a result, ramp-up of M&O partner programs were constrained for 3 years across the entire nuclear security enterprise, preventing the program from reaching the required staffing levels and delaying the Federal program office's completion of Phases 6.2 and 6.2A by 4 months.

FY 2020 planned activities include:

- Complete all Component Conceptual Design Reviews
- Complete ETU-1 deliveries to the Air Force
- Begin Separation Control Test Vehicle warhead deliveries to the Air Force
- Transition to the baseline design stage after completion of Component Conceptual Design Reviews
- Continue releasing Development Engineering Releases and producing Component Developmental Build Lots to progress designs toward Component Baseline Design Reviews in FY 2021

2.5.5.3 Challenges and Strategies

Table 2–25 provides a high-level summary of W80-4 LEP challenges and the strategies to address them.

Table 2–25. Summary of W80-4 Life Extension Program challenges and strategies

Challenges	*Strategies*
The program faces the challenge of a parallel design with the Air Force Long Range Standoff cruise missile. This is the first effort in more than 30 years to design a warhead and delivery platform on similar timeframes under significantly different security constructs.	DOE/NNSA closely aligns W80-4 LEP efforts with those of DoD to refine program goals and define the interface scope in detail. This collaboration ensures coordinated cost-informed decisions and interdepartmental schedule alignment. Component product realization teams have completed Component Scope and Requirements Exchanges between national security laboratories and nuclear weapons production sites. This early involvement increases the effectiveness of the product realization process.
The scope of the W80-4 LEP and joint work with the Air Force present some cross-organizational risks, especially with respect to schedule and requirements validation.	DOE/NNSA is constantly working to identify and implement opportunities to reduce schedule uncertainty and risk; modify, reduce, or eliminate requirements that do not impact safety, security, or the military effectiveness of the warhead; and develop processes for increased communication and efficiency between design and production activities.
Previous LEPs have used up existing supplies of certain materials. This program must reconstitute qualified material production streams and production capabilities.	DOE/NNSA will work with design agencies and production facilities to re-establish capabilities, modify specifications, and in some cases find suitable alternative material.

2.5.6 W87-1 Modification Program (Formerly W78 Replacement Warhead)

After fielding of the B61-12, the W78 warhead will be the oldest warhead in the stockpile. DOE/NNSA's mission is to sustain the nuclear stockpile and, where possible, improve the safety and security of the Nation's nuclear weapons throughout their complete life cycles. Critical components within the W78 are aging, and the military requirements for the safety and security features of W78 warhead have changed since entering the stockpile in 1979. DOE/NNSA will replace the W78 with the W87-1 to meet DoD and DOE/NNSA requirements for performance, safety, and security and field it on the Ground-Based Strategic Deterrent by 2030, as specified in the 2018 *Nuclear Posture Review*.

2.5.6.1 Accomplishments

- Restarted Phase 6.2 (Feasibility Study and Down Select) Activities
- Released the W87-1 NNSA Program Plan
- Coordinated a joint MK21A/W87-1 Integrated Master Schedule with DoD
- Established key Product Realization Teams and Integrated Product Teams
- Published program documents, including a Systems Engineering Plan, Requirements Management Plan, Risk and Opportunity Management Plan, Integrated Product Teams Implementation Plan, and Program Control Plans
- Established an initial Work Breakdown Structure via functional decomposition
- Established technology maturation transition plans with supporting Defense Programs organizations, as appropriate
- Developed program needs and coordinated with the DOE/NNSA *Nuclear Posture Review* implementation task on a production and capabilities roadmap
- Completed the feasibility study of the conceptual W87-1 nuclear explosive package in the Navy Mk5 aeroshell
- Documented the W87-1 design architecture

2.5.6.2 Status

The Nuclear Weapons Council has authorized restart of Phase 6.2 activities, and the program is on track to support fielding on the Ground-Based Strategic Deterrent by 2030. DOE/NNSA has developed program plans and management documents and is developing W87-1 design options for feasibility analyses. The program is also supporting a feasibility study of the W87-1 nuclear explosive package in a Navy flight vehicle, as specified in the 2018 *Nuclear Posture Review*.

FY 2020 planned activities include:

- Complete the Customer Requirements Review
- Continue the feasibility study of design options
- Advance technology maturation
- Continue program management and control implementation
- Conduct requirements analysis
- Integrate with Air Force acquisition programs

2.5.6.3 Challenges and Strategies

Table 2–26 provides a high-level summary of W87-1 Modification Program challenges and the strategies to address them.

Table 2–26. Summary of W87-1 Modification Program challenges and strategies

Challenges	*Strategies*
Development must be integrated with Air Force aeroshell acquisition schedules and the Ground-Based Strategic Deterrent delivery platform acquisition program.	DOE/NNSA is a member of the Air Force Project Officers Group and maintains regular communication with the Air Force and its related acquisitions programs though the Project Officers Group.
Production is predicated on all newly manufactured components and a nuclear material manufacturing modernization strategy that relies on large, multi-year investments in component and material capabilities.	DOE/NNSA actively supports commodity and capability programs that will provide the materials, components, and capabilities in time for the future stockpile. The W87-1 Modification Program will establish inter-program agreements with applicable commodity and capability programs to identify requirements, dependencies, risks reporting, and inter-program management strategies. To meet plutonium pit production requirements, DOE/NNSA will continue to invest in LANL production capabilities and repurpose the MFFF (now the Savannah River Plutonium Processing Facility) at SRS.
Program success is contingent on the development of new technologies to address antiquated design, material obsolescence, and performance expectations. The W87-1 Modification Program must meet stringent technical requirements, including a greater component life expectancy, reduced manufacturing cost and development time, increased safety and security, and improved maintainability.	DOE/NNSA finished a technology readiness assessment in FY 2018 and is establishing inter-program agreements with technology maturation programs to identify requirements, dependencies, risks reporting, and inter-program management strategies. DOE/NNSA is incorporating lessons learned from previous life extension and major modernization programs into W87-1 Modification Program plans, including the W87-1 Modification Program Plan, Requirements Management Plan, Risk and Opportunity Management Plan, Configuration Management Plan, System Engineering Plan, and Program Control Plans.

2.5.7 Ballistic Missile Warhead Follow-up Systems

NNSA is working with DoD to implement the 2018 *Nuclear Posture Review* through defining the appropriate ballistic missile warheads to support threats anticipated in the 2030s. This involves the Next Navy Warhead (formerly referred to as the Interoperable Warhead 2 [IW2] or BM-Y) and the Future Strategic Missile Warhead (formerly referred to as IW3 or BM-Z). These analyses cover a broad range of activities to address the aging of systems such as the W87-0 and the timing of replacement of warheads that have recently been life-extended. For example, the W76-1 had a first production unit in FY 2008 that was designed and provisioned for a 30-year deployment criterion and by default falls within concerns for these advanced planning scenarios. These considerations are being evaluated for release of a more detailed implementation strategy later in FY 2019 that will enable DOE/NNSA to determine the initial scope and leveraging opportunities for components.

2.5.7.1 Accomplishments

DOE/NNSA and DoD are still coordinating on implementation. There is nothing significant to report.

2.5.7.2 Status

The Nuclear Weapons Council has charted a series of analyses to support out-year planning and will inform future decisions on the composition of warheads in the 2030s. These analyses will include deliverables of warheads anticipated in the 2030s that will, in turn, inform the design and certification workload in the 2020s.

2.5.7.3 Challenges and Strategies

Table 2–27 provides a high-level summary of Ballistic Missile Warhead Follow-up Systems challenges and the strategies to address them.

Table 2–27. Summary of Ballistic Missile Warhead Follow-up Systems challenges and strategies

Challenges	*Strategies*
Understanding the aging of existing components/systems that assure advanced planning for replacement before adverse actions occur.	Continue support of existing surveillance operations.
Assuring capabilities are available to address changing threat environments.	Commitment to programs such as Stockpile Responsiveness to assure the nuclear security enterprise can fully support contingency operations should they be called upon.
Assuring that the resources (e.g., people and physical infrastructure, etc.) are supported in the 2020s to enable the deliverables anticipated in the 2030s.	DoD/NNSA actively supports the design, certification, and production processes.

2.5.8 Sea-Launched Cruise Missile

DoD is conducting a study over the next couple of years to develop requirements and schedules for the sea-launched cruise missile. Many options are currently under evaluation.

2.6 Weapons Dismantlement and Disposition

The Weapon Dismantlement and Disposition (WDD) Program disassembles retired weapons into their major components. Those components are then assigned for reuse, storage, surveillance, or disposal. Dismantlement of retired nuclear weapons is scheduled to provide the material and components required for the stockpile (including LEPs) and external customers to maintain the proficiency of technicians and to balance the work scope at the production plants.

WDD spans all eight sites, and dismantlement rates are affected by many factors, including logistics, legislation, weapon system complexity, and the availability of qualified personnel, equipment, and facilities. DOE/NNSA's current dismantlement plan balances these constraints while maintaining strict adherence to the National Defense Authorization Acts for FY 2017 and FY 2018. The WDD work scope includes management of retired nuclear weapon systems (e.g., managing safety issues), characterization of weapon components, disassembly of weapons and their components, and final component disposition.

2.6.1 Accomplishments

- Trained production technicians at Pantex for future LEP work including hands-on experience with programs in dismantlement
- Developed and refined secondary dismantlement schedules at Y-12 to meet the material and component reuse demands of the B61-12 and W80-4 LEPs
- Finalized a special secondary dismantlement plan for legacy CSAs staged at Y-12 that pose a unique dismantlement challenge
- Completed W76-0 harvesting requirements for unique parts that will help sustain the W76-1
- Kept the size of legacy excess components from growing and reduced storage constraints at Pantex for incoming parts used by the stockpile

- Implemented Warhead Measurement Campaign requirements to capture unique weapon radiation signatures from the B61, W76, and B83 nuclear weapons
- Implemented the weapons and secondary dismantlement schedules per requirements

2.6.2 Status

DOE/NNSA continues to make significant progress on dismantling weapons and dispositioning components. WDD is on pace to complete the goal of dismantling the large number of weapons that were retired at the end of FY 2008. WDD has not identified safety issues with nuclear weapons in the retired status, and DOE/NNSA has developed return schedules to remove retired weapons from DoD facilities while fully meeting DoD operational requirements. Finally, WDD has characterized the components coming from the dismantlement line, and sites are eliminating excess component inventories on schedule.

2.6.3 Challenges and Strategies

Table 2–28 provides a high-level summary of Weapons Dismantlement and Disposition Program challenges and the strategies to address them.

Table 2–28. Summary of Weapons Dismantlement and Disposition Program challenges and strategies

Challenges	*Strategies*
Meeting weapon dismantlement and disposition requirements within legislative restrictions (e.g., *John S. McCain National Defense Authorization Act for FY 2019* (P.L. 115-232 language).	Use process and cost models to evaluate future dismantlement excursions to inform decisions related to dismantlement plans.
Canned subassembly (CSA) dismantlement and disposition plans must provide sufficient strategic materials for upcoming LEPs, hold CSAs for reuse in other LEPs, and address the dismantlement of a special CSA type in storage at Y-12.	Work closely with all weapon program managers to balance material and component needs from dismantled CSAs against future reuse possibilities. Develop alternative CSA dismantlement plans that provide needed materials while maintaining CSAs with higher reuse potential. Finalize the dismantlement strategy for the special CSA type in storage at Y-12.
Significantly reduce site legacy inventories of weapon components.	Work closely with sites to prioritize disposition projects that leverage the capabilities of other sites.

Chapter 3
Stockpile Stewardship Science, Technology, and Engineering

> ***Major Stockpile Stewardship Program Accomplishments***
>
> - *Completed the Vega subcritical experiment, which concludes a series of experiments to assess modeling capabilities for studying the effects of substituting insensitive high explosives for conventional high explosives.*
> - *Conducted key plutonium experiments to increase understanding of the effects of aging on plutonium.*
> - *Developed an uncertainty quantification tool kit that aids in assessing and certifying stockpile nuclear weapon designs.*
> - *Selected source and detector technologies for the Neutron Diagnosed Subcritical Experiments to be used in upcoming subcritical experiments.*
> - *Accepted DOE/NNSA's new flagship High Performance Computing system, Sierra at LLNL, in September 2018.*
> - *Simulations for the Large Scale Calculations Initiative have assessed the limits of existing calculation capabilities and point the way toward future improvements.*
> - *Achieved the highest fusion yield to date at the National Ignition Facility – $2{\times}10^{16}$ neutrons or 55 kilojoules, approaching the burning plasma threshold.*

The Stockpile Stewardship Program is central to maintaining a credible deterrent and ensuring the safety, security, and effectiveness of the Nation's nuclear stockpile. With more than three-quarters of warheads in some stage of the life extension process and to ensure a responsive and resilient nuclear deterrent as described in the 2018 *Nuclear Posture Review*, the Stockpile Stewardship Program sustains and advances science, technology, and engineering (ST&E) capabilities that are essential to qualify, assess, and certify nuclear weapons. With sustained investments, the Stockpile Stewardship Program enhances understanding of nuclear weapons and their performance in unique, severe, and evolving physical phenomena they are designed to experience. The Stockpile Stewardship Program exercises the nuclear security enterprise's capabilities across the entire nuclear weapon life cycle that are critical for sustaining deterrence into the future. The program also ensures the ST&E proficiency of DOE/NNSA's workforce for the future and helps maintain the readiness of its infrastructure to support near-term and future workloads. Finally, it provides foundational ST&E capabilities that provide a hedge against prospective and unanticipated risks and prevent technological surprise.

The Stockpile Stewardship Program was established in 1994 to sustain the deterrent in the absence of nuclear explosive testing. Since then, the Stockpile Stewardship Program has advanced DOE/NNSA's understanding of nuclear weapon ST&E. 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 the present day and future nuclear stockpiles. For more than 20 years, the program has developed and deployed capabilities that have provided DOE/NNSA with important, high-fidelity data to maintain the stockpile in the absence of nuclear testing.

The sections in this chapter discuss the drivers for the Stockpile Stewardship Program into the future, the current capabilities and anticipated advances, and the strategies and approaches that frame the program in more detail. Areas of focus include: (1) sustaining the current evolving stockpile; (2) maturing new deterrence options for replacement systems to include shortened development cycles; (3) mitigating against an evolving threat environment; (4) advancing the ability to predict weapon performance in untested configurations; and (5) evaluating the effect of new materials and processes, the reuse of aging components in future systems, and enhancing production throughput. 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 the Stockpile Stewardship Program will be used to directly address items within the 2018 *Nuclear Posture Review*.

3.1 Enduring Drivers for Stockpile Stewardship Science, Technology, and Engineering

Responsible stockpile stewardship demands continuous development of a qualified workforce, as well as computational, experimental, and testing capabilities. These capabilities are essential for stewardship of the current stockpile, but must be enhanced to improve understanding of nuclear weapons performance to ensure the effectiveness of the stockpile in the future. Enhancing capabilities for the future also ensures that the nuclear security enterprise will remain responsive and will attract and retain the requisite stockpile expertise in the workforce.

3.1.1 Assessment of 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. The annual stockpile assessment process evaluates the safety, performance, and reliability of weapons based on physics and engineering analyses, experiments, and computer simulations. Assessments also may evaluate the effect of aging on performance and quantify performance thresholds, uncertainties, and margins. These evaluations rely on all available sources of information, including surveillance, non-nuclear hydrodynamic tests, subcritical experiments, materials evaluation, modeling and simulation, and enhanced surveillance techniques. They involve 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 are quantitative and combine data and theories with simulations of nuclear weapons to arrive at a conclusions that also relies on expert judgment.

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 rigorous review of the results and certification basis by teams of weapons scientists and engineers. The laboratory teams responsible for each weapon type and its assessment include individuals with extensive weapons experience and access to 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. 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.

At the conclusion of the annual assessment review, the Directors of the three national security laboratories and the Commander of U.S. Strategic Command (USSTRATCOM) provide written assessments on the state of each warhead type in the nuclear weapons stockpile. These annual assessment letters are included in the congressionally mandated Report on Stockpile Assessments that is signed by the Secretaries of Energy and Defense and delivered to the President.

The annual stockpile assessment review process is not an annual recertification of the warheads in the stockpile; it is an assessment of each warhead's existing certification basis in light of information generated by the Stockpile Stewardship Program in the past year.

3.1.2 Ensuring the Future Stockpile

The evolving international security environment and the aging stockpile drive requirements for life extension programs (LEPs), modern replacements for existing stockpile systems, and tailored supplemental deterrent capabilities. Ensuring the resiliency of the U.S. nuclear deterrent requires qualification- and certification-ready options, from materials through components to systems, to be available when needed for down-select decisions, development, and production. The qualification and certification pathways for these options must be matured ahead of time. This maturation necessitates advances in qualification and certification methodologies, improvements to the responsiveness of the nuclear security enterprise, better integration with other agencies, and development of new and emergent capabilities for the qualification and certification processes.

3.1.2.1 Certification

The Advanced Certification subprogram improves the methodology and physics-based capabilities used to assess and certify that the evolving stockpile will operate as intended and deliver matured technologies, diagnostic techniques, data analysis methods, and design options for future stockpile needs. The subprogram also preserves and reanalyzes legacy nuclear test data and conducts simulations of nuclear and non-nuclear test data to benchmark simulation codes to understand how weapons perform and how they may fail, improve the technical components of the quantification of margins and uncertainties paradigm, and improve the fidelity and agility of certification methodologies.

3.1.2.2 Quantification of Margins and Uncertainties

Certifying the performance of a weapon by assessments employing predictive capabilities is a large annual effort requiring the coordination of significant resources and expertise. It is addressed through the quantification of margins and uncertainties methodology, which evaluates the confidence of a prediction, thus enabling risk-informed decisions. This methodology's confidence factor of a prediction is the ratio of margin (M) to uncertainty (U), or M/U. The margin measures the degree to which the predicted value of a performance metric exceeds the point where that metric becomes unacceptable. Uncertainty is the metric's range of variability due to factors such as statistical uncertainty and gaps in knowledge. It is determined using both data gathered experimentally and data calculated via databases for physical quantities, physical models, and numerical simulations.

It is desired that the M/U confidence factor be significantly greater than 1.0. A value at or less than 1.0 motivates actions to increase the confidence factor by increasing the margin or decreasing the uncertainty. Increasing the margin might include shortening the interval between limited lifetime component replacements or implementing changes during LEPs, modifications (Mods), or alterations (Alts). The Stockpile Stewardship Program's approach to decreasing the uncertainty is to perform research and development (R&D) in areas such as characterizing the properties of materials to which weapon performance is sensitive or by improving the fidelity of the models used to simulate the operation of the warhead.

3.1.2.3 Qualification

The Delivery Environments (formerly called Weapons Systems Engineering Assessment Technology), Nuclear Survivability, and Component Manufacturing Development subprograms concentrate on stewarding, advancing, and qualifying 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.

3.1.3 Responsiveness

The 2018 *Nuclear Posture Review* called for rapid implementation of the Stockpile Responsiveness Program established by Congress in Section 3112 of the *National Defense Authorization Act for Fiscal Year 2016* to "effectively respond to emerging threats, unanticipated events, and technological innovation through science and engineering" (Senate Report 114-236, *Energy and Water Development Appropriations Bill, 2017*). This program, along with the Stockpile Stewardship and Stockpile Management Programs, will contribute to the overall stockpile responsiveness policy to ensure DOE/NNSA exercises all phases of the nuclear weapons life cycle.

The Stockpile Stewardship and Stockpile Management Programs exercise many, but not all, of the end-to-end capabilities at the national security laboratories and nuclear weapons production facilities to maintain the ability to respond to new requirements that address emerging threats. In particular, detailed design, development, qualification, production, and certification of a prototype nuclear explosive package (NEP) are capabilities that are not exercised fully to respond to future warhead requirements.

DOE/NNSA established collaborations with the Office of the Secretary of Defense (Nuclear Matters), USSTRATCOM Commander, and relevant Air Force and Navy organizations and began technical work to execute this program in FY 2017. After reviewing emerging threats, technical challenges, and opportunities, DOE/NNSA has selected a set of challenge scenarios for concept studies and potential design, prototyping, and flight testing.

3.1.4 Integration with Other NNSA Missions

Since their inception, the national security laboratories have applied their nuclear weapons expertise to challenges beyond maintaining the Nation's stockpile. These challenges include nuclear nonproliferation, assessing and countering nuclear threats, and understanding the nuclear capabilities of adversaries.[1] Historically, these activities were built on the periphery of the core Stockpile Stewardship Program. Today, the complex global security environment demands dedicated experiments, enhanced theoretical and computational models, and reinterpretation of archival nuclear test data. The Capabilities for Nuclear Intelligence program addresses many of these demands. In addition, global security programs leverage Stockpile Stewardship Program investments and capabilities that otherwise would not be available to the broader national security mission. In addition to global security applications, stockpile stewardship tools and capabilities increasingly are being applied to develop advanced conventional (i.e., non-nuclear) weapon systems. In performing such activities, national security laboratory experts exercise their critical design and engineering skills and provide broader experience and validation opportunities, turning synergistic technology advances in those areas into direct benefits for stockpile maintenance and sustainment (e.g., enabling efficient modern radar design for LEPs).

[1] Additional information about these activities can be found in *Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats: FY 2020 – FY 2024* (DOE/NNSA 2019).

3.1.5 Attracting and Retaining Expert Stockpile Stewards

The scientists, engineers, and technicians of the stockpile stewardship workforce and the expertise they possess are the lifeblood of the Stockpile Stewardship Program. Their collective expertise, combined with DOE/NNSA's world-class experimental and computational facilities, enables Stockpile Stewardship Program success and forms the backbone of the Nation's deterrent. DOE/NNSA ensures that the best science and engineering options are available to support national security decisions, which requires recruiting and retaining highly skilled technical staff.

Maintaining a consistent high-caliber workforce as NNSA transitions between generations is essential for retaining institutional knowledge and long-term program effectiveness. The DOE/NNSA core mission is compelling and provides a wide range of research opportunities. The eight management and operating (M&O)-managed national security sites must continue to develop and maintain leading-edge research facilities and forward-looking scientific and technical programs to attract and retain top talent to accomplish that mission. This mission-centered work is supplemented by broader national security applications that provide other important research challenges and working environments. New staff have the opportunity to pursue innovative research by teaming with more experienced staff who provide direction, mentorship, and institutional knowledge. Laboratory-, site-, and plant-directed R&D programs provide scientists and engineers the opportunity to pursue self-directed research in areas of national interest. The Stockpile Responsiveness Program provides additional opportunities for the workforce to develop and exercise skills that are crucial to maintaining and modernizing tomorrow's stockpile.

The Stockpile Stewardship Program contributes to the pipeline of the future national security laboratory workforce through the Academic Alliances, including the Stockpile Stewardship Graduate Fellowship, Predictive Science Academic Alliance, and Laboratory Residency Graduate Fellowship programs. These alliances foster university research in fields that are unique to stockpile stewardship through direct funding. The research includes properties of materials under extreme conditions such as hydrodynamics, low-energy nuclear science, radiochemistry, and HED physics. For additional information on the DOE/NNSA workforce, see Chapter 7.

3.2 Stockpile Stewardship Science, Technology, and Engineering Elements and Status

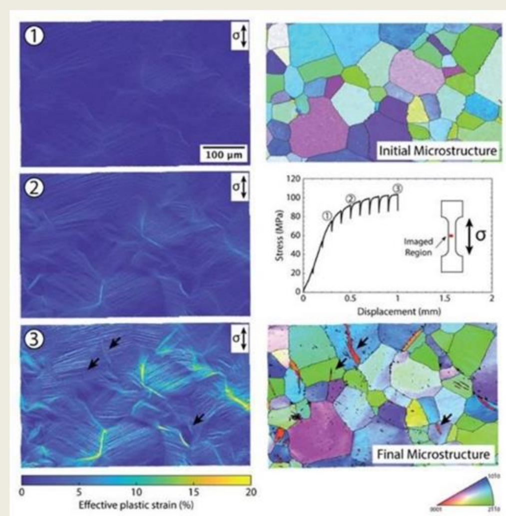
Stockpile Stewardship Program ST&E elements play a major role in the full range of stockpile activities. The high-level FY 2018 accomplishments in the sidebar on page 3-1 are the result of using the program's experimental, modeling, and simulation capabilities to design weapon subsystems and quantify their expected performance for the weapon program of record. These capabilities enable the nuclear survivability qualification of several components. The four major elements that enable Stockpile Stewardship science are the Science Program, the Advanced Simulation and Computing (ASC) Program, the Engineering Program, and the Inertial Confinement Fusion Ignition and High Yield (ICF) Program.

3.2.1 Science Program

The Science Program designs and conducts scientific experiments to advance understanding of weapon performance. The data collected in those experiments are used to improve the accuracy of computer models of nuclear weapons' physics and performance. This work enables the priorities set by the 2018 *Nuclear Posture Review*, namely, sustainment of existing stockpile systems, development of qualification- and certification-ready options for the future tailored deterrent, assessment and mitigation of diverse and advanced 21st century threats, and broad investments across the Science Program's portfolio to enable more responsive and agile manufacturing capabilities through R&D. The Program emphasizes the use of experimental data to address NEP performance issues and provides enabling capabilities required by its partners in the Stockpile Stewardship Program. This work enables advanced performance assessments of nuclear weapons so that DOE/NNSA can meet emerging national security needs beyond stockpile maintenance.

The Science Program deliverables and activities enable multiple mission tasks:

- Annual assessment of the stockpile
- Prompt resolution of stockpile issues (e.g., significant finding investigations [SFIs])
- Aging and lifetime assessments
- Threat assessment and mitigation options for a resilient nuclear deterrent
- Agreements between DOE/NNSA and DoD regarding LEP interface requirements for data delivery, component development, and performance assessments
- Certification-ready design options for the future stockpile, including LEPs, modern system replacements, and tailored deterrence supplements
- Certification statements for LEPs and the future stockpile, based on advanced certification methodologies and requirements for data and performance assessments
- Production modernization through gains in efficiency and agility via production agency partnerships
- Advances in understanding and modeling of primary boost and secondary performance
- Non-nuclear materials innovation, characterization, testing, and evaluation in support of certification and replacement of legacy materials that are no longer available for modernization activities (see sidebar)
- Delivery of essential experimental facilities, diagnostic technologies, and capabilities for stockpile assessment, qualification, and certification
- Enhancing the pipeline of future stockpile stewards and refining their expertise via experimental proving grounds



Material Strain Rate Maps. *High-resolution local strain maps (left) show how titanium microstructures (right) deform during a tensile test. The initial material (1, top panels) transforms into the final deformed microstructure (3, bottom panels). Data are collected at various times during the tensile test, corresponding to the load drops in the stress-displacement curve (middle right). Understanding microscopic deformation processes and bulk material failure is important when introducing new materials to the stockpile.*

Five types of experiments are supported by the program:

- **Nuclear physics.** To improve predictive capability, experiments are conducted at the Los Alamos Neutron Science Center (LANSCE) Weapons Neutron Research Facility to reduce the uncertainties in nuclear cross sections (i.e., the probabilities of nuclear reactions) and to study the physics of fission and fusion processes

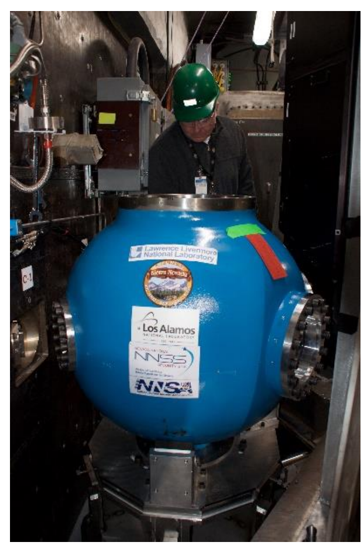
- **Plasma and atomic physics.** Atomic data such as x-ray opacities (i.e., the probability of an x-ray interacting with matter) and plasma physics parameters are central to DOE/NNSA's predictive capability
- **Chemistry.** Laboratory-scale research on the chemistry of materials in weapon components, especially aged components, is critical to predicting the effect on weapons performance
- **High explosives.** Understanding all aspects of the development, manufacturing, processing, and disposition of high explosives (HE) is essential for the safe and effective use of HE (the details of the dynamic behavior as HE detonates and burns are required for accurate predictions of primary performance; dynamic behavior is particularly important when considering replacement of conventional high explosives (CHE) with insensitive high explosives (IHE) within the context of operational safety in the nuclear security enterprise)
- **NEP materials.** Understanding the behavior of NEP materials at the extreme conditions in a nuclear weapon is essential to predict weapons performance in normal, abnormal, and hostile environments

The Science Program consists of six subprograms and academic alliances:

- Advanced Certification
- Primary Assessment Technologies
- Dynamic Materials Properties
- Advanced Radiography
- Enhanced Capabilities for Subcritical Experiments
- Secondary Assessment Technologies
- Academic Alliances and Partnerships

3.2.1.1 Accomplishments

- Completed the Vega subcritical experiment at the Nevada National Security Site (Vega was the final experiment in a series of subcritical experiments studying the effects of substituting IHE for CHE in stockpile systems)
- Completed a Level 1[2] milestone on the initial conditions of boost (this body of work contributes to certification of current and future LEPs by advancing modeling predictions and assessments of the uncertainties of the initial conditions of the boost process in stockpile systems)
- Completed experimental campaigns on the National Ignition Facility (NIF) and delivered HED data to enable assessment of legacy and potential replacement materials for W80-4 LEP applications



Subcritical experiment at the Nevada National Security Site's U1a Complex.

[2] Level 1 milestones are multi-institutional deliverables that result in key outcomes or noteworthy advances in NNSA assessment, experimental, simulation, or production capabilities. These milestones typically require significant investment of resources across multiple subprograms.

- Conducted key plutonium experiments to increase understanding of the effects of aging on plutonium [diagnostic and facility improvements enabled additional plutonium experiments on Joint Actinide Shock Physics Experimental Research (JASPER) and other platforms]
- Began production science experimental efforts in plutonium chemistry aimed at improving pit certification methodologies and pit production efficiency
- Formulated and initiated qualification of a large lot of HE material to provide a source of materials for LEPs, subcritical experiments, and future stockpile options
- Developed less insult-sensitive explosives to help both DoD and DOE/NNSA formulate explosives that are safer for deployment without sacrificing energy and performance
- Selected the source and detector technology for the neutron diagnosed subcritical experiments that will be used in the upcoming Excalibur subcritical experimental series (the Excalibur series will qualify a new flash-neutron diagnostic for further studies of plutonium aging, manufacturing technologies, and future LEPs)
- Advanced the uranium production science initiatives for the future stockpile through (1) manufacture of castings with different specifications and (2) continued efforts to study the potential for reforming components to enable alternative techniques for the manufacture of future stockpile components
- Completed multi-year HED experiments on NIF and the Omega laser facility (Omega) that provided data for validating and advancing ASC codes used to assess stockpile performance
- Completed modern performance simulations of an atmospheric test event that differs significantly from current stockpile devices (this expands the validation domain to support a broader class of design options for future LEPs)
- Developed and fielded an improved Advanced Radiographic Capability at NIF to obtain new stockpile-relevant data
- Conducted experimental campaigns on the Z pulsed power machine (Z) and NIF that developed platforms to study a specific aspect of weapons physics (these platforms will enable experiments whose data will be used to improve models and reduce uncertainties in annual assessment and LEP simulations)
- Completed the planned Sierra Nevada series of development and qualification hydrotests on the Dual-Axis Radiographic Hydrodynamic Test (DARHT), Contained Firing Facility, and U1a Complex (U1a) in FY 2019 (this series of experiments will provide increased confidence in annual assessments, ensuring the safety of nuclear systems remains robust and enabling researchers to enhance safety, where possible, as they work to extend the life of the aging stockpile)

3.2.1.2 Status

The Science Program is vital to ensuring stockpile sustainment, stockpile modernization, and a resilient deterrent. To sustain the evolving stockpile, the Primary Assessment Technologies and Dynamic Materials Properties subprograms are improving the Nation's understanding of the effect of aging on primary performance; experiments for the LEPs, Alts, and Mods; and investments to improve necessary experimental capabilities. The Secondary Assessment Technologies subprogram is investigating the effect of canned subassembly aging on secondary performance studies that are part of a key FY 2019 milestone. The Science Program supports the annual stockpile assessment through advances in the understanding of boost, which also was the focus of an FY 2018 milestone. This milestone was led by Primary Assessment Technologies in partnership with Advanced Certification and ASC. A more complete understanding of advanced weapon physics phenomena is also the goal of NIF, Z, and Omega HED platforms and upcoming subcritical experiment series such as Red Sage, Nimble, and Excalibur.

Resiliency of the deterrent is the driver for assessment capabilities development by (1) the Primary Assessment Technologies Capabilities for the Nuclear Intelligence focus area, (2) higher-fidelity testing environments produced by Secondary Assessment Technologies, and (3) enhanced survivability options developed by Primary Assessment Technologies and Dynamic Materials Properties.

Enhancing the experimental capabilities necessary to underwrite certification of the evolving stockpile is a principal driving force for the Science Program. Projects underway include:

- The Enhanced Capabilities for Subcritical Experiments (ECSE) facility will fill a key gap in late-time primary implosion data by delivering enhanced radiographic and neutron diagnostics for subcritical experiments
- Providing intermediate-scale plutonium experiments is the intent of the Primary Assessment Technologies subprogram-sponsored effort to restore a capability to perform experiments at the LANSCE Proton Radiography Facility (plutonium material property experiments are also conducted at gas gun facilities, including JASPER; Technical Area 55; and HED facilities, including NIF and Z)
- Increased demand for a full range of plutonium experiments to support aging and plutonium modernization and manufacturing options for the future stockpile is being addressed by new investments and national coordination by Dynamic Materials Properties subprogram
- Uranium manufacturing, including maturation and qualification of direct cast manufacturing, is a new investment priority for Secondary Assessment Technologies subprogram

Broad investments across the Science Program portfolio are being made to enable more responsive and agile manufacturing capabilities through R&D.

Key Science Program Facilities

Stockpile modernization was the focus of the U1a Complex (U1a) subcritical experiment series, Lyra and Sierra Nevada; several Dual-Axis Radiographic Hydrodynamic Test (DARHT) and Contained Firing Facility hydro experiments; and many smaller-scale experiments executed for LEPs and pit reuse options in FY 2018.

- ***U1a** is presently the only complex where focused and integrated subcritical experiments combining high explosives with plutonium can be conducted. The Enhanced Capabilities for Subcritical Experiments facility will be housed in this complex.*
- ***DARHT** uses two large x-rays to create ultra-fast motion pictures of materials undergoing hydrodynamic implosion. Experiments at DARHT use surrogates in place of plutonium.*
- *The **Contained Firing Facility** provides single-frame, single-axis, radiographic hydrodynamic test capabilities within a building rated for tests of the largest primaries in the stockpile.*

3.2.1.3 Challenges and Strategies

Table 3–1 provides a high-level summary of the Science Program's challenges and strategies.

Table 3–1. Summary of Science Program challenges and strategies

Challenges	*Strategies*
Sustainment of the Evolving Stockpile 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 assess the effects of plutonium aging and predict pit lifetimes • Provide capabilities to support stockpile assessments, LEP reuse, and surety decisions • Reinstate the capability for explosively driven plutonium experiments using proton radiography and continue to conduct plutonium experiments in relevant regimes • Conduct experiments and analyses to resolve the principal remaining uncertainties associated with boost • 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 • Deliver constraining data using HED experimental platforms to inform choices of differently manufactured materials and to compare weapons output capabilities • Complete systematic studies of the opacity of high-Z materials using Z and NIF • Demonstrate new x-ray sources for weapons survivability testing
Future Deterrent The development of options for LEPs, modern replacements, and tailored deterrence options that are certification-ready is a key element of stockpile responsiveness	• 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 experiments. • Advance certification methodologies to be used in future certification statements
Threat Mitigation 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	• Enhance computer codes that simulate the environments weapons may experience, especially combined environments, to ensure weapons will work as designed • Develop and recapitalize experimental capabilities required for assessments with increasingly more realistic source environments • Enable improved performance assessments for stockpile systems • Mature mitigation options from materials, through components, to systems
Weapon Physics Development of an empirical understanding of weapons' physics, especially boost and thermonuclear burn processes, is important to advancing the ability to predict weapon performance, especially for untested weapon configurations	• Achieve a robust understanding of weapons' physics, including boost, supported by a full range of experiments, including radiation transport; hydrodynamics; plasma, nuclear, and material properties; weapon output, effects, and survivability; and platform and diagnostics development [this work is conducted at HED physics facilities (NIF, Z, and Omega)]
Weapon Materials Materials used in the stockpile have properties that affect weapons performance [the NEP performance effects of material changes (e.g., aging or manufacturing changes) must be evaluated to determine the effect on weapons performance and non-nuclear materials require characterization and analysis to support modeling and overall certification]	• Understand the effects on weapon performance of aging (in particular, aging plutonium) through execution of the National Plutonium Aging Strategy, studies on aging, canned subassembly, and evaluations of new materials and processes through Production Science partnerships on plutonium, uranium, and HE, and non-nuclear materials • Explore advanced material manufacturing technology, such as additive manufacturing • Deliver high-pressure materials property data at weapon-relevant regimes for plutonium, its surrogates, and other weapons-relevant materials • Continue R&D for scaled-up production of IHE for the post-B61 LEP and the W80-4 to ensure a robust material supply

Challenges	Strategies
Advanced Diagnostics and Experimental Capabilities Enhanced capabilities are required to recreate, interrogate, and diagnose materials and physics at weapon-like conditions at experimental facilities focused on delivering such data	• Provide the Nation with the ECSE facility, a world-class radiographic and neutron diagnostic system, to provide better understanding of late-time implosion physics for the certification of the evolving stockpile • Deliver world-class experimental capabilities, including hydrodynamic testing at both DARHT and the Contained Firing Facility; subcritical experiments at U1a; dynamic plutonium experiments on small-scale instruments; guns (e.g., TA-55 and JASPER); LANSCE's Proton Radiography Facility; and nuclear science, materials' characterization, and HED physics experiments with NIF and Z • Develop and exercise experimental and diagnostic capabilities to evaluate foreign and proliferant-based nuclear threats • Develop capabilities to address potential changes in STS environments (i.e., outputs and effects, thermal and mechanical environments) • Sustain hydro facilities (e.g., Contained Firing Facility/flash x-ray and DARHT) to ensure availability to support stockpile development programs

DARHT = Dual-Axis Radiographic Hydrodynamic Test
ECSE = Enhanced Capabilities for Subcritical Experiments
HE = high explosives
HED = high energy density
IHE = insensitive high explosive
JASPER = Joint Actinide Shock Physics Experimental Research
LANSCE = Los Alamos Neutron Science Center
NEP = nuclear explosives package
NIF = National Ignition Facility
Omega = Omega Laser Facility
SFI = significant finding investigation
STS = stockpile-to-target sequence
TA-55 = Technical Area 55
U1a = U1a Complex
Z = Z pulsed power facility

3.2.2 Engineering Program

The Engineering Program provides capabilities for an agile and responsive nuclear stockpile that will survive the complex environments encountered during the lifetime of a weapon. The Engineering Program's mission is focused on design, qualification, and assessment of the integrated weapon system prior to detonation. Nuclear weapons are complex systems with thousands of specialized components. Before arriving at its target, a weapon will have experienced many years of aging, the bumps and vibrations of travel on roads or submarines, the shocks and vibrations associated with flight, and possibly nearby nuclear explosions caused by an adversary's attempt to disable the weapon. Confidence that all components will work together and properly function requires experiments, validated modeling and simulations, careful assessment and selection of materials with appropriate characteristics and properties for all components, and flight testing.

Execution of the Engineering Program involves collaboration with multiple DOE/NNSA programs and external DoD partners. The program partners with ASC by providing the experimental tools and diagnostics that are used to generate data that support validation and verification for simulation capabilities. The Engineering Program also partners with the Science Program in areas of component or system qualification and certification and nuclear survivability. Types of efforts involving significant collaborations supported by the Engineering Program include:

- **Advanced manufacturing.** Advanced manufacturing methods are essential to achieving the efficiency and agility required for production of the future stockpile. Moreover, legacy methods often cannot be replicated. R&D of these methods and assessment of their effect on NEP performance is an element of stockpile responsiveness.

- **Non-nuclear materials science and engineering.** Virtually every class of materials, including metals, polymers, glasses, ceramics, and electronic and optical materials, is used in the non-nuclear portions of nuclear weapons. All of the materials in these components and systems must be tested and certified for the many environments that a nuclear weapon experiences.
- **Engineering science.** The ability to deliver a weapon safely and reliably and to arm, fuze, and fire it requires a broad suite of theoretical, computational, and experimental research. Some of that research, particularly materials science and radiation science, can be conducted in laboratory-scale facilities.
- **Radiation science.** Research on the interaction of radiation with a weapon and the weapon's subsequent response is essential to meet military requirements. This multi-disciplinary research is coupled with engineering and materials science. Whereas many experiments require HED physics facilities such as Z, NIF, and Omega, the unique capabilities of Saturn, the High-Energy Radiation Megavolt Electron Source (HERMES) III, the Ion Beam Laboratory, and the Annular Core Research Reactor are key to advancing radiation science.
- **Microsystems science.** The extreme radiation requirements for weapons can far exceed the capability of commercial microelectronics to survive and function. Microsystems research provides designs and manufacturing processes that enable devices and circuits to meet stringent radiation requirements.

Creating and studying atomic-scale structures advance DOE/NNSA's ability to predict material property changes over long periods of time due to factors such as extreme environments, aging and fatigue. As seen above, researchers funded by the DOE/NNSA often use engineering and silicon fabrication facilities such as the Center for Integrated Nanotechnologies to aid in these studies.

The Engineering Program consists of five subprograms:

- **Enhanced Surveillance** provides surveillance diagnostics and material lifetime science needed to ensure that aging issues are identified in the stockpile before they affect performance.
- **Delivery Environments** (formally known as the Weapon System Engineering Assessment Technologies subprogram) is responsible for ensuring systems endure current and future STS environments in both normal and abnormal environments and perform effectively upon target execution.
- **Enhanced Surety** develops cost-effective, advanced safety, security, and use control technologies for incorporation into stockpile weapon systems.
- **Nuclear Survivability** provides the tools and technologies necessary to ensure that U.S. nuclear weapons survive current and future hostile, fratricide, and combined environments arising from adversary defensive actions and performance of friendly weapon systems in the battlespace.
- **Stockpile Responsiveness** strengthens the ability of the United States to accelerate the development cycle of nuclear weapons and respond to technological uncertainty.

3.2.2.1 Accomplishments

- Demonstrated the feasibility of advanced power supplies for NNSA applications
- Developed and tested advanced use control technologies for next-generation weapon systems

- Developed high-fidelity environmental sensors for the High Operational Tempo Sounding Rocket program to investigate shock and vibration in flight and improve environmental response models
- Initiated a successful multi-site program to retrieve War Reserve components from all systems going through current or near-term dismantlement and/or alteration activities
- Advanced a canned subassembly modeling code to a version that provides significant improvements in run times and the ability to run 3D sensitivity studies. Performed modeling for three systems in support of lifetime estimation
- Achieved full demonstration of an x-ray graded collimation diagnostic, resulting in high-quality imaging data and reduced imaging timelines for surveillance activities
- Completed a long-term investment to evaluate batteries and existing lifetime prediction models by assessing the material characteristics and performance for old batteries
- Initiated the Interagency (DOE/DoD) Threat Environments Working Group to identify challenges related to weapon delivery and survivability, and capabilities needed to address these challenges (the group was established in April FY 2018 and in addition to NNSA/Engineering, its sponsors in DoD are Air Force Nuclear Weapons Center, Air Force Research Laboratory, Air Force/A10, Navy Strategic Systems Programs, Missile Defense Agency)
- Evaluated application of current radiation transport methodologies to assess performance of advanced materials in radiation environments and developed plans for R&D to support certification, qualification, and assessment activities (this work leverages the source development and experimental opportunities provided by the Science and ICF Programs)
- Observed and characterized the effect and sensitivity of cavity system-generated electromagnetic pulse to desorption and cavity surface blow-off; improved basic understanding of phenomena and provided validation data for system-generated electromagnetic pulse modeling and simulation code suites
- Developed a 5-year plan for application of HED facilities and experiments to support studies of U.S. nuclear weapons performance in hostile radiation environments (Nuclear Survivability)
- Completed first round of consultations with DoD, resulting in the start of two challenge problems of mutual interest

3.2.2.2 Status

The Engineering Program is focusing on the future challenges of the U.S. nuclear deterrent. The program considers future delivery environments, hostile threats, component and material aging concerns, and how to produce a deterrent within the timelines needed by the warfighter and military planners. As the program shares these concerns with a number of DOE/NNSA and DoD partners, the program has built robust working relationships with a number of outside agencies and internal DOE/NNSA groups to ensure efficient work toward a common goal.

The Stockpile Responsiveness Program maintains and exercises the required capabilities to respond to emerging threats, technical challenges, and other issues that could threaten the deterrent. The program also identifies opportunities to accelerate the nuclear weapons development life cycle and reduce the costs of development and production. The Engineering Program provides experimental data, improved models, and a better understanding of weapon materials to inform stockpile assessments and the LEPs.

3.2.2.3 Challenges and Strategies

Table 3–2 provides a high-level summary of the Engineering Program’s challenges and strategies.

Table 3–2. Summary of Engineering Program challenges and strategies

Challenges	*Strategies*
Technologies with the potential to effect survivability and other military requirements are changing; the United States must have an ability to anticipate and respond to these changes in a timely manner	Develop improved hydrodynamic and subcritical experimental capabilities to enable greater throughput and more accurate prediction of current and future configurations through the National Hydrodynamics Test Complex initiative
There are few weapons scientists and engineers with experience designing and qualifying new nuclear weapon systems; the window for transitioning this experience to the next generation of stockpile stewards is closing	The Archiving and Data Management Program managed in the Office of Engineering, Stockpile Assessments, and Responsiveness is 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 as needed
Weapons are being kept in the stockpile past their original lifetimes, and new materials with unique aging properties are being incorporated into LEPs; this challenge is exacerbated by a limited ability to conduct destructive surveillance testing (establishing that aging will not adversely affect the stockpile will require new diagnostics and predictive science capabilities)	Prioritize nondestructive evaluation techniques through the Enhanced Surveillance subprogram, improving predictive models of aging issues
Environments associated with nuclear explosions created by adversary defenses and friendly systems cannot be completely replicated in the laboratory, and the number of nuclear tests that the United States conducted to understand these environments was limited and is of diminishing relevance to current and future technologies and environments (assuring that nuclear weapons will survive these environments will require improved experimental and simulation capabilities}	• Develop improved radiation and hostile environment experiments • Improve testing, modeling, and simulation capabilities • Develop technologies and system designs for enhanced survivability in evolving environments.
Higher-fidelity assessments of material changes due to aging, obsolescence, replacement for hazard mitigation, and the high cost of production modernization for NEP and non-NEP materials are required	Expand experimental and computational abilities to study these material changes through design-production agency partnerships, and to rapidly identify and deliver solutions to emerging materials issues
Equipment, facilities, and infrastructure for assessing the performance of nuclear weapons through delivery (normal and abnormal), hostile, and combined environments are significantly aged and in need of refurbishment and capability extension (support to current programs and fielded systems has historically been prioritized over the growing list of deferred maintenance and capability enhancements required to support the future complex)	• Prioritize stewardship of the Nation's capability to test in normal, abnormal, hostile, and combined environments • Expand investment in new and existing test and experimentation facilities to support the current and future stockpile
Assuring that weapons will survive flight increasingly relies on modeling and simulation validated by laboratory experiments (a predictive capability to describe the response of nuclear weapons to the conditions encountered during flight does not yet exist; closing this gap will require large-scale simulations and new experimental capabilities)	• Align priorities and develop plans to ensure DOE/NNSA can readily support experimental and predictive numerical capabilities (i.e., personnel, expertise, facilities) to ensure STS survivability (in normal, hostile, abnormal environments) • This effort includes development and/or advancement of existing experimental and computational capabilities, refurbishment of existing facilities, and hiring of new personnel to ensure successful execution • Efforts will be performed in an informed and collaborative manner with interagency partners)

Challenges	*Strategies*
Successfully transfer design expertise to the next generation while actually shortening the acquisition cycle	• Pursue challenge problems, as part of the Stockpile Responsiveness Program, developed in consultation with DoD that stress these capabilities within the available funding • Develop out-year Stewardship Capability Delivery Schedule (formerly called the Predictive Capability Framework) pegposts to demonstrate the 2- and 5-year concept-to-prototype responsiveness cycles that have been established • The Stockpile Responsiveness Program emphasizes the use of early-career staff in these challenge problems, mentored by senior, experienced designers

NEP = nuclear explosives package
STS = stockpile-to-target
U.S.C. = United States Code

3.2.3 Inertial Confinement Fusion Ignition and High Yield Program

The vast majority of energy generated by a nuclear weapon is produced from matter in an HED state (pressures greater than 1 million atmospheres), characterized by extreme temperatures and densities similar to conditions found in the center of the sun. Accessing these extreme weapon-relevant environments outside of underground tests requires facilities containing state-of-the-art driver platforms (e.g., lasers and pulsed power machines). DOE/NNSA's ICF Program focuses on exploring these extreme conditions through focused ignition and HED research initiatives. The primary HED research facilities that access these conditions include NIF, Z, and Omega. These facilities conduct both ignition and HED research to explore issues in materials science, radiation transport, and hydrodynamics that are relevant to nuclear weapon performance.

Secretary Perry visits the Z Pulsed Power Machine at Sandia National Laboratories.

The ICF Program provides important scientific understanding and experimental capabilities to validate the weapons simulation codes and models that enable assessment of the U.S. nuclear weapons stockpile and certification of components and subsystems for LEPs. These facilities provide the only platforms on which the simulation codes that couple transport processes with hydrodynamic models can be experimentally validated. The program supports development of experimental configurations and diagnostics to conduct HED physics research to address weapons physics, survivability, and performance issues. This experimental basis, combined with archived legacy data from underground nuclear tests, gives confidence in the codes and models used to support annual assessments and certifications, to plan LEPs, and to resolve SFIs.

The ICF Program directly supports long-term R&D efforts in ignition science, with the goal of developing a self-sustained, thermonuclear, burning plasma (i.e., ignition) platform, and ignition-generated fusion yields, for Stockpile Stewardship Program applications. An ignition platform would provide direct access to weapon-relevant regimes and nuclear environments for the study of high-yield, weapon-relevant conditions. Pursuing laboratory-scale thermonuclear ignition is an important objective of the Stockpile Stewardship Program and is a scientific grand challenge. Development of a high-yield experimental platform would provide (in a laboratory setting) direct access to weapon conditions, weapon phenomena, and x-ray/nuclear fluences that have not been available since underground nuclear tests. Such a platform would be able to validate models at extreme conditions of pressure, temperature, and density that approach those achievable only with nuclear explosive testing. The demonstration of ignition, which will enable replication of the physics phenomena in a nuclear detonation without an actual nuclear test, remains a major unmet goal for DOE/NNSA.

The ICF Program consists of five subprograms:

- Ignition and Other Stockpile Programs
- Diagnostics, Cryogenics, and Experimental Support
- Pulsed Power Inertial Confinement Fusion
- Joint Program in High Energy Density Laboratory Plasmas
- Facility Operations and Target Production

Key ICF Program Facilities

- *The **National Ignition Facility (NIF)** was designed to produce thermonuclear ignition. Since completion of the National Ignition Campaign, NIF's role has expanded to tackle a broad array of weapons physics issues, including material properties, radiation flow, thermonuclear burn, and outputs and effects, while continuing the pursuit of thermonuclear ignition.*
- *The **Z pulsed power machine (Z)** is a pulsed-power facility capable of delivering 26 million amps of current to small radii targets (10 centimeters or less), where the electromagnetic forces drive dynamic experiments to investigate weapon physics topics such as the properties of materials, opacity, radiation flow, and thermonuclear burn.*
- *The **Omega laser facility (Omega)** provides a platform for HED physics experiments to investigate issues for both weapons performance and inertial confinement fusion. Omega also contributes to diagnostic development and serves as a staging platform for experiments at NIF.*

3.2.3.1 Accomplishments

- Obtained data on a Z experiment to constrain aging models by comparing the response of new and naturally aged plutonium in regimes not previously attained for this alloy
- Began a series of experiments that will provide data needed to validate radiation transport understanding for legacy and future design options
- Performed plutonium experiments on NIF to measure plutonium strength and atomic structure at stockpile-stewardship relevant conditions in support of all weapons systems
- Developed new or improved capabilities at each ICF facility this fiscal year:
  - Achieved the highest fusion yield to date on NIF of 2×10^{16} neutrons, or 55 kilojoules
  - Z achieved new levels of neutron output for future use in evaluating weapon performance in radiation environments
  - Executed the first double-shell target implosions on NIF as another approach to investigating thermonuclear burn. These highly complex targets were built by a LANL/LLNL/General Atomics collaboration
  - Executed chamber-confined tritium experiments on Z with 5 times more concentration of tritium than before, enabling new diagnostics that will provide critical data for ICF and weapon physics
  - Performed experiments on NIF to enable assessment of potential replacement materials for stockpile applications, including a broad suite of experimental platforms and diagnostics, such as Advanced Radiographic Capability
  - Completed an inertial confinement fusion scaling design study at LANL, in collaboration with the Nevada National Security Site, based on historical and present data to gain insight on the approach to achieving ignition and robust burn on ICF platforms
  - Improved direct-drive implosion performance at the Laboratory for Laser Energetics' Omega Facility and established a new direct-drive yield record of 1.6×10^{14} neutrons

3.2.3.2 Status

DOE/NNSA's ICF Program conducts both ignition and HED research to explore issues in materials science, radiation transport, and hydrodynamics that are relevant to nuclear weapon performance. Since conclusion of the National Ignition Campaign in 2012, the program has transitioned to achieve a balanced portfolio between near-term stockpile science experiments and longer-term ignition platform development, maintain a long-term strategy across its research portfolio, and improve operational efficiency at the HED facilities.

Currently, HED efforts conduct a broad area of research that is important to the Stockpile Stewardship Program. These efforts provide experimental data needed to inform design and material replacement options for LEPs, provide data to plutonium aging and manufacturing assessments, inform assessments of hostile threats against U.S. weapon survivability, and develop platforms that enable assessment of nuclear weapon performance and potential surveillance findings. To support these needs, the HED program is focusing upon four major technical areas (thermonuclear burn, radiation hydrodynamics and transport, materials and plasma properties, and outputs and survivability).

> ***Research Grants***
>
> *DOE/NNSA and the DOE Office of Science have awarded 26 research grants totaling $13.8 million to support work related to high energy density laboratory plasmas.*

Early ignition experiments on NIF evaluating laser indirect drive capsules indicated differences between the code predictions and the data. These indirect drive experiments revealed unexpected physical behavior and technical complexities that will require time to study and resolve. Advances in diagnostic platforms and experimental techniques have provided insight into where the models used in the codes are diverging from the experimental data; this insight is of great interest to stockpile stewardship. Today, the implosion experiments are more hydrodynamically stable and yield performance closer to that predicted by the code simulations. Progress is being made in better understanding and controlling the hydrodynamic instabilities and implosion symmetry that will be required to advance nuclear performance.

The ICF Program is pursuing two additional approaches to ignition. One path is laser direct drive, which is principally studied on Omega at the University of Rochester. If this path is shown to be promising, it may be possible to convert NIF to symmetric direct laser drive to achieve multi-megajoule yields with the present laser energy. The second path is magnetic direct drive, which is principally studied at the Z facility. If this path is shown to be promising, it may be possible to build a larger pulsed power facility capable of 10-megajoule-class yields.

Scientists and engineers working on all three approaches are collaborating in a nationally coordinated effort. This national effort is outlined in the *2018 Inertial Confinement Fusion Program Framework*, which describes the ICF Program's 2020 goal. This goal is to determine the efficacy of NIF for achieving ignition, along with developing credible scaling arguments for all three ignition approaches for achieving multi-megajoule yields. The long-term goal is to establish the requirements for a future HED capability as a major capital project. This refers to several proposed capabilities:

- Consolidation of target fabrication and R&D activities at NIF
- A power and energy upgrade to NIF
- A next-generation pulsed power facility to succeed Z

The national ICF Program must continue to pursue the challenge of ignition because of its importance to experimental investigations of thermonuclear burn and survivability issues for the future stockpile. Much of the ICF research provides an avenue to establish the quality of relevant science through collaboration with the broader scientific community.

3.2.3.3 Challenges and Strategies

Table 3–3 provides a high-level summary of the ICF Program challenges and strategies.

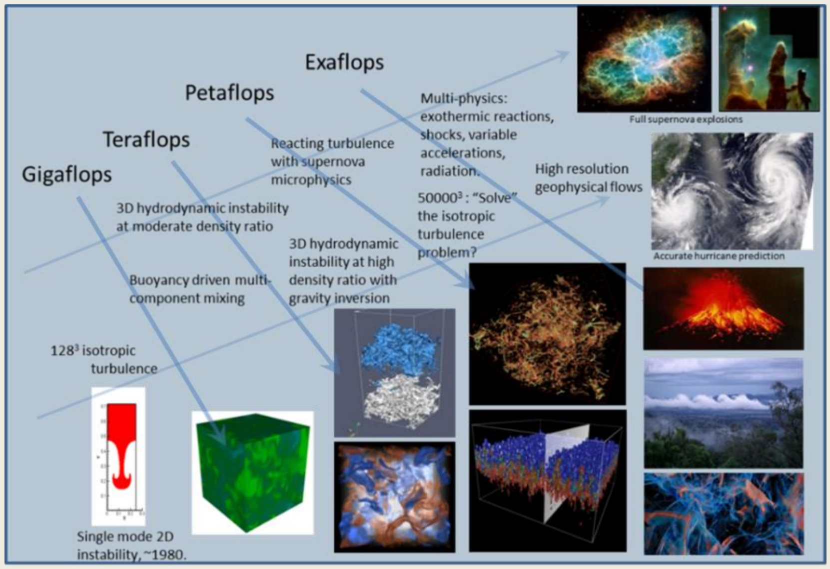
Table 3–3. Summary of Inertial Confinement Fusion Ignition and High Yield Program challenges and strategies

Challenges	*Strategies*
Thermonuclear Burning Plasmas Demonstrate thermonuclear burn and, ultimately, high yield in the laboratory, which would enable new certification capabilities	Pursue R&D using three major ignition approaches: laser indirect drive, laser direct drive, and magnetic direct drive (these ignition efforts, technology development efforts, and the development of future stockpile stewards in this program is based on ICF Program planning documents (e.g., the *2018 Inertial Confinement Fusion Program Framework* and the 2016 *Pulsed Power Science & Technology Strategic Outlook*), working group recommendations (e.g., *National Implosion Stagnation Physics Working Group Report*), and recommendations in the *2015 Review of the Inertial Confinement Fusion and High Energy Density Science Portfolio*.)
Radiation Transport and Hydrodynamics Better understand the behavior and hydrodynamic coupling between radiation and materials	Conduct focused experiments targeting key aspects of complex hydrodynamic flows in the HED regime to gather benchmarking data.
Outputs and Survivability Insufficient data exists to fully benchmark models of the radiation outputs from U.S. systems and adversaries' systems, the response of U.S. systems to hostile environments, and extreme environments such as the electromagnetic pulses that nuclear weapons may create	Use HED facilities to provide intense x-ray and neutron sources that can be used to understand some of these scenarios and support the qualification of components of U.S. systems to meet nuclear survivability requirements
Material Properties From the late phases of a primary implosion through the secondary explosion, the nuclear weapon materials are heated to very high temperatures and pressures. Understanding the response of key weapon components to these conditions is central to weapon assessments and certification	Conduct focused materials experiments on the HED facilities to provide precision data on these 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.
HED Code Validation and Verification Modeling weapons-relevant HED experiments and phenomena requires multi-physics code capabilities and benchmarked input models (e.g., equations of state, opacity); maintaining robust experimental and theoretical support for validation and verification of these complex tools and models is needed for them to be effective	Ensure the continued use of the ICF Red Team to assess the progress each ignition approach has made, along with assessing cross-platform code validation, uncertainty quantification, and code sharing efforts
HED Experimental Operations Improve the efficiency of facility operations and provide targets and transformative diagnostics for HED physics and ignition experiments	Use the ICF and HED Councils to review and prioritize key experimental campaigns that are then coordinated by each facility to ensure optimum experimental throughput • A National Diagnostics Working Group identifies and pursues transformative diagnostics for each major HED facility within budget constraints that are tightly aligned with programmatic needs • A Target Fabrication Working group ensures target R&D and production is balanced to meet experimental facility requirements
Future Stockpile Stewards Recruiting, retaining, and maintaining a cadre of talented scientists and engineers	Pursue path to ignition as a national grand challenge to attract future stockpile stewards, advance the broad HED capabilities, and maintain healthy and vibrant fundamental science programs on HED facilities

HED = high energy density
ICF = Inertial Confinement Fusion Ignition and High Yield Program

3.2.4 Advanced Simulation and Computing Program

The ASC Program develops and deploys predictive simulation capabilities, via the integrated weapons codes, used in the certification work of the Stockpile Stewardship Program. LEPs, SFIs, and other aspects of the Directed Stockpile Work rely on the people, state-of-the-art computational platforms, and validated simulation tools that are used in the annual assessment of the nuclear weapons stockpile. Simulation tools integrate experimental measurements and the foundational knowledge gained from legacy testing, so they represent the Nation's current understanding of nuclear weapons' physics and all aspects of weapon performance. Predicting a weapon's performance throughout its life cycle requires simulation at many spatial and temporal scales. The image to the right highlights the importance of having the ever-improving simulation and computing capabilities to solve key weapons problems and quantify their uncertainties.



Turbulence is one example of a physical phenomenon that is difficult to simulate and will require exascale computing to resolve for some stockpile applications. NNSA and the DOE Office of Science are working toward exascale computing platform advances that will make weapons simulations more realistic.

ASC trains and uses a stable community of subject matter experts with the know-how to leverage high performance computing (HPC) to better model the physical behavior of nuclear weapons systems performance at nominal or near-nominal conditions; understand engineering in normal, abnormal, and hostile environments; and know all aspects of weapons surety and weapons outputs. The program's success also relies on the expertise and measured data from the Science, Engineering, and ICF Programs within the Stockpile Stewardship Program.

The costs to construct and maintain the high-tech infrastructure are leveraged with close collaborators, such as the DOE Office of Science. The DOE Exascale Computing Initiative is an example of the partnership between the ASC and the Office of Science that provides a pooling of resources for better leveraging of R&D investments in next-generation computing technologies, software tools, and application codes with computer vendors, the national laboratories, and universities. Such collaboration will deliver two exascale-class system to the Office of Science in FY 2021–2022 and one to NNSA in FY 2023. NNSA and the DOE Office of Science are currently conducting a joint procurement of these exascale systems and will share non-recurring engineering costs for selected solutions that will meet NNSA and Office of Science mission needs. This collaboration will save NNSA $40 to $60 million. More details of the initiative can be found in Appendix C.

3.2.4.1 Accomplishments

- Improved ability to perform NEP simulations under hostile and STS conditions using an improved HE model, which is necessary to perform sensitivity studies for the W80-4 LEP
- Added capabilities to more accurately simulate additive manufacturing via powder melt, which will allow better part designs and more targeted testing
- Performed a full system simulation of the Halfbeak underground nuclear test on the Trinity system, the first ASC Advanced Technology System (this is one of the most detailed, large-scale calculations ever performed by the complex and will provide insights on long-standing questions related to weapon performance)
- Enhanced Monte Carlo transport capabilities to support the secondary performance and future stockpile management activities
- Completed simulations at all NNSA laboratories as part of the Large Scale Calculations Initiative to test the limits of current simulations capability and point the way toward future improvements (the calculations addressed mission-relevant questions and have already led to enhancements of the integrated codes and associated workflows and identification of future needs)
- Installed and benchmarked NNSA's first advanced architecture prototype HPC system – Astra at SNL (this system pioneers a new type of computing architecture at a large scale that is expected to perform very efficiently on weapons calculations)
- Accepted DOE/NNSA's new flagship HPC system, Sierra, in September 2018 (the heterogeneous architecture required substantial efforts on the part of code development teams for the last several years to effectively use the graphics processing units, but is already showing order of magnitude speedups for many applications compared to runs on standard central processing units)

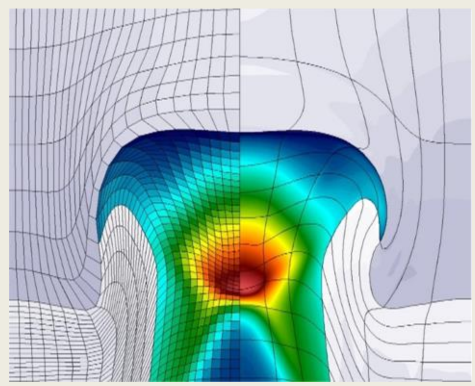
The Sierra Supercomputing System at LLNL is the second fastest computer in the world (as of November 2018) with 125 petaFLOPS; over 90 percent of the computing power is in the graphics processing units.

- Partnered with the DOE Office of Science to procure major systems through the Collaboration of Oak Ridge National Laboratory, Argonne National Laboratory, and LLNL (CORAL-2)
  - In this second effort, CORAL-2 will deliver exascale class systems
  - Laboratory experts exhaustively reviewed proposals from multiple computer vendors, and this analysis provided hard evidence of the value of DOE's R&D investments over the last decade
  - The capability of the computers offered by vendors is 3-4 times greater than what would have been obtained without the combination of critical Exascale Computing Initiative R&D investments in vendor technology, and the intense level of competition engendered among the vendors by the large scale of the joint NNSA and Office of Science HPC procurements

3.2.4.2 Status

The ASC Program continues to provide qualified staff, integrated codes, and the HPC platforms needed to design, produce, certify, and qualify the current and future deterrents. The need to produce validated results with decreasing reliance on the underground test base is a principal driver for the Program. The ASC Program works toward meeting this need using several strategies:

- Develop more accurate and reliable models of weapons-relevant physical phenomena, thereby increasing trustworthiness of the codes
  - Identification of phenomena and regimes that are becoming more relevant for the stockpile of the future (e.g., microstructure of materials manufactured by new techniques) and extension of the models and codes to properly represent them
  - First principles atomistic-scale simulations play an important role in developing these models, and machine learning will play a critical role in including these effects in a cost-effective manner in large, multi-physics simulations
- Improve the ability to analyze deformed (e.g., crash scenario) geometry to support the thermal safety assessment in an abnormal environment
- Port the ASC simulation capabilities to Sierra to demonstrate ASC code performance on next-generation computer architectures
- Identify phenomena and regimes that are becoming more relevant for the stockpile of the future (e.g., the microstructure of materials manufactured by new techniques) and extend models and codes to properly represent them (atomistic-scale simulations play an important role in developing these models, and advanced machine learning will play a critical role in including these effects in a cost-effective manner in large, multi-physics simulations)
- Collaborate with the other ST&E elements to provide large- and small-scale experimental data to validate the models and codes
- Leverage modern HPC architectures to allow higher-fidelity simulations, which will more properly represent the physics and engineering models (e.g., smaller-scale physical parameters) and allow more accurate 3D representations of weapons system components (see sidebar)
- Enhance the workflow tools that accompany the integrated codes (supporting the ability to run larger jobs), extract and visualize meaningful information, and formalize uncertainty quantification to provide more directly relevant information to decision-makers
- Move to a more modular and agile simulation code base with abstraction layers to isolate machine-specific optimizations that can respond more readily to rapidly evolving computer architectures
- Explore methods (e.g., machine learning or data analytics) to enable sensitivity analyses with improved physics modeling and improved workflow elements
- Develop and implement new algorithms that are more performant to rapidly changing hardware



DOE/NNSA is developing new, high-order, hydrodynamic algorithms that will run more efficiently and robustly on future computer architectures with greater precision per zone (boxes). Pictured above is a comparison between older (left) and newer (right) LLNL simulation tools used to examine a shock wave propagating through a material. These advances in modeling capabilities allow DOE/NNSA to capture more accurate density gradients (indicated by the color map) and provide the ability to map curve features of the wave. Continued improvements like this are expected to make weapons simulations faster and less user intensive.

The need to maintain the current capability and keep it available to weapons designers, engineers, and analysts is another significant program driver. This requires adapting the integrated and science code base to new computer architectures whose evolution is being driven primarily by market forces that are not strictly aligned with DOE/NNSA's programmatic needs. The program is being proactive in modernizing its current weapons modeling and simulations capabilities while undergoing this major computing paradigm shift.

3.2.4.3 Challenges and Strategies

Table 3–4 provides a high-level summary of the ASC Program's challenges and strategies.

Table 3–4. Summary of Advanced Simulation and Computing Program challenges and strategies

Challenges	*Strategies*
The stockpile is evolving away from as-tested designs through aging LEPs, and manufacturing obsolescence	Partner with the DSW, Science, and Engineering Programs to understand the nature of these changes, establish requirements, and continue efforts to improve the ability to model and understand the physics of these problems
The threat space for which weapons must be certified is evolving	Coordinate with customers through implementation of the 2018 *Nuclear Posture Review* to understand the new needs for threat response and respond with credible simulation capabilities
Current simulation capabilities are at risk because of evolving computer architectures	Develop codes that will migrate capabilities to new architectures, and partner with system vendors to coordinate on specific long-term research (the Large Scale Calculations Initiative will inform future strategies to mitigate the risks posed by this challenge)
Recruiting and retaining personnel with the necessary skill sets is difficult because of the unique training and experience requirements and the limited availability of qualified U.S. citizen graduates with advanced degrees in the requisite specialties and is further complicated by industry competition for those resources	Conduct the Predictive Science Academic Alliances Program, which supports work at universities and trains graduate students, many of whom come to work at the DOE/NNSA laboratories (the national security laboratories also maintain large summer intern programs and strong post-doctoral programs to familiarize potential hires with the laboratories and the DOE/NNSA mission)
The modeling capability is currently inadequate to incorporate advanced manufacturing methodologies fully with maximum efficiency	Develop new material property models and solution methods to allow simulation of both advanced manufacturing processes and the behavior of the resulting materials in DSW-relevant applications
• Water and power supply requirements are becoming inadequate and will drive changes in the facilities, network, and archival infrastructures. • Facility upgrades are required for Advanced Technology Systems 3 and 4 (ATS-3 and ATS-4), which will be delivered in 2020 and 2023, respectively	Complete the ongoing Exascale Class Computer Cooling Equipment and Exascale Computing Facility Modernization programs at LANL and LLNL, respectively
User demand for computer time for nuclear security applications is outstripping availability	Along with the Advanced Technology systems, ASC deploys Commodity Technology systems at the laboratories for additional computing capacity for the nuclear security enterprise user community (in FY 2020, it will kick off its Commodity Technology System 2 (CTS-2) procurement activity to procure next-generation, more powerful Commodity Technology systems to address the increasing demand for computing resources)

ASC = Advanced Simulation and Computing Program
DSW = Directed Stockpile Work Program

3.3 Strategies for the Future

The enduring drivers for the Stockpile Stewardship Program pose challenges that must be addressed. The first generation of science-based stockpile stewardship has ensured confidence in the nuclear deterrent, without reliance on additional nuclear testing, through application of the innovative ST&E required to assess the current stockpile and certify changes to that stockpile. The next-generation science-based stockpile stewardship (NextGen science-based stockpile stewardship) will anticipate future threats and formulate responsive solutions; robustly compete ideas for best future solutions; predict aging mechanisms and the onset of failures; optimize production throughput rates; and ensure readiness, responsiveness, and agility. Benefits include lowering costs; exercising the skill base by practicing aspects of the warhead development cycle from design to prototype; developing next-generation tools and capabilities; and investing in infrastructure and facilities to provide an effective deterrent. DOE/NNSA must improve predictive capabilities for weapon-related phenomena through theory, simulation, and experimental capabilities.

3.3.1 Stewardship Capability Delivery Schedule

DOE/NNSA and the national security laboratories have revised an established framework to guide ST&E capability development (**Figure 3–1**) in four key areas. In previous years this activity was called the Predictive Capability Framework; the name was recently changed to Stewardship Capability Delivery Schedule. The name change and the new focus areas better reflect the advances necessary for mission delivery, and to achieve objectives laid out in the 2018 *Nuclear Posture Review* and the *Nuclear Weapons Council Strategic Plan for Fiscal Years (FY) 2019-2044* in an integrated manner.

- Stockpile Sustainment will guide the efforts that support the needs of the current U.S. nuclear stockpile.
- Future Deterrence will develop responsive technologies and architectures that will reduce cycle times for future weapon development.
- Threat Mitigation will develop and mature technologies and experimental capabilities to simulate combined and emerging hostile environments that future weapons must be able to survive.
- Modern Materials and Manufacturing will develop advanced materials and ways to manufacture materials and components to be robust to hostile environments, extend lifetimes, and reduce production life cycle time and cost.

3.3.2 Capital Investments Supporting Stockpile Stewardship

To achieve the schedule illustrated in Figure 3–1, DOE/NNSA must invest in next-generation facilities in key capabilities such as advanced computing, radiography, pulsed power science, accelerators, advanced manufacturing, and advanced material characterization. Each of these areas has one or more capital projects in the conceptual planning phase to address foreseeable needs for the stockpile (see **Table 3–5** below and Figure 4–5 in Chapter 4, "Physical Infrastructure" (the 25-year programmatic line-item schedule). In addition to addressing predictive capability needs, these investments will contribute significantly to the NextGen science-based stockpile stewardship vision and thereby increase confidence in the Nation's future deterrent.

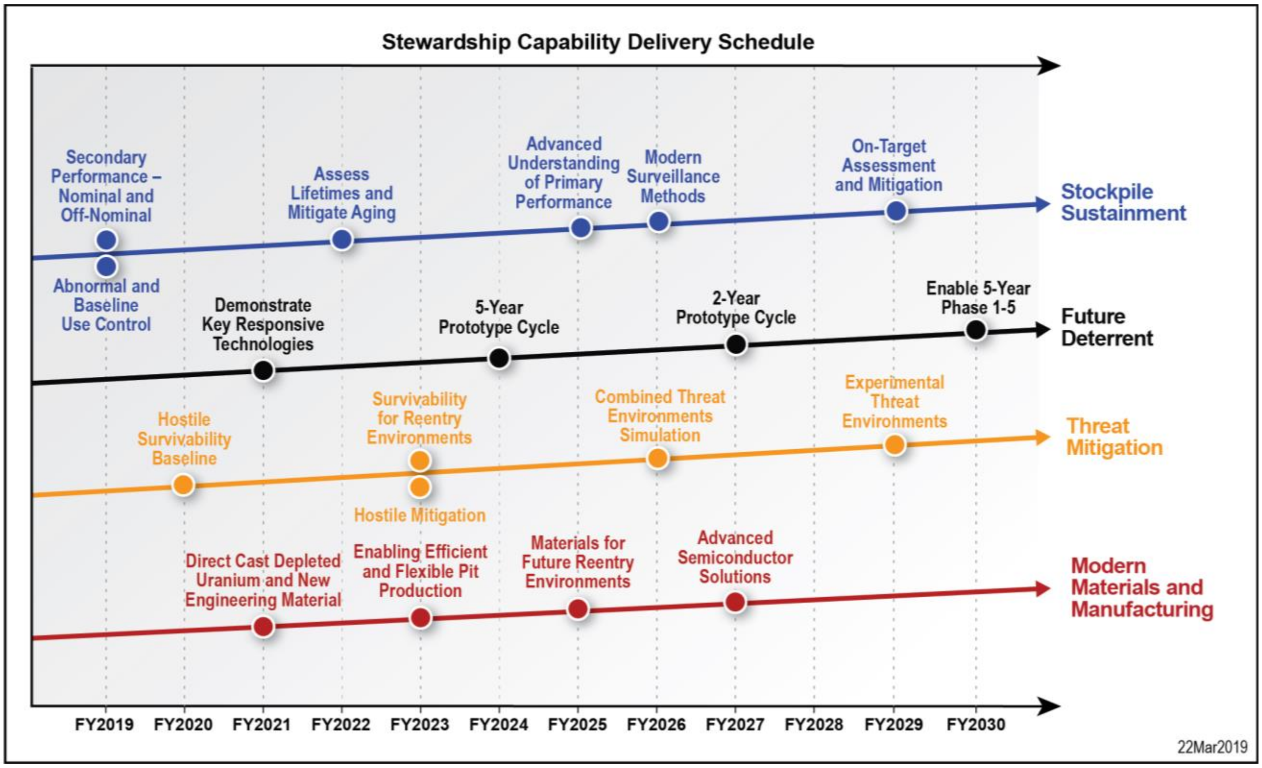


Figure 3–1. Stewardship Capability Delivery Schedule – the four key focus areas needed to address mission delivery

Table 3–5. Capital investments to ensure NextGen science-based stockpile stewardship

Project	*Significance*
Advanced Radiographic and Diagnostics Hydrodynamic Test Building Upgrade	Enhances capability for non-SNM hydrodynamic experiments for LEP certification and annual assessments
DARHT Axis-1 Modernization	Modernizes an aging facility that provides a unique, highly specialized capability to take dual-axis, multiple-exposure radiographs of materials and assemblies under hydrodynamic conditions
Sigma Replacement	• Creates a new depleted uranium and beryllium research and advanced development processing facility, which supports plants, Alts, and LEPs with its depleted uranium materials science and hazardous materials component fabrication capability • Modernizes the ability to design and qualify nuclear weapon electrical systems (materials, devices, and components) to survive severe x-ray and gamma-ray radiation environments.
Refurbish/Recapitalize SATURN Accelerator	Restores the original capability with modest modernization to design and qualify nuclear weapon electrical systems (materials, devices, and components) to survive severe x-ray and gamma-ray radiation environments (this will extend the life of Saturn to meet current requirements, but will not provide capabilities needed to respond to potential emerging threats)
Consolidated Environmental Test Facility	Consolidates capabilities currently housed in SNL's Environmental Test Laboratory and Aerothermodynamics Laboratory and will enable performance of multiple, combined environmental tests
Combined Radiation Environments for Survivability Testing Complex	Combines current Annular Core Research Reactor capabilities (high-fidelity neutron and gamma-ray environments) with an independent gamma-ray irradiation capability in a safe, purpose-built facility for the ability to develop and certify weapons to survive combined radiation (neutron and gamma) environments

Project	*Significance*
Future HED Capabilities	Increases the performance and operational capabilities of NNSA's HED facilities, Z and NIF, to achieve stockpile stewardship objectives through production of higher pressures and temperatures and higher neutron and x-ray fluence
Full Spectrum Anechoic Chamber	Provides improved experimental and test capabilities for weapon response to intense electromagnetic environments for model validation and improved quantification of design margins
Microsystems Sustainment	Replaces a portion of the radiation-hardened microelectronics production capabilities by providing agile cleanroom space that mitigates growing mission risks
Full Replacement of SATURN and HERMES Accelerators	Replaces the aging Saturn and HERMES capabilities with improved performance and operational capabilities to produce intense x-ray and gamma-ray radiation environments and enables long-term support of several key weapons-related activities in radiation effects
Test Capability Revitalization Process Phases 3/4	Focuses on NNSA's large system- and subsystem-level test facilities in thermal, fire, acceleration, impact, shock, and other environments where a remote location is necessary to mitigate hazards associated with creating extreme environments
Energetic Materials Characterization	Advances predictive capabilities for safety and performance assessments, resolves SFIs, evaluates material responses to all phases of the stockpile-to-target sequence, and develops new and replacement materials in support of evolving HE technical requirements

Alt = alteration
DARHT = Dual-Axis Radiographic Hydrodynamic Test
HE = high explosive
HED = high energy density
NIF = National Ignition Facility
SFI = significant finding investigation
SNM = special nuclear material
Z = Z pulsed power facility

3.3.3 Defense Programs Advisory Committee

DOE/NNSA chartered the Defense Programs Advisory Committee in 2013 to provide independent advice in crafting future strategies by providing analysis, evaluation, and guidance regarding stewardship and maintenance of the Nation's nuclear deterrent. The Committee is composed of external experts who advise DOE/NNSA.

The Defense Programs Advisory Committee's activities may include, but are not limited to, periodic reviews of the diverse major activities of the Office of Defense Programs (i.e., assessments of the Nation's stockpile; the research, development, test, and evaluation infrastructure needed to maintain the stockpile and overall nuclear deterrent; and the nuclear weapons production facilities and related manufacturing technologies), and the overall DOE/NNSA. The Committee recently completed an assessment of NNSA's understanding of plutonium aging and has begun an analysis of competing strategies in the post-exascale era (see Appendix C). The Committee's next study, to be followed in FY 2020 or later, will be an assessment of progress by the Stockpile Responsiveness Program to achieve its mandated mission (see Section 3.2.2.3).

3.4 Nuclear Test Readiness

The United States continues to observe the 1992 nuclear test moratorium. DOE/NNSA maintains the readiness to conduct an underground nuclear 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:

> The 2018 *Nuclear Posture Review* directs that, "NNSA will maintain the capability to resume underground nuclear explosive testing if called upon to do so. The United States will not seek Senate ratification of the Comprehensive Nuclear Test Ban Treaty, but will continue to observe a nuclear test moratorium that began in 1992. This posture was adopted with the understanding that the United States must remain ready to resume nuclear testing if necessary to meet severe technological or geopolitical challenges."

- DOE/NNSA is required by the 1993 PDD-15 to maintain the capability to conduct a nuclear test within 24 to 36 months.
- Nuclear test response time depends on the specific details of the test.
- Assuring full compliance with domestic regulations, agreements, and laws relating to worker and public safety and the environment, and 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 through the Stockpile Stewardship Program. Test readiness is a product of a robust, technically challenging Stockpile Stewardship Program that exercises essential underground testing elements at the Nevada National Security Site, such as mining, and investments in both the personnel and infrastructure of the nuclear security enterprise.

Operations such as subcritical experiments at U1a are exercising the people, physical assets, and infrastructure required for an underground nuclear test. These involve critical skills and formality of operations; including weapons design; 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 will continue 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 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.

Finally, the test readiness strategy is to reconstitute underground testing elements when needed, rather than maintaining obsolete facilities and capabilities. Additional details that remain valid can be found in the 2011 *Nuclear Test Readiness Report to Congress, Appendix B.* This report is largely based on a 2006 study, which for key skills noted that significant retirements had occurred in key positions.

Chapter 4
Physical Infrastructure

4.1 Overview

> ***Physical Infrastructure Major Accomplishments***
>
> - *Began constructing the primary buildings replacing 70-year old uranium production facilities in Oak Ridge, Tennessee.*
> - *Identified the recommended alternative for rebuilding America's plutonium pit production capability by 2030.*

The 2018 *Nuclear Posture Review* clearly calls out the need for infrastructure modernization to ensure a resilient, enduring, and credible stockpile; reduce the risk to mission; and improve employee, public, and environmental safety. The increased demand on the existing infrastructure due to multiple concurrent life extension programs (LEPs) and the science technology and engineering activities in the Stockpile Stewardship Program presents many complex challenges, including an aging infrastructure that is failing at increasing rates. In spite of these difficulties, DOE/NNSA has made significant efforts to modernize the infrastructure, eliminate excess facilities, and improve management practices. DOE/NNSA, with Congress's support, has also increased the resources allocated to improving the condition and functionality of the infrastructure and disposing of unneeded facilities.

Figure 4–1 illustrates the size and scope of the DOE/NNSA nuclear security enterprise infrastructure that influence the challenges and strategies discussed in this chapter. Planning and managing the extensive, diverse infrastructure across DOE/NNSA's eight sites requires an understanding of function, age, and condition and a variety of new tools, techniques, and approaches to manage the complex suite of infrastructure assets to support the Stockpile Stewardship Program.

DOE/NNSA has implemented new tools for collecting data on infrastructure systems to improve scheduling, anticipate needs, and improve prioritization. It has also devised better processes to operate more efficiently and prioritize investments across the nuclear security enterprise based on mission need, capability health, and risk reduction. These new approaches have already yielded some success, but many challenges remain. DOE/NNSA must sustain assets to support mission needs. Long-term asset management requires balanced investment decision-making across four key elements of life cycle asset management, as shown in **Figure 4–2**.

Chapter 4 begins with a set of high-level, enterprise-wide challenges as the backdrop for the subsequent discussions. More specific challenges are contained in the discussions for each subsection, as appropriate. The asset management life cycle model shown in Figure 4–2 is used to frame the discussion for different types of investments across a variety of funding sources and sponsoring programs. Sections 4.2 through 4.5 each reflect a portion of that model. Each of these sections describes the different acquisition strategies and funding approaches necessary to build long-term infrastructure modernization programs. Programmatic equipment is then discussed in Section 4.6 as one of the three key elements of capability sustainment.[1] Section 4.7 includes ongoing modernization activities for information technology and cybersecurity in support of the enterprise. Section 4.8 provides a discussion of how the portions of

[1] Most capability management models identify three basic capability components: Facilities and Infrastructure, Equipment, and People. Chapter 4 covers the first two of these; people are covered in Chapter 7.

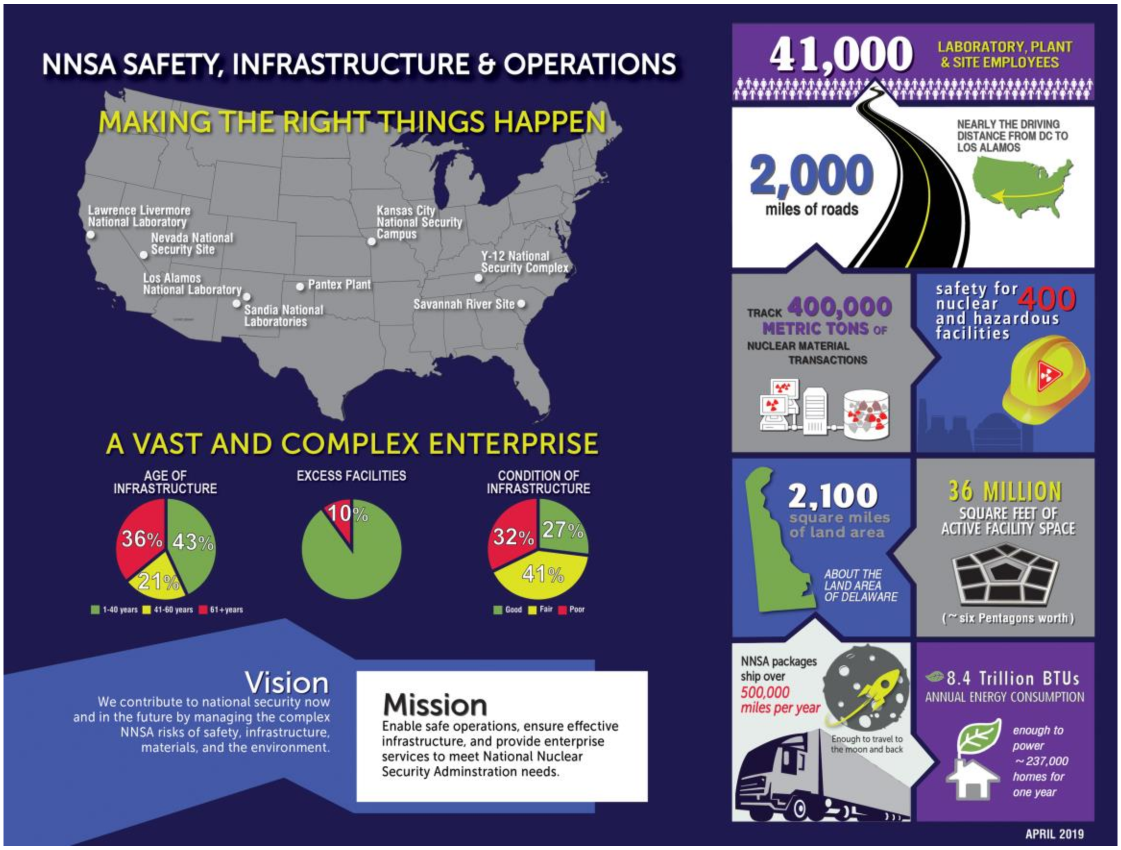


Figure 4–1. DOE/NNSA infrastructure size and scope

DOE/NNSA outside the direct nuclear weapons mission areas leverage the nuclear security enterprise investments for their own national security mission needs. Section 4.9 concludes the chapter with a discussion on management and performance.

Within each section of Sections 4.2 through 4.5, various funding strategies and acquisition approaches are the organizing framework for discussion. 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. Acquisition approaches include line-item acquisition, recapitalization via minor construction, and sustainment investments.

Figure 4–2. Asset management life cycle

Challenges and Strategies

DOE/NNSA is responsible for developing and implementing infrastructure modernization strategies to meet the following challenges posed by internal and external stakeholders to enable the Stockpile Stewardship Program:

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

This section outlines these challenges. 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.

The condition of nearly one-third of DOE/NNSA's infrastructure is insufficient to meet mission needs (see **Figure 4–3**). Nearly 60 percent of facilities and equipment are more than 40 years old. Nearly 30 percent of facilities were constructed during the early Cold War era, and 10 percent are deemed excess to mission needs. The success of DOE/NNSA's unique national security mission is dependent upon 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.

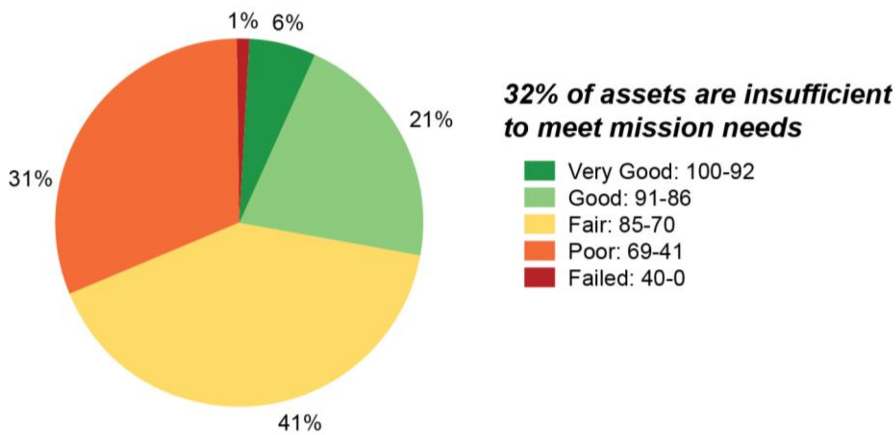


Figure 4–3. Asset condition by replacement plant value percentage

The Need for Enterprise-Wide Life-Cycle Asset Management

While there has been strong support for several specific requirements for ensuring the safety, security, and reliability of the nuclear weapons stockpile, such as the LEPs and construction of the Uranium Processing Facility, DOE/NNSA has not sufficiently prioritized sustaining many small capabilities that enable the Stockpile Stewardship Program. Going forward, DOE/NNSA must find a balance between 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 has approximately 300 major programmatic facilities that average over 40 years old. The remaining 5,000 mission-enabling assets such as office and laboratory buildings, electrical distribution systems, and security infrastructure, also have an average age of over 40 years old. Upgrading or replacing this infrastructure will require significant and sustained investment. By addressing infrastructure needs, DOE/NNSA can also improve workforce recruitment and retention.

A More Responsive, Resilient Enterprise

The 2018 *Nuclear Posture Review* identified the need for a more responsive and resilient infrastructure to support multiple concurrent weapon programs. The nuclear security enterprise of today lacks resiliency; 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.

DOE/NNSA's challenge is to develop an infrastructure modernization strategy that is responsive and resilient enough to enable development and deployment of new designs and refurbishments more rapidly and at lower risk than is currently possible to meet expected future demands. In addition to infrastructure planning, DOE/NNSA and its management and operating (M&O) partners can exercise 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.

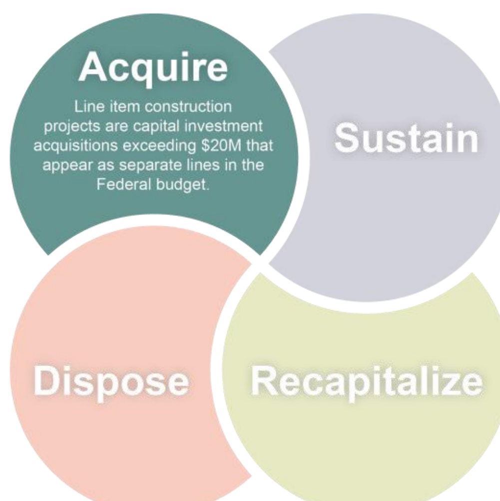
More Efficient, Effective Execution

DOE/NNSA is taking steps to arrest the declining state of infrastructure by enhancing and optimizing resources, including employing innovative management tools to facilitate a data-driven, risk-informed planning process that will guide investment decisions. Sites are also making efforts within their budgets to recapitalize facilities and equipment in support of multiple capabilities. The nuclear weapon enterprise aspires to have best-in-class safety and physical security practices, emergency preparedness and response, and enhanced cybersecurity, with expertise to counter the unexpected.

Overall, DOE/NNSA is shrinking its large infrastructure footprint while providing new, state-of-the-art facilities to meet growing mission requirements. DOE/NNSA must continue to improve project execution to address risks and meet mission needs. DOE/NNSA is constantly challenged by the magnitude of a failing and obsolete infrastructure that crosscuts all of the nuclear security enterprise with respect to sustainment, modernization, and life-cycle management.

4.2 Acquisition Through Line-Item Construction

In 2018, DOE/NNSA has approximately 5,000 assets with an average age of approximately 46 years. The largest and most complex of those facilities will require line-item construction projects for recapitalization. Since aging facilities represent increasing risk to mission execution and these projects require significant coordination over multiple years, DOE/NNSA is developing a 25-year line-item construction plan to address these major infrastructure issues.



The primary challenge to DOE/NNSA's line-item construction portfolio is the timely enactment each year of the President's budget. In addition, the sizes and complexities of these projects lead to several program and project management challenges. In spite of these challenges, DOE/NNSA has demonstrated success: 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 can present a challenge to meeting enterprise needs in a responsive and timely manner.

DOE/NNSA is improving the Line Item Construction Planning processes to support the 2018 *Nuclear Posture Review*, Weapons Activities requirements, and other DOE/NNSA mission requirements. These improved planning processes have identified a large capital outlay requirement over the 25-year planning period that more realistically captures NNSA's modernization needs than previous resource projections.

4.2.1 Programmatic Line-Item Projects

In 2018, DOE/NNSA has nearly 300 major programmatic facilities with an average age of approximately 46 years that could eventually require line-item construction projects for replacement. Since aging facilities represent increasing risk to mission execution, DOE/NNSA is seeking a line-item portfolio solution to reduce the average facility age to a sustainable level while also meeting program requirements. **Figure 4–4** demonstrates the historical average age growth of NNSA's major programmatic facilities and the planned reduction in average age after completing the projects identified in NNSA's new long-term major capital asset modernization strategy, which was developed via the Capital Acquisition (CapAx) process.

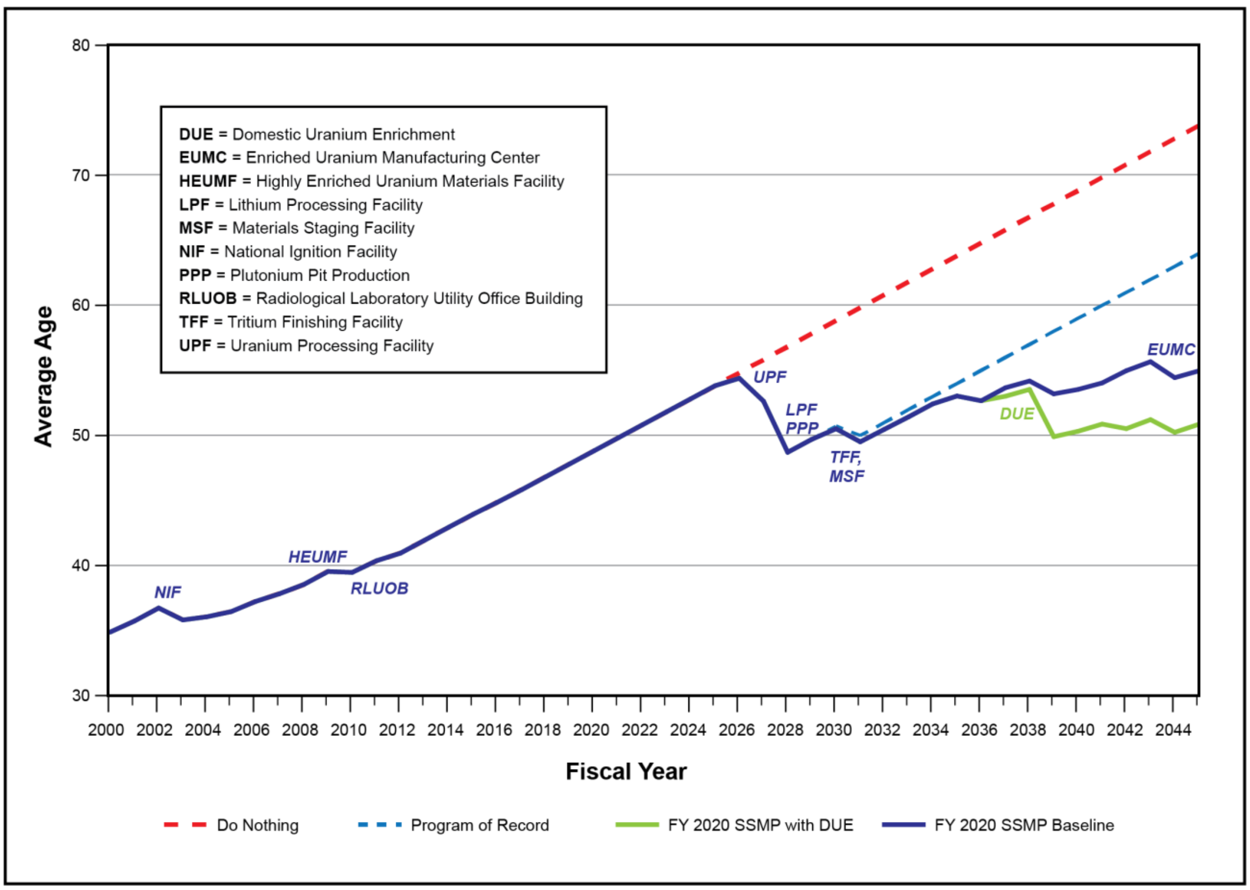


Figure 4–4. Historical average age growth of NNSA major programmatic facilities and a projection of the planned stabilization of average age after executing the FY 2020 President's Budget Request-informed line-item plan

4.2.1.1 CapAx – the Long-Term Planning Process

In 2017 and 2018, DOE/NNSA developed CapAx to integrate the planning, programming, budgeting and evaluation process with the DOE capital acquisition process. This annual effort mirrors DOE/NNSA's LEP planning process through the use of site expertise, programmatic reviews, and independent Federal cost and schedule estimates. Support is provided by representatives from all of the sites and responsible Federal offices across DOE/NNSA. The final 25-year schedule of major projects is determined by senior DOE/NNSA leadership.

DOE/NNSA will track the average age of major programmatic facilities from 2018 onwards to judge the adequacy of the long-term infrastructure modernization plan to improve infrastructure resiliency. Average age is an easily calculated metric that can be used as a proxy for risk to mission. NNSA infrastructure planners developed this approach after engaging with interagency peers from the National Aeronautics and Space Administration which has been using this metric as a key part of their strategic planning process since at least 2011. In addition to this portfolio-level metric, each mission area will be evaluated for future modernization needs.

The planning estimates and schedule dates shown on the 25-year programmatic line-item schedule (see Figure 4–6 at the end of this section) are supported by the FY 2020 President's Budget Request. The planned start and end dates for the "ongoing projects" are more certain than those in the "under review" and "new proposals" categories. DOE/NNSA will continue to update the 25-year schedule annually based on new mission needs assessments, cost estimates, programmatic prioritization, and the availability of funding. Once DOE/NNSA begins each project and conducts an analysis of alternatives, some planned acquisitions may convert to alternate strategies to meet mission needs. These decisions could change future projections.

DOE/NNSA manages line-item capital acquisition projects through a defined DOE acquisition process with five critical decision points shown in (**Figure 4–5**), which serve as major milestones approved by a Project Management Executive. Each critical decision marks further certainty in project scope and requires successful completion of the preceding phase. The NNSA will sometimes combine CD-2 and CD-3 to reduce acquisition time while maintaining program management requirements.

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

CD-0 documents that a mission need, such as a scientific goal or a new capability, requiring material investment exists. The mission need does not necessarily specify the facility, technology, or configuration of the project though these things are often described at some level.

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

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

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

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

Figure 4–5. Critical Decision overview

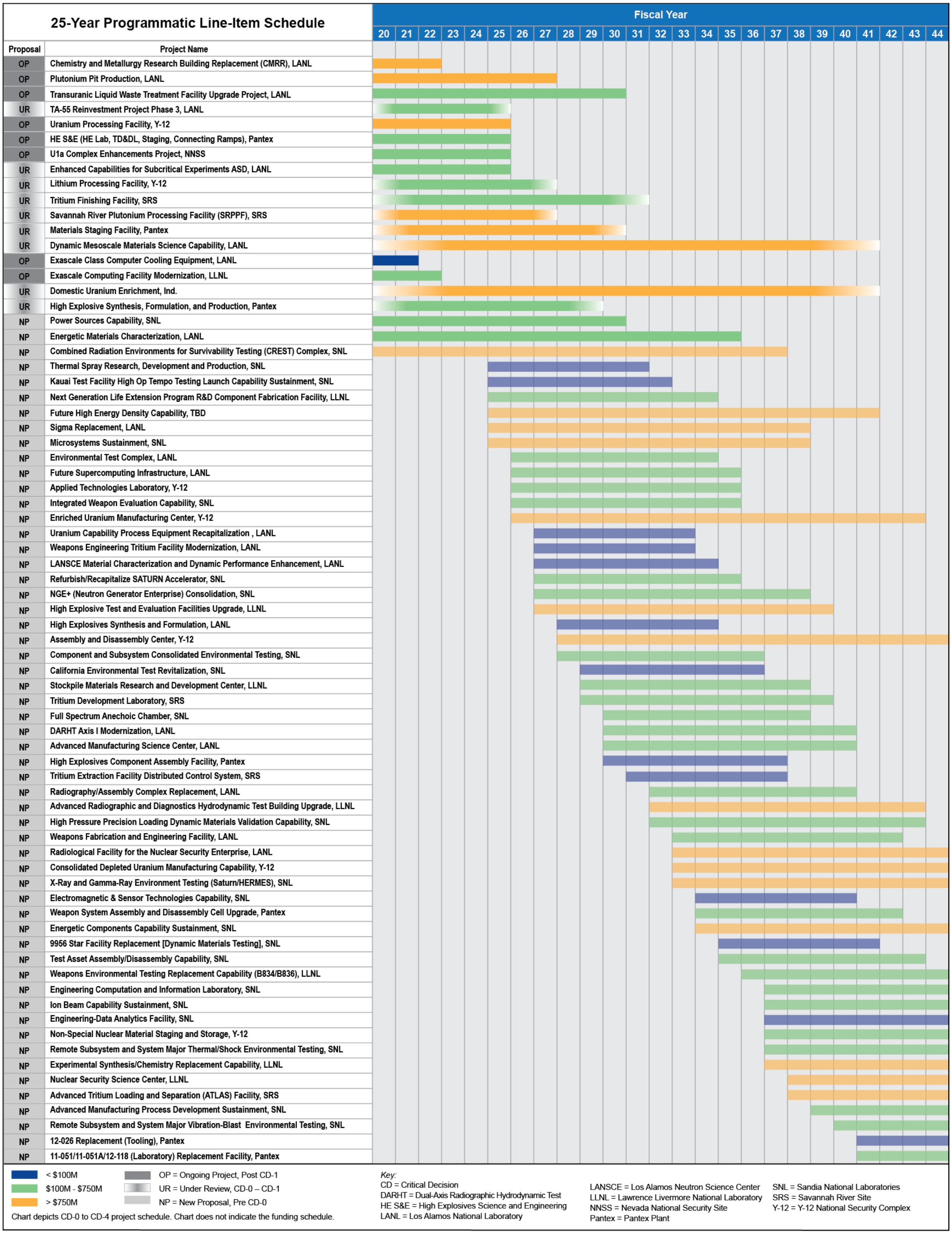


Figure 4–6. DOE/NNSA 25-year programmatic line-item schedule

4.2.1.2 Current Projects

DOE/NNSA is currently executing multiple programmatic line-item projects that are past Critical Decision 1 (CD-1), "Approve Alternative Selection and Cost Range." These projects are listed in **Table 4–1** and shown in Figure 4–6. Cost and schedule estimates for these projects vary from conceptual design-based estimates to baselined project estimates.

Table 4–1. Programmatic line-item projects that are past Critical Decision 1

Project	*Project Description*
Chemistry and Metallurgy Research Replacement (CMRR)	The CMRR Project will ensure 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 will reconfigure space in Radiological Laboratory Utility Office Building and Plutonium Facility (PF-4) and install additional analytical chemistry and materials characterization equipment.
High Explosives Science and Engineering Facility	The High Explosives Science and Engineering Facility will consolidate 15 aging facilities into three new, efficient facilities to conduct science, technology, engineering, and production activities in assembly/disassembly and high explosives. Most of the current facilities were built over 70 years ago, lack the electrical infrastructure to meet mission requirements, and have safety and security limitations as a result of failing infrastructure.
Transuranic Liquid Waste Facility	Treating transuranic liquid waste is a key support capability for DOE/NNSA operations at PF-4. The current facility that treats liquid waste has passed 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.
Uranium Processing Facility	The Uranium Processing Facility project ensures the long-term viability, safety, and security of DOE/NNSA's enriched uranium capability. It supports the Nation's 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 replaces 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, 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.
Exascale Class Computing Cooling Equipment	This project will increase the cooling capacity for high performance computing. The scope includes installation of five additional open-celled cooling towers to the north of the existing towers, extension of the process loop piping to the east of the existing piping loop, seven new process water pumps, four new heat exchangers, and associated piping. The project also includes installation of the supporting electrical equipment and components necessary for the function of the mechanical equipment, and additions to the building's automated control system.
Exascale Computing Facility Modernization	The project will modify the existing high performance computing center at LLNL to accommodate the increased infrastructure demands of exascale computing platforms, to include upgrades to the electrical and mechanical capabilities of the facility. The existing cooling tower complex will be expanded for additional cooling, and the electrical system will be upgraded to allow additional power for high performance computing.
U1a Complex Enhancements Project and ECSE Advanced Sources and Detectors (ASD) Project	The U1a Complex Enhancement Project consists of infrastructure modifications to provide the U1a Complex at the Nevada National Security Site with the infrastructure to house and field multi-pulse radiography. This includes structures, systems, and components necessary for deployment of the ECSE ASD Project's pulsed x-ray radiography equipment and potential future neutron-diagnosed subcritical experiments technology that will produce valuable data on the phenomena associated with the final stages of a weapon implosion.

ECSE = Enhanced Capabilities for Subcritical Experiments

4.2.1.3 Projects Under Review

DOE/NNSA is currently executing multiple projects that are past CD-0, "Approve Mission Need," but have not yet completed CD-1. These projects are considered "under review" until the formal CD-1 alternative selection is made. These projects are listed in **Table 4–2** and shown in the 25-year plan in Figure 4–6. For more detail on the programs and capabilities supported by these modernization projects, please review SSMP Chapter 2, "Stockpile Management," and Chapter 3, "Stockpile Stewardship Science, Technology, and Engineering." Cost and schedule estimates for these projects vary from planning estimates to conceptual design-based estimates.

Table 4–2. Programmatic line-item projects that are under review

Project	*Description*
Domestic Uranium Enrichment	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 and nonproliferation needs. The U.S. Government does not currently have the capability to enrich uranium. Enriched uranium is required in varying assays and forms to meet U.S. national security and nonproliferation mission requirements, including low-enriched uranium as fuel for tritium production reactors; high-assay low-enriched uranium for fuel for research reactors; and highly enriched uranium for fuel for naval reactors.
Lithium Processing Facility	The Lithium Processing Facility project at Y-12 replaces lithium component manufacturing capabilities currently located in a 75-plus-year-old building. The facility has structural issues such as cracked support beams and concrete spalling due to years of caustic chemical contamination that present a high-risk safety environment for both workers and process equipment. Lithium components are vital to canned subassembly production, and lithium capabilities support Directed Stockpile Work LEPs, joint test assemblies, international agreements, several DOE/NNSA offices outside the weapons programs, and other agencies beyond DOE.
Material Staging Facility	Current staging facilities are not sufficient to meet staging capacity demands. Pantex has converted operational bays to staging bays to accommodate total material staging needs. The current material staging facilities are 46-70 years old and in need of refresh. This project has received CD-0 "Approval of Mission Need" and is developing the material for a CD-1 "Approve Alternative Selection and Cost Range" approval. This project will resolve the mission staging gap as identified by DOE/NNSA.
Plutonium Pit Production Projects	DOE/NNSA requires a sustained production capacity of no fewer than 80 pits per year by 2030. There are two distinct Plutonium Pit Production Projects under development: the Savannah River Plutonium Processing Facility (SRPPF) and the Los Alamos Plutonium Pit Production Project (LAP4). The SRPPF recommended alternative will provide the capability to remanufacture, at a minimum, 50 War Reserve pits per year by 2030 at SRS. The LAP4 project will meet the remaining pit production demand. DOE/NNSA is reviewing how to implement LAP4 through the DOE Order 413 process given the maturity of LANL's pit production program; the initial critical decision point for this program is under discussion. LAP4 is included in this section only as a reflection of the connection with SRPPF.
Tritium Finishing Facility	The Tritium Finishing facility line-item project will construct two new production buildings and relocate the vulnerable reservoir-related capabilities from the current facility to the newer, centralized production 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.
ECSE ASD Project	Late-time plutonium implosion measurements are required to develop and refine modern predictive models that are used in certifying the safety and reliability of our nuclear stockpile. DOE/NNSA cannot currently measure the final stages of a subcritical imploding plutonium system with the required fidelity. Pulsed x-radiography is a demonstrated capability for making these measurements. The ECSE ASD Project fills this 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.
TA-55 Reinvestments Project, Phase 3	The TA-55 Reinvestments Project will support design and construction of the 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.

ASD = Advanced Sources and Detectors
CD = Critical Decision
ECSE = Enhanced Capabilities for Subcritical Experiments
PF-4 = Plutonium Facility
TA-55 = Technical Area 55

4.2.1.4 New Projects with FY 2020 Funding Requests

Three new project proposals were identified, analyzed, and included in the FY 2020 Request by as part of the CapAx process. DOE/NNSA will determine appropriate out-year funding to develop and execute these proposals as the projects mature. DOE/NNSA are evaluating the mission needs associated with these project proposals and performing analyses to determine whether or not to prioritize the execution of these projects. Note that one project, the High Explosives Synthesis, Formulation, and Production Facility, has already reached CD-0; this ability for DOE/NNSA to execute early critical decision gates faster for these new projects is a testament to the capital acquisition execution improvements enabled by the CapAx planning process.

The FY 2020 project proposals shown in **Table 4–3** below reflect a new focus on modernizing DOE/NNSA's non-special nuclear material (non-SNM) production capabilities. Over the past two decades, DOE/NNSA has focused on modernizing the high-cost, high-importance nuclear strategic materials capabilities. Over the past 5 years, DOE/NNSA has begun to focus on the non-nuclear strategic materials, lithium and tritium. Now, DOE/NNSA is undertaking line-item projects that will improve the ability to produce and qualify non-SNM components.

Table 4–3. CapAx project proposals in the FY 2020 President's Budget Request

Project Proposal	*Description*
Power Sources Capability	All current and planned nuclear weapon systems require power source development and support from design, and production through surveillance activities. Requirements are unique to nuclear weapons, and commercial vendors are not viable for this work. There is an immediate risk to DOE/NNSA's power sources capability because of the gap between the current state of the capability and the required state based on the forecast increased demand and poor facility conditions. DOE/NNSA also supplies advanced power sources for other national security mission needs that cannot be commercially sourced. The proposed 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. Dedicated laboratories could include dry room, battery testing, and chemistry/wet laboratories. Specialized spaces could include rapid product realization, destructive testing, x-ray analysis laboratories, and hazardous storage.
Combined Radiation Environments for Survivability Testing (CREST) Complex	The Annular Core Research Reactor (ACRR) provides high-fidelity neutron and gamma-ray environments that emulate nuclear weapon environments in support of weapons development and certification. The current ACRR facility is 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 from 4 to 3 days per week. Nearly every weapon component in the stockpile undergoes testing at the ACRR; demand is increasing; and there is no backup capability in the Nation. The proposed CREST project would explore options to provide a replacement facility into which the existing reactor fuel could be relocated. CREST could also combine the current ACRR capabilities with an independent gamma-ray irradiation capability in a safe, purpose-built facility. New or improved nuclear material storage, handling, and processing space and associated laboratories, offices, and other infrastructure would also be considered in the scope.
High Explosives Synthesis, Formulation, and Production Facility	This project will address challenges at the supplier's formulation facility and their difficulty with meeting 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 future high explosive 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. This project has already reached CD-0 after the program performed requirements development in 2018.

4.2.1.5 Other New Proposals

The project proposals in this section are a representative subset of the projects that were added to the 25-year plan after approximately 200 project proposals were reviewed by DOE/NNSA. They are included to show the kinds of high-importance programmatic mission needs that are continuously under review by DOE/NNSA for modernization. No new programmatic line-item projects are scheduled to start between FY 2021 and FY 2024. As such, no funding is requested for these projects in the 2020 President's Budget Request. Some of these projects could be accelerated into the Future Years Nuclear Security Program (FYNSP) (or delayed further or cancelled) in the future after DOE/NNSA conducts more analyses. DOE/NNSA's 25-year plan and the FY 2020 President's Budget Request together present an executable and affordable schedule of line-item proposals.

The Government Accountability Office identified a "bow wave" of construction projects in previous DOE/NNSA line-item plans. Based on internal CapAx analysis, DOE/NNSA now recognizes that, given the amount of time necessary to start and build up the teams that complete line-item construction projects, a trough is forming outside the FYNSP where planned annual line-item construction requirements decrease. DOE/NNSA is already analyzing this problem to determine potential solutions. The project proposals in the tables below could be a part of the solution to resolving this known planning gap. This and new emergent issues will be addressed during the ongoing FY 2021 to FY 2025 planning process. The trough can be seen in the 25-year budget project figure in Chapter 8 (Figure 8–31).

The potential projects shown in **Table 4–4** could improve DOE/NNSA's ability to perform the science, technology, and engineering (ST&E) that underpins the Stockpile Stewardship Program.

Table 4–4. Potential projects to improve DOE/NNSA's ability to perform science, technology, and engineering

Project Proposal	*Description*
Dynamic Mesoscale Material Science Capability	There is a gap in science tools for stockpile stewardship between atomic scale materials phenomena (addressed by facilities such as NIF and Z) and the integral scale (addressed by DARHT and the U1a Complex). This project would provide a new capability to characterize microstructure and materials responses in the middle scale or "mesoscale."
Energetic Materials Characterization	This project would support research and development (R&D) to advance predictive capabilities for safety and performance assessments and qualification and surveillance; evaluate material responses to all phases of the stockpile-to-target sequence; resolve significant finding investigations; provide technical data on which to base annual weapon assessments; and develop new/replacement materials in support of evolving high explosive technical requirements. The project would 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.
Future HED Capability	HED physics experiments provide data that are vital to maintaining the stockpile; existing facilities (Z, NIF, and others) will need refurbishments, and new capabilities will be proposed within this project to address future questions. The project scope is undefined. Defense Programs will perform a strategic review of the ICF HED portfolio and review a suite of alternatives for modernization of HED capabilities at a later date.
High Explosive Test and Evaluation Facilities Upgrade	The High Explosives Application Facility, which integrates synthesis, formulation, and explosives testing operations in one facility, is at capacity for fielding stewardship and stockpile LEP development work. This infrastructure investment would provide critical capability and capacity upgrades to support near-term warhead development programs, and stockpile certification. The project would expand experimental bays and laboratory space for small-scale and component scale experiments, including integration of novel diagnostics.

DARHT = Dual-Axis Radiography Hydrodynamic Test
HED = high energy density
ICF = Inertial Confinement Fusion Ignition and High Yield Program
NIF = National Ignition Facility
Z = Z pulsed power facility

The potential projects shown in **Table 4–5** could improve DOE/NNSA's ability to perform the production, engineering, and assembly missions that underpin the Stockpile Stewardship Program.

Table 4–5. Potential projects to improve DOE/NNSA's ability to perform production, engineering, and assembly missions

Project Proposal	*Description*
California Environmental Test Revitalization	The capabilities housed in these facilities enable researchers to test the effects of normal, abnormal, and hostile environments (e.g., shock, vibration, vacuum, force, acceleration, thermal, pressure) on weapon systems and components. They provide a fundamental understanding of aging phenomena to support component lifetime assessments, and experimental capabilities, diagnostics, and data to understand the physics of component impact, subsystem response, and weapon performance when subjected to stockpile-to-target sequence environments. They directly support design, development, qualification, and evaluation of the stockpile. This project proposal would consolidate or refurbish five assets at SNL with multiple specialized laboratories and testing tools for weapons design and engineering analysis, system qualification, model validation, and significant finding investigations. Alternatively, a phased approach could be taken to stagger these necessary renovations.
Environmental Test Complex	These experimental functions support warhead geometry and weapons assembly/subassembly experimental capabilities. This project proposal would recapitalize and modernize the environmental testing facilities and high explosives shock and vibration testing capabilities at LANL. The scope would include options for relocating mechanical testing.
Integrated Weapon Evaluation Capability (Formerly Weapons Evaluation Facility Surveillance)	As part of the Annual Assessment cycle, SNL collects component, subsystem, system, and joint test assembly data to ensure the stockpile retains its deterrent value. Laboratory test equipment for qualification, surveillance, field testing, and aircraft compatibility are currently developed in multiple buildings. Many of the facilities housing test equipment are obsolete and/or in deteriorating condition and have high maintenance and repair costs. The conditions present increased risk to tester development schedules in support of weapon modernization design, qualification, and production activities. This project would consolidate testing facilities to enable faster and more efficient testing processes and allow the development of new testing strategies. Facility investment must provide secure high-bay, mid-bay, and light electrical laboratories; collaboration space; and general office space. A new R&D centrifuge would better support environmental and Nuclear Enterprise Assurance testing and enable the prove-in of new technologies to be implemented at the Weapons Evaluation Test Laboratory at Pantex, thereby reducing integration times.
Kauai Test Facility (KTF) High Op Tempo Testing Launch Capability Sustainment	KTF provides the key development, test, and evaluation capabilities that are essential to nuclear deterrence and broader national security missions. The High Operational Tempo Sounding Rocket Flight Test program would provide a test platform with a high-risk tolerance for new technologies that can duplicate many of the combined launch environments needed to qualify components, technologies, and subsystems. This would support DOE/NNSA's goal to accelerate development cycles and shorten the duration of future weapons modernization programs. KTF needs investment to replace aging temporary facilities that support crucial test launches on behalf of the Nation's nuclear deterrence efforts. This project would explore modernization solutions to include removal and replacement of the outdated trailers, the concrete loading dock, and the delaminating/rusting overhead structure with a facility designed and constructed to survive an errant launch or launch pad mishap
Microsystems Sustainment	The most pressing near-term strategic radiation-hardened microsystems infrastructure need is to address growing risks associated with the capabilities provided by the Silicon Fabrication Facility (SiFab), which was commissioned in 1988 with a 25-year design life. Without significant investment, SiFab cannot credibly support current and future technology needs through 2040. Compounding the growing risks is that SiFab's ceiling height and outdated foundation design will not support the requirements of semiconductor replacement tools. This project proposal would consider replacing a portion of SiFab's radiation-hardening capabilities by providing agile clean room space that mitigates growing mission risks among other cost-effective alternatives.
Next-Generation LEP R&D Fabrication Facility	The ability to test stockpile systems at the subsystem and device scale involves engineering environmental testing and hydrodynamic experiments that rely on the ability to rapidly fabricate precision parts. Fabrication and inspection is a fundamental capability in supporting science, technology, and engineering (ST&E) of stockpile LEPs and replacement programs and essential to streamlining and increasing throughput of the design agency development pipeline. This proposed LLNL facility would provide both critical capability and capacity augmentation to support design agency prototyping and stockpile system

Project Proposal	***Description***
	development for the stockpile certification. It would also serve as a production technology development, maturation, and insertion research hub for design/production agency collaboration on next-generation production technologies. This project proposal would replace or refurbish a set of important workshops at LLNL.
Neutron Generator Enterprise Consolidation	Neutron generators must meet the highest levels of reliability and survivability and be periodically replaced. In 1995, when DOE/NNSA designated SNL as the production agency for neutron generators, operations were moved into existing buildings, resulting in operations housed in eight buildings on multiple sites. Material movement and product staging in multiple locations causes inefficiencies, suboptimal workflows, and increased time and risk factors (damage, loss, quality, and security). In addition, the facilities and infrastructure are aging, presenting increasing risks to mission work. The proposed consolidated complex would significantly improve workflow and efficiency, enabling DOE/NNSA's neutron generator operations at SNL to better meet national security needs. Flexible-use space would allow for agile response to unanticipated requirements, installation and testing of replacement equipment, and investigation of new technologies.
Weapons Fabrication and Engineering Facility	Consolidation of the weapons manufacturing capability in conjunction with localized engineering design and testing support would enable a more efficient, cost-effective, and expedient response to DOE/NNSA mission needs at LANL, and support site consolidation and transformation efforts. This project proposal would provide the consolidated fabrication and engineering facility necessary to provide reliable, effective, safe non-nuclear component machining in concert with enhanced engineering design, analysis, and prototype testing for the Stockpile Stewardship Program's Pit Manufacturing and Plutonium Sustainment efforts.
Weapon System Assembly and Disassembly Cell Upgrade	This project would provide additional production cell capacity to support the forecasted increase in workload. The proposed project would include installation of task exhaust; modifications to blast doors; replacement of dehumidifiers; installation of heating, ventilating, and air conditioning equipment, hoists, fire systems, and Radiation Alarm Monitoring Systems; and start-up activities. Expected activities for the third cell include installation of new flooring, minor system modifications, and start-up activities.

Table 4–6 lists potential projects that could improve DOE/NNSA's ability to perform the Strategic Materials production process development mission.

Table 4–6. Potential projects to improve DOE/NNSA's ability to perform the Strategic Materials mission

Project Proposal	***Description***
Applied Technologies Laboratory	Development capabilities currently performed in legacy facilities provide material to production, develop and demonstrate new uranium and lithium technologies, and provide weapons quality assurance. The improvements and technological advancements performed in these facilities are critical to flexibility in accommodating DOE/NNSA design laboratory requirements, improving productivity, reducing operating costs, and protecting workers and the public. Two facilities are over 70 years old and are in poor condition. Most work is currently conducted in three facilities totaling about 200,000 square feet. This project would provide a new facility to consolidate applied technology mission activities.
Tritium Development Laboratory	Legacy facilities that support radiological R&D in the tritium production and handling process were shut down in 2003, concurrent with the legacy 232-H production facility. Prior to 2003, SRS Building 232-H was used for radiological development and technology demonstration for the current H Area New Manufacturing Facility. The Tritium Development Laboratory project would provide a new radiological Tritium R&D capability to resolve the Tritium R&D Mission gap. The NNSA nuclear security enterprise lacks the radiological capability to develop and demonstrate tritium process technologies and mature gas transfer systems with actual tritium. As a result, most technology development needed for risk reduction, efficiency, or modernization cannot proceed beyond Technology Risk Level 6. Until this Tritium R&D mission gap is resolved, opportunities for increasing efficiencies and reducing operations and maintenance costs are limited. This project proposal would explore creation of a new radiological tritium R&D facility with the capability to perform testing and demonstration to mature processes and gas transfer systems to Technical Readiness Level 7 in operational environments.

4.2.2 Mission Enabling Line-Item Construction Projects

In addition to programmatic line items, DOE/NNSA funds mission-enabling infrastructure line items such as site-wide utilities, office and laboratory space, and services to support the nuclear weapons mission (see **Figure 4–7**).

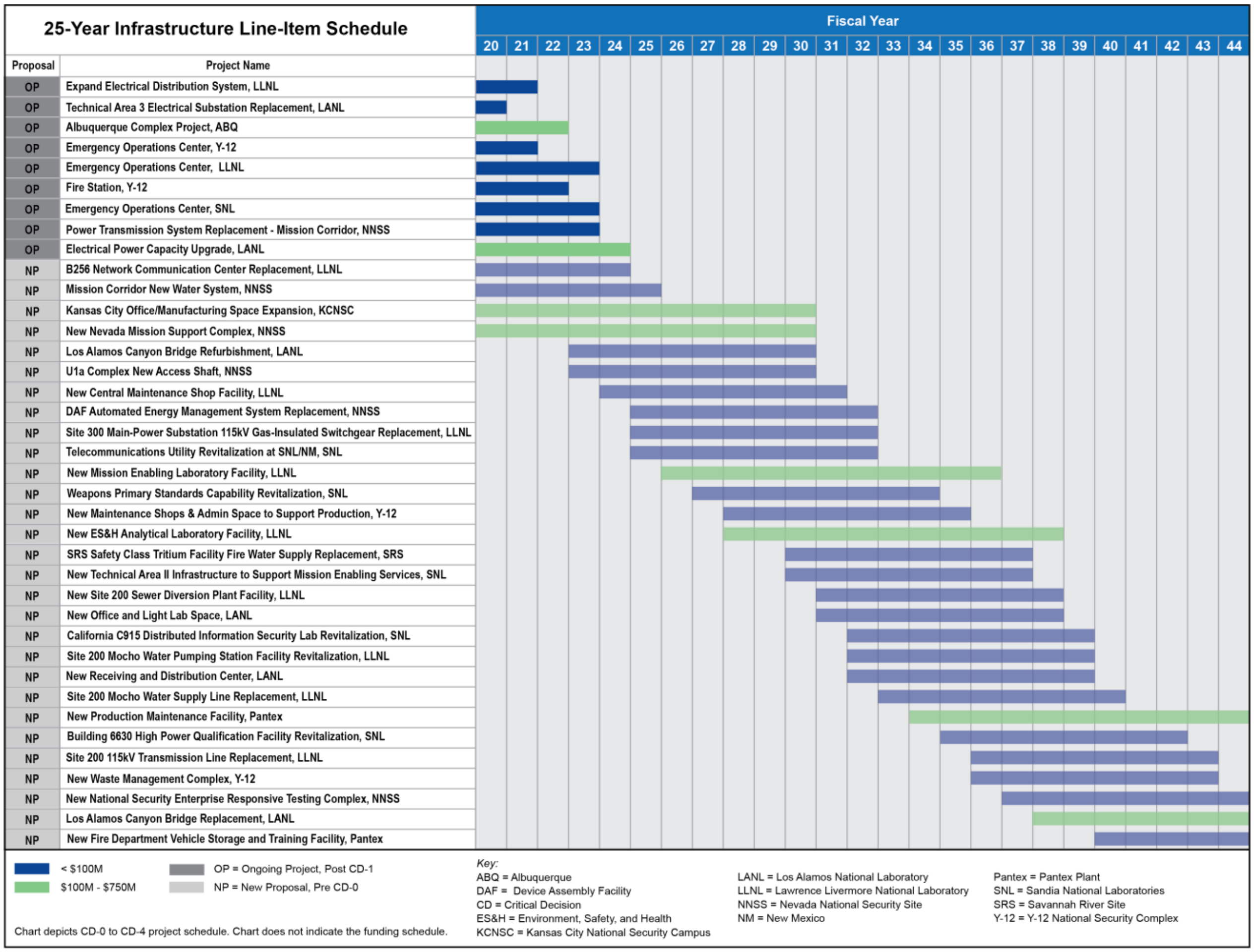


Figure 4–7. DOE/NNSA 25-year infrastructure line-item schedule

DOE/NNSA is already executing multiple ongoing mission enabling projects that are past CD-1. These projects are listed in **Table 4–7**.

Table 4–7. Ongoing mission-enabling projects

Project	*Description*
Technical Area 3 Substation Replacement, LANL	The new modern substation 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 the LANL and Los Alamos County.
Expand Electrical Distribution System, LLNL	This project provides the most urgent electrical infrastructure needs by providing a reliable alternate electrical feed to mission-critical facilities at LLNL and SNL-California by expanding the electrical distribution systems at LLNL and providing a new electrical connection to the SNL-California site. As a supplement to the existing distribution system, it improves resiliency for certain mission-critical facilities at LLNL and SNL-California.
Power Transmission System Replacement – Mission Corridor, Nevada National Security Site	The project will replace a 55-year-old 138-kilovolt (kV) power transmission system in the Nevada National Security Site Mission Corridor in Mercury, Nevada to provide the Nevada National Security Site with reliable power and communications to mission-critical facilities. This project will design and construct a new 138-kV power transmission system in the Nevada National Security Site Mission Corridor. This power transmission system will replace and upgrade 23 miles of the degraded existing power transmission system and upgrade the collocated fiber optic lines to meet vital national security mission requirements. The project will be executed to allow continued operations of current mission-critical facilities.
Electrical Power Capacity Upgrade, LANL	This project addresses 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, including Directed Stockpile Work simulation requirements, is expected to exceed the capacity and performance requirements of LANL's existing transmission and distribution system. A significant electrical demand increase will support critical Directed Stockpile Work requirements for LEPs, significant finding investigations, and ongoing Stockpile Stewardship Program, national security, R&D, and other work.
Fire Station, Y-12	The project 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.
Albuquerque Complex Project	The NNSA Albuquerque Office Complex is beyond its design life and does not meet NNSA's needs. Construction has started on a 333,000-square-foot building to house approximately 1,200 employees. The building is being constructed on DOE property in Albuquerque, New Mexico, adjacent to Kirtland Air Force Base. The new building is designed to Leadership in Energy and Environmental Design Gold Standards.
Emergency Operations Center, Y-12	The project 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*.
Emergency Operations Center, SNL	This project 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.
Emergency Operations Center, LLNL	This project 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.

At the time of writing this SSMP, no mission-enabling projects are "under development" from CD-0 to CD-1. However, multiple new proposals for such projects are planned to begin in the FYNSP. A description of these proposed projects can be found in **Table 4–8**.

Table 4–8. New proposals for mission-enabling projects

Project Proposal	Description
Mission Corridor New Water System, Nevada National Security Site	The project would replace end-of-life wells, tanks, distribution lines, pumps, and support facilities to provide water supply and distribution to the Device Assembly Facility, U1a Complex, Control Point, Area 6 Complex, and other critical mission facilities.
B256 Network Communication Center Replacement, LLNL	The project would provide a new facility to meet current and future communications needs. The existing facility has reached its capacity and cannot accommodate new or updated networks and systems. The facility will accommodate modern communication equipment configuration requirements and eliminate a single point-of-failure for networking, telecommunications, and safety alarms
Kansas City Office and Manufacturing Space Expansion Project	KCNSC needs a sustainable long-term office and manufacturing space solution to meet workload and mission needs or risk the inability to meet cost, schedule, and performance objectives An analysis of required spaces is being developed to inform decisions about long-term office and manufacturing space solutions.
New Nevada Mission Support Complex	A proposed Nevada Mission Support Complex project would provide sustainable infrastructure that supports the health, safety, and welfare of the employee, the public, and the environment. As NNSA moves toward a smaller, safer, more secure, and less expensive enterprise, consolidation of functions into newer and fewer facilities at the Nevada National Security Site are necessary to align the site with DOE and NNSA Strategic Plans. The Nevada Mission Support Complex will collocate functions, improve collaboration and productivity, address workforce recruitment and retention challenges, and enable resources to be redirected toward critical mission work and away from infrastructure maintenance on obsolete facilities.

4.2.3 Defense Nuclear Security Line-Item Projects

DOE/NNSA's Defense Nuclear Security (DNS) Program continues to manage numerous projects, as outlined in the *10-Year Physical Security Systems Refresh Plan* submitted to Congress in August 2017. Two ongoing DNS line-item construction projects are beyond CD-1, as outlined below. DNS will continue to evaluate infrastructure needs to determine whether additional new projects are necessary in the future.

4.2.3.1 Ongoing Projects

West End Protected Area Reduction (WEPAR) – The WEPAR project will reduce the size of the protected area at Y-12 from 150 acres to approximately 90 acres. This project will have two beneficial outcomes. First, the sensitive facilities remaining within the now reduced perimeter will be protected by a new, correspondingly smaller, Perimeter Intrusion Detection and Assessment System (PIDAS), 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 is currently developing the approval performance baseline (CD-2) and the approval to start construction or execution (CD-3) package.

Device Assembly Facility (DAF) – The DAF Argus Project at the Nevada National Security Site will continue to install new security system elements into the DAF Building and perimeter. The installation has been completed on the perimeter, and installation of the interior is currently underway. Project completion is expected in FY 2021.

4.3 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. These projects provide an immediate return on investment and 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.

4.3.1 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 Dynamic Equations of State Facility at LANL and the Battery Test Facility at SNL. These investments are 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 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 safety, security, environmental, and program risk; 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 impacts, 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 2018, DOE/NNSA completed 56 recapitalization projects, a 21 percent increase from 2017. This improved performance reflects the impact of advanced planning based on detailed data and the use of the improved reporting tools and processes.

Several completed projects serve as examples of addressing specific criteria in the risk-based assessments:

- White Space Modification for Additive Manufacturing Installation at KCNSC
- New Dynamic Equation of State Facility at LANL

- High Explosives (HE) Synthesis Pilot Plant Renovation at LLNL
- Building 151 Hood Replacement at LLNL
- DAF Fire Suppression Lead-In Lines Replacement at the Nevada National Security Site
- DAF Storage Vault Upgrade at the Nevada National Security Site
- Multiple Building Emergency light Replacements at Pantex
- Primary Standards Laboratory Revitalization at SNL
- Electrical Substation Installation at SRS
- Building 9204-02 Penthouse Floor Shoring at Y-12

Equation-of-State Facility at LANL

4.3.1.1 Current Recapitalization Projects

DOE/NNSA currently has approximately 240 active individual projects. The majority of these projects are below $10 million. There are more than a dozen projects ranging between $10-20 million that leverage new authorities provided by Congress to DOE/NNSA. Projects that have common attributes are placed into multi-year portfolios. Below are some examples of DOE/NNSA's ongoing portfolios and projects.

$10-20 Million Project Examples

- Revitalization for Crystal Laboratory Relocation at LANL
- Dual-Axis Radiography Hydrodynamic Test (DARHT) Weather Enclosure Addition at LANL
- Applied Materials and Engineering Capabilities Modernization Facility at LLNL
- New Mercury Building at the Nevada National Security Site
- New Gas Analysis Laboratory at Pantex
- Secondary Electrical Feed Installation at Pantex
- New Z pulsed power facility (Z) and Technical Area IV Missions Support Facility at SNL
- New Data Center Facility at SNL

Project Portfolio Examples

- Area Modification for Production Security Verification at KCNSC
- Plutonium Facility (PF-4) Fire Water Loop Component Replacement at LANL
- High-Level Radiochemistry Gloveboxes Laboratory Revitalizations at LLNL
- U1a Complex New Refuge Chamber Drift Installation at the Nevada National Security Site
- 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

4.3.1.2 Recapitalization Program Planning Improvements

DOE/NNSA is launching efforts to better understand long-term programmatic capability and associated capacity throughput requirements to better evaluate infrastructure options. One example is the biennial infrastructure planning "Deep Dive" reviews, which are held at each site as part of an effort to improve long-term planning and ensure that mature project proposals are integrated into the overall plan prior to receiving funding. This demonstrates an emphasis on facility life cycle management, which will result in better investment decisions based on understanding the overall condition, capabilities, capacity, readiness, and reliability of DOE/NNSA's infrastructure. Additionally, more front-end planning studies are being initiated to ensure that NNSA can integrate multiple Federal and M&O site organizations while designing multi-project plans to address complex infrastructure challenges. The new Kansas City Strategic Infrastructure of Non-Nuclear Components (SINC) is an example of an ongoing DOE/NNSA integrated infrastructure front-end planning study.

Together, these efforts strengthen our modernization plans by ensuring that projects are fully scoped, well-integrated, and executed on time and within budget. Additionally, DOE/NNSA developed a Master Asset Plan to communicate more detailed infrastructure health and the modernization strategies developed to enable the Stockpile Stewardship Program.

4.3.2 Site-Directed[2] Minor Construction Investments

DOE/NNSA contracts for site management and operation 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 the sites. 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 use and whether the site has a multi-program portfolio.

Many DOE/NNSA M&O partners use indirect funding to address high-priority needs at each site. On multi-program sites, indirect funding pools may be created through institutional assessments or other similar mechanisms. The 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 is aligned with accounting standards for demonstrating a causal-beneficial relationship, i.e., indirect funds are used for multi-program functions and purchases that deliver benefits across programs. In addition, M&O partners are 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-program sites, especially the laboratories. These IGPPs are often small 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 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

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

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.

4.3.3 Defense Nuclear Security Minor Construction Investments

The Security Infrastructure Revitalization Program (SIRP) was created by DNS to address the significant decline in the physical security infrastructure supporting the DOE/NNSA mission at the eight sites. 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 upgrades required. The plan considers multiple funding vehicles, but the majority of the plan does not rise to line item construction level, with project costs under $20 million.

The *10-Year Physical Security Systems Refresh Plan* documents needed security infrastructure investments and is critical to the overall effectiveness of the revitalization effort Ever-changing threats, technologies, and system requirements present challenges to ensuring that capital projects effectively address the most current threats and mitigate current risks.

DNS approved minor construction projects at six sites for FY 2019 (by site):

- TA-72 Outdoor Range Upgrades Project, LANL
- Range Facility Replacement, LLNL

4.4 Sustainment

Sections 4.1 through 4.3 described the ways in which DOE/NNSA acquires or modernizes facilities. This section focuses on how DOE/NNSA maintains and operates existing infrastructure in support of the nuclear security mission. Each site 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.

4.4.1 Infrastructure Operations and Facility Sustainment

The Operations of Facilities 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.

DOE/NNSA's sustainment activities are carried out through a combination of innovative tools that feed into risk analyses that support infrastructure management decisions. These decisions ensure that critical resources are dedicated to maintaining facilities already in good condition and repairing the highest risks in DOE/NNSA assets. One of these innovative 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 single source of information on the condition of all 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 aim at sustaining 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 that is required 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 maintenance activities that were not performed when they should have been or were scheduled to be and were put off or delayed for a future period. Repair Needs are the objective 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. Deferred Maintenance and Repair Needs are calculated and tracked by M&O partners in the Facilities Information Management System.

The Asset Management Program repairs and replaces major building systems that are common across the DOE/NNSA enterprise (e.g., roofs; heating, ventilation, and air conditioning [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.

RAMP Before and After at Pantex

4.4.2 Programmatic Facility Sustainment

In some instances, the nature of core mission areas leads to direct programmatic sustainment funding for certain operations. For example, the ST&E Program is responsible for the high-performance computational capabilities needed for stockpile stewardship in modeling, simulation, and experiments conducted at various facilities and experimental capabilities such as inertial confinement fusion. Within ST&E, operational costs at facilities are directly supported and budgeted within the Inertial Confinement Fusion Ignition and High Yield (ICF) and Advanced Simulation and Computing (ASC) Programs. The ICF Facility Operations and Target Production subprogram supports efficient operations at the National Ignition Facility (NIF), Omega Laser Facility (Omega), Z, and the Trident and NIKE facilities (see Chapter 3, Section 3.2.3, for more information on NIF, Z, and Omega). Similarly, the ASC Facility Operations and User

Support subprogram provides the facilities and services required to provide 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.

The ICF facilities provide experimental access to the HED physics regime and are principle tools used for primary assessment, secondary assessment, and nuclear survivability. These capabilities are further leveraged by mission partners at DoD and the UK's Atomic Weapons Establishment. As part of 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 Sandia National Laboratories' Z Machine

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/or Advanced Technology systems. Each laboratory's computing capability comprises not only the high performance computing (HPC) system itself, but also ancillary physical components such as physical 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 or include multiple buildings.

ASC manages the costs associated with each laboratory's current computing centers and considers multiyear 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.

4.4.3 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.

4.4.4 Sustainment through Leased Facilities

Leases are an important and useful real estate strategy to address short-term needs. They 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 piloting a new lease rating system to provide a quantitative method for evaluating existing and future leases. This system evaluates the rent, terms and conditions, existing tenancy length, exit strategy, and space utilization rate to produce a unified score for a prospective lease. As this system matures, it will be increasingly integrated into the DOE/NNSA lease strategy and decision-making process.

4.4.5 Defense Nuclear Security Sustainment Investments

DNS has a process in place for funding operations and sustainment of safeguards- and security-related equipment and facilities. During the annual programming process, M&O partners submit requests for funding these sustainment activities. Some of these activities include upgrading or replacing training equipment and facilities. For FY 2019, numerous sustainment projects were approved, including firearms range refurbishments and replacement of Protective Force tactical training simulators.

4.4.6 Chief Information Officer Sustainment Investments

NNSA's Office of the Chief Information Officer (OCIO) has processes and procedures in place for providing funding to the sites for operations and sustainment of cybersecurity components, hardware, and software related to sustainment of information assurance capabilities and operations, including replacement of network switches and routers.

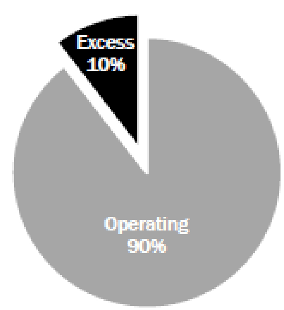
4.5 Addressing Excess Facilities

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 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 and require more than $50 million to disposition then the responsibility to disposition resides with DOE's Office of Environmental Management.

DOE/NNSA's FY 2018 budget included more than $50 million to continue reducing the risks posed by excess facilities and to demolish buildings. In FY 2018, DOE/NNSA:

- Demolished the TA-16-0280 complex and characterized and planned for disposition of the TA-16-0460 complex in the HE area and Building TA-16-0306 at LANL
- Demolished 14 facilities operated by DOE/NNSA's Kansas City Field Office on Kirtland Air Force Base (NC-135) in New Mexico (where SNL is collocated) in an area needed by the Air Force for flight path safety
- Eliminated one asset at the Nevada National Security Site as part of the modernization effort for the Mercury area
- Continued risk reduction at Y-12's Alpha 5, Beta 4, and Building 9206, including work to drain the Alpha 5 mercury house system, de-inventory oils and fluids in Alpha 5 and Beta 4, remove legacy material, and close tanks and dikes



NNSA Excess Facilities

- Demolished the Alpha-5 Annex and Building 9720-24 at Y-12, Building 232-1H at SRS, and Building 363 at LLNL
- Planned the isolation, disposition, and reroute of utilities at Alpha 5 and Beta 4, which is related to the reduction of the protected area at Y-12
- Characterized and planned for disposition of Buildings 9720-22 and the Beta 4 ancillary Buildings 9404-16, 9409-20, and 9811-04 at Y-12

In addition, in FY 2018, Congress provided $225 million to the DOE Office of Environmental Management to demolish high-risk excess facilities at Y-12 and LLNL.

4.6 Modernization of Programmatic Equipment

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

DOE/NNSA manages and funds equipment procurement across the nuclear security enterprise through multiple programs. Programs such as LEPs or the Engineering Program 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 Support, and Operations of Facilities, Maintenance and Repair of Facilities, and in some cases, the Recapitalization Program. To add further complexity, 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. 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 base capability program serves the mission of its respective overarching office, the integrated nature of nuclear weapons work creates natural mission overlap between these offices and other programs. In these cases, to better align planning and programming activities among relevant DOE/NNSA programs, the Programmatic Recapitalization Working Group serves as a forum to coordinate efforts involving more complex equipment projects. The working group also provides guidance to M&O partners on appropriate funding offices for acquiring particular items of equipment.

Equipment modernization, replacement, and refurbishment are key activities tied to the 2018 *Nuclear Posture Review* guidance 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 below are in alignment with the *Nuclear Posture Review* mandate and provide the baseline activities essential to maintaining a functional nuclear security enterprise.

4.6.1 Programmatic Equipment Investments

Equipment investments by mission-specific programs are dictated by programmatic need. LEPs, Stockpile Systems, ST&E, and Weapons Technology and Manufacturing Maturation are examples of programs in this category.

For the weapons programs (LEPs and Stockpile Systems), equipment purchased ranges from radiography machines, shaker tables, blast tubes, and 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 to component design and would cover these costs, as the requirements for that equipment would be tied directly to their program. For example the W88 Alt 370 supported purchase of the Molecular Beam Epitaxy tool used to produce strategic radiation-hardened heterojunction bipolar transistors and other testing equipment like the hypersonic wind tunnel and laser vibrometer required for design and qualification. The W80-4 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 part requirements.

Weapon programs also invest in equipment and infrastructure necessary to maintain their schedule. Many times, 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 LEPs can benefit, CBI (described below) is also a major source of funding.

ST&E Program investments cover a range of highly specialized and common equipment that is essential to the high tech work of stockpile stewardship. This equipment provides or facilitates environments for testing and experimentation, produces data from those experiments, and helps synthesize the data from the experiments to inform design, production, qualification, and surveillance activities. Examples include ASC Program needs, equipment tied to subcritical and hydrodynamic experiments, and advanced radiography. Given the specialized nature of this equipment, these investments can be quite costly. Typically, new equipment is procured by programs as mission needs arise or new facilities or capabilities come on line. In addition, as urgent needs arise, CBI makes investments in equipment tied to ST&E Program missions that are tied to LEP schedules.

The Additive Manufacturing (AM) and Component Manufacturing Development (CMD) Programs, make equipment investments aimed at proving-in 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 Production Support would be expected to purchase the remaining equipment needed to realize the AM/CMD-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. Examples of equipment procured through these programs include a variety of additive manufacturing machines, advanced testers, and other supporting equipment.

4.6.2 Capabilities-Based Investments

CBI supports programmatic equipment and facility investments at all DOE/NNSA sites. These projects are prioritized based on requirements and risks documented by the potential user programs. All CBI projects must provide an enduring capability and not be specific to a single weapon system. CBI projects support consolidation and replacement of unreliable facilities and infrastructure that have exceeded life cycle expectations and pose safety and program risks to people and the mission. Over the past year, the CBI portfolio has evolved.

CBI Accomplishments

- *Accelerated 12 projects from future years into the current fiscal year.*
- *Completed the High Explosive Synthesis Pilot Plant at LLNL, reconstituting the capability to perform synthesis of pilot-scale quantities of high explosives via remote operations reliably and safely to support LEPs.*
- *Completed the JASPER Large Bore Gun upgrade at the Nevada National Security Site, enabling plutonium information gathering to support weapon design and certification.*
- *Completed special nuclear material workstations and facility modifications at Pantex, establishing a second requalification line to support current and future LEPs.*

Table 4–9 provides a high-level summary of CBI challenges and strategies.

Table 4–9. Summary of Capabilities-Based Investments Program challenges and strategies

Challenges	Strategies
Planned projects for execution in a given fiscal year were delayed until project funds were made available, impacting execution and performance metrics.	CBI began disbursing dedicated planning funds in the current fiscal year to support project planning in the next two fiscal years.
Unclear responsibilities among DOE/NNSA organizations to fund projects to recapitalize/maintain nuclear security enterprise capabilities may cause confusion within DOE/NNSA and at the sites when determining funding alignments and priorities.	The Programmatic Recapitalization Working Group was established in 2018 as a forum for DOE/NNSA and the sites to raise and resolve issues around responsibility, and to increase DOE/NNSA's understanding of the state of programmatic infrastructure across the enterprise. Participants include representatives from DOE/NNSA organizations and the site M&O partners.

4.6.3 Production Support Equipment Investments

The Production Support Program provides base capabilities to enable assembly, disassembly, and production activities funded by the LEPs, Stockpile Systems Program, or Weapons Dismantlement and Disposition Program. The Production Support Program's equipment scope is generally site-specific, as opposed to integrating multi-site activities, which is the mission of the Management, Technology, and Production Program. The program also maintains specific base production capabilities for critical nuclear weapon components, such as neutron generators at SNL and detonators at LANL.

Equipment procurement and installation within the Production Support Program can range from the Major Item of Equipment level ($5 million and above) to the purchase of equipment well below $100,000. 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. Still, equipment funding out of the Production Support Program is small in relation to the labor costs associated with maintaining a functional and responsive nuclear security enterprise.

Typical investments funded by the Production Support Program include:

- Multi-weapons system base capabilities in component manufacturing, assembly, and disassembly, including gloveboxes, mills, and lathes
- Strategic materials-related process and production equipment in the absence of dedicated programs or resources for those projects
- Equipment for moving product
- 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
- Simulation capabilities, including HPC and qualified analysts, to support improved reliability (and thus decreased waste and costs) and an accelerated timeline for production activities, including the use of advanced manufacturing techniques

4.6.4 Infrastructure Recapitalization, Operations, and Maintenance Equipment Investments

The Operations of Facilities Program funds activities that include some costs associated with the 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 needs to manage and support the equipment/capability
- Activities used 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 needs necessary for the equipment/capability to function effectively in support of programmatic needs
- Training required to operate the equipment/capability in a safe, secure, and effective manner

The Maintenance Program funds activities that include sustaining and preserving equipment in a condition that is suitable to perform its desired purpose. Maintenance funding can be used to replace equipment without an increase to capability or capacity.

The Recapitalization Program supports installation, replacement, or upgrade of personal property assets that directly support or are integral to weapon activity deliverables. There is a tradeoff between maintenance and operations funding and equipment or asset recapitalization.

4.6.5 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 (see Section 4.3.2). Programmatic equipment that supports multiple programs should be allocated to those programs in accordance with the benefits received.

4.6.6 Defense Nuclear Security Investments

For FY 2018, DNS directed numerous equipment purchases related to typical security equipment modernization. These approvals included arms, 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.

4.6.7 Chief Information Officer Equipment Investments

NNSA's OCIO provides funding to the sites for the purchase and upgrade of networks, systems, and applications related to cybersecurity operations. These purchases may include firewalls, intrusion protection systems, intrusion detection systems, security hardware components, software system upgrades, and other security-related purchases to improve, modernize, and maintain cybersecurity operations.

4.7 Modernization of Information Technology and Cybersecurity Infrastructure

NNSA's OCIO continues to play a critical role in enhancing the responsiveness and resiliency of DOE/NNSA infrastructure by improving information technology (IT) and cybersecurity and focusing on threats and vulnerabilities. Classified computing for DOE/NNSA has grown dramatically over the past 30 years and, with each decade of growth, there have been substantive movements toward enterprise solutions. Reducing and mitigating cybersecurity risks, and supporting changes within the DOE/NNSA weapons life cycle continue to be major drivers of this growth. The current cybersecurity risk driving development and implementation of Enterprise Secure Network (ESN) 2.0 is the necessary use of a global IT supply chain for the weapons programs. Three approaches are proposed to mitigate cyber risks:

1. Evaluate and replace all software and hardware having supply chain issues
2. Build an enterprise infrastructure that validates/distributes/controls all software and hardware including those with supply chain issues
3. Build and implement a security architecture that will ensure continued the protection of information and information assets

Implementation of the NNSA OCIO's IT and cybersecurity projects is critical to the overall effectiveness of the nuclear security enterprise. Changing threats, technologies, and network and system requirements will continue to present challenges, but the criticality of DOE/NNSA's nuclear security missions and the consequences of failure demand that all elements of the nuclear security enterprise remain secure.

4.7.1 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 shown above. **Table 4–10** below lists examples of ongoing and completed IT and cybersecurity projects.

4.7.2 Planned NNSA OCIO Projects in 2020

NNSA's OCIO will begin six new projects in FY 2020:

- Deployment of Phase I of the hybrid cloud platform for the Enterprise Secure Computing (ESC) cloud-based technologies for application hosting at LLNL
- Deployment Phase I of the hybrid cloud platform for the ESN 2.0 West Coast communication hub, which leverages cloud-based technologies for classified application hosting at LLNL
- Deployment of Phase I of the small hybrid cloud platform for the ESC testing environment for mission software at SNL
- Deployment of Phase I of the hybrid platform for the ESC cloud-based technologies for classified application hosting at the East Coast Data Center
- Deployment of a hybrid cloud platform in support of the Joint Technology Demonstrator project for Weapons Activities at KCNSC
- Deployment activities to support network monitoring, including construction and monitoring services, at SRS

Table 4–10. Ongoing and recently completed information technology and cybersecurity projects

Activities	Description
Virtual Desktop East/West	This project will provide standard desktop applications and processes for the nuclear security enterprise, ensuring a desktop configuration with flexibility and agility that will empower staff to complete their work.
Network Sensor Monitoring Upgrade	DOE/NNSA is upgrading the enterprise portion of its network cybersecurity monitoring tools. This upgrade will bring unprecedented new capabilities to inspect network traffic to detect and respond to malicious network activity.
Enterprise Desktop	A centralized, secure process for distribution of source code/binaries for all hosted applications will be utilized. This process will allow administrators to select pre-approved software packages or request evaluations of new packages as needs arise. These software packages will be downloaded from the original equipment manufacturers, validated, transferred to the Enterprise Secure Network (ESN), and loaded into a central software repository. Patches and updates for this software will follow consistent processes to increase network protection and promote anti-subversion security protocols.
Application Hosting	DOE/NNSA will implement a private cloud infrastructure, using Microsoft Azure Stack, to host all enterprise applications. This infrastructure will be hosted at geographically separated locations. Applications will be able to utilize one or both sites as deployment hosting environments, depending on mission needs. The cloud infrastructure will have a storefront offering services and components that are pre-accredited. As the environment and the processes governing it mature, more components will be accredited and made available in the storefront. Configuration management processes and tools will be provided to application owners and will dictate technical refresh activities.
Enterprise Networks	The new network will adopt platform and will reduce the requirement for application integration and patching of the underlying operating systems, application services, and other infrastructure elements. Platform as a service will be available for applications as they are ready to be migrated from ESN 1.0 to the new network.
Enterprise Secure Network	This project seeks to provide the comprehensive and consolidated logical secure infrastructure necessary to provide secure, reliable, effective non-nuclear components that will allow design, development, and prototyping of weapon hardware, software, systems, and applications. The architecture will allow DOE/NNSA programs to develop solutions using cloud-ready tools and applications in a classified cloud environment without redesign.
Application Migration	Application rationalization will determine the suitability of applications to keep, upgrade, or terminate using a risk-based approach. Critical applications will be migrated from individual sites into the new cloud environment. During the application migration work stream, appropriate technologies and products will be selected and migrated to a streamlined and optimized DOE/NNSA application portfolio. A multi-year migration strategy for moving the applications into the cloud will be developed, with appropriate participation from stakeholders. The strategy will span both classified and unclassified networks to ensure efficient and secure investments in IT products.
Enterprise Services	DOE/NNSA will implement products and services that will introduce a true enterprise cloud-based model for IT services and delivery. This opportunity to reexamine site hosting requirements and adopt more cloud-oriented architectures that will provide best-in-class security for the Defense Programs, Defense Nuclear Nonproliferation, and Counterterrorism and Counterproliferation programs. This will move DOE/NNSA to a cloud model with common services and enterprise applications.
Center of Excellence for Threat Intelligence Project	DOE/NNSA will enhance the sensor stack to add increased capabilities and performance, meet departmental mandates regarding cybersecurity data taxonomy, and build a collaborative effort for developing, training, and leveraging site cybersecurity defenders focused on enterprise threat.
Joint Development Environment (JODE)	The United Kingdom's (UK) Gateway Enhancements, also referred to as JODE, will automate existing collaboration processes between the United States and the UK Atomic Weapons Establishment. JODE is a joint U.S.-UK effort to create a collaborative environment within a secure network. To facilitate this automated joint collaboration, a secure Virtual Desktop Infrastructure will be established where users from the United States and the UK can share information in real time. Implementation JODE will provide a secure Virtual Desktop Infrastructure for classified data exchange improvements that enable effective communications while supporting real-time and large-scale information exchanges between the United States and the UK.
Plutonium Pit Production Mission Support	DOE/NNSA will establish an infrastructure in support of implementation of unclassified and classified wired and wireless infrastructure, to include cybersecurity, IT, and Operational Technology components, in support of meeting the 80 pits per year mission.

4.8 Leveraging Weapon Activities Investments Across DOE/NNSA

Several other DOE/NNSA programs (e.g., Defense Nuclear Nonproliferation [DNN], Counterterrorism and Counterproliferation, and Emergency Management Programs) rely on infrastructure funded by Weapons Activities. These programs are described in DOE/NNSA's *Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats (FY 2020 – FY 2024)*.

4.8.1 Support of Nonproliferation Efforts

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

- Technical Area 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

DNN's R&D program relies on supportive capabilities at a number of laboratories, plants, and sites that enable mission-relevant R&D activities

- The Nevada National Security Site 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 laboratories
- The DAF hosts and facilitates detection experiments for university and laboratory projects that transition to mature systems
- SNL, LANL, LLNL, and the Nevada National Security Site provide critical expertise and infrastructure to support a number of weapons-related experimental campaigns
- 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 the Nevada National Security Site, 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

DNN's Material Management and Minimization Program relies heavily on the infrastructure maintained by other DOE/NNSA offices. Impacts of the aging infrastructure on the implementation of key nonproliferation programs are summarized below.

- **Conversion Program.** Y-12's uranium facilities perform casting activities that produce low-enriched uranium-molybdenum (LEU-Mo) material that will allow conversion of the U.S. high-performance research reactors that currently use highly enriched uranium (HEU). Aging casting furnaces at Y-12 are a programmatic risk to production of future LEU-Mo material. The casting technology for the Uranium Processing Facility will be different than what is currently available at Y-12, but the capabilities at the Uranium Processing Facility or other facilities at Y-12 could be used to accommodate the Office of Material Management and Minimization's casting needs for the U.S. high performance research reactors conversion project in the future.

- **Conversion Program.** 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.
  - Under the proposed Dilute and Dispose approach, the Waste Isolation Pilot Plant (WIPP) would be used to permanently dispose of diluted plutonium oxide. WIPP is also being used to dispose of transuranic waste generated from other nonproliferation 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, and to construct a transuranic waste storage pad and loading capability for shipping diluted plutonium oxide to WIPP.
  - The H-Canyon at SRS processes off-spec HEU into blended low-enriched uranium material for disposition.
  - Savannah River National Laboratory provides R&D for a variety of material disposition activities.
  - Enriched uranium operations infrastructure at Y-12 allow analysis, processing, and packaging of materials to be down-blended or properly disposed.
- **Nuclear Material Removal Program.**
  - DOE/NNSA's Secure Transportation Asset Program provides resources for multiple material removal campaigns. The 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 receives reactor fuel 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.

DNN'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 and facilities for testing prototype safeguards equipment, and for training 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, DNN offices will work with the appropriate program managers to ensure NPAC goals are incorporated as resources allow.
- NPAC uses the Nevada National Security Site as a training ground to develop a U.S. capability to perform field verification activities for suspected nuclear explosions. Focused exercises will

coordinate with other programs' activities as appropriate and are expected to begin at the Nevada National Security Site in FY 2020-2021, with the goal of an integrated field exercise, potentially at the Nevada National Security Site, in FY 2022-2023 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 to test warhead monitoring and verification capabilities and assess the feasibility of equipment deployment at weapons facilities. In FY 2019, this will include demonstration and testing of a prototype Portal Monitor for Authentication and Certification system, which is a radiation portal monitor designed specifically to facilitate deployment in sensitive nuclear weapons-related facilities in support of potential future monitoring and verification initiatives. These types of 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, and support the U.S. ability to engage technically with partner countries under initiatives such as the International Partnership for Nuclear Disarmament Verification.
- 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 also co-hosted, with Defense Programs support, two Nuclear Non-Proliferation Treaty transparency visits for non-nuclear weapons state representatives to stockpile stewardship facilities at LANL and SNL. These visits demonstrated how stockpile stewardship supports the U.S. commitment to forego nuclear explosive testing.
- NPAC uses KCNSC, LANL, LLNL, SNL, and the Nevada National Security Site 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, and 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.

4.8.2 Support of Counterterrorism and Counterproliferation and Emergency Operations Efforts

The Counterterrorism and Counterproliferation Program (CTCP) relies heavily on the infrastructure maintained and primarily used by other DOE/NNSA offices, in particular the Stockpile Stewardship Program. CTCP leverages both the physical infrastructure detailed below, and human capital and skill sets developed and occasionally co-supported by DOE/NNSA's Stockpile Stewardship Program, intelligence and analytical programs, emergency response activities, and fuel-cycle related programs. While CTCP may use only a small portion of these human capital and physical assets' total capacity, this shared use supports critical national security efforts and brings unique and scarce capabilities to bear on the counterterrorism and counterproliferation missions.

- To deepen the scientific and technical knowledge of nuclear threat device concepts, CTCP makes use of the Neutron Science Center, DARHT, gas guns, Ancho Canyon, and the Proton Radiography Facility at LANL; the Superblock, Contained Firing Facility, High Explosives Application Facility, and gas guns at LLNL; the Z Facility and Thunder Range at SNL; and the National Criticality Experiments Research Center, Joint Actinide Shock Physics Experiment Research gas gun, Big Explosives Experimental Facility, and Baker Compound at the Nevada National Security Site. Understanding nuclear threat device concepts also requires HPC platforms to design predictive models concerning device performance and experimental facilities to refine and validate these models. Computer platforms and codes supporting these functions include those developed specifically for nuclear counterterrorism analysis, and others developed for the Stockpile Stewardship 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 the Stockpile Stewardship Program provide a strong foundation for the technical nuclear forensics mission. The Stockpile Stewardship Program supports much of the expertise, facilities, nuclear material handling infrastructure, and historic knowledge necessary to perform technical nuclear forensics. 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.
- Finally, to support reachback and training to build international capacity, and in support 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 Radiation Assistance Program, based at nine DOE/NNSA 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; and Emergency Operating Centers located at several national laboratories. 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.

4.9 Management and Performance

Since 2011, DOE/NNSA has delivered approximately $2 billion in projects, a significant portion of 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 5
Secure Transportation Asset

The Secure Transportation Asset (STA) Program provides safe, secure transport of the Nation's nuclear weapons, weapon components, and special nuclear material (SNM) throughout the nuclear security enterprise to meet nuclear security requirements and support Defense Programs and broader DOE/NNSA missions. STA provides secure transport for a variety of government agencies. 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 140 over-the-road shipments and made 40 limited life component deliveries without incident.*
- *Executed vehicle sustainment efforts to ensure mission vehicles are upgraded and maintained to provide reliable mission support.*
- *Awarded the Mobile Guardian Transporter Test Article 1 Rolling Chassis Contract and completed the Manufacturing Readiness Review for Test Article 2.*

The components of the STA security concept are specialized vehicles, secure trailers, specially trained Federal agents, and leading-edge communication systems.

DOE/NNSA Defense Programs is STA's highest-priority customer. STA also provides secure transport for other NNSA and DOE programs and offices and other government agencies, such as the NNSA Nuclear Counterterrorism and Incident Response Program, the NNSA Office of Naval Reactors, the DOE Office of Nuclear Energy, and the National Aeronautics and Space Administration. STA also supports international shipments.

Since its formal creation in 1974, STA has a record of no loss of cargo and no radiological release on any shipment. To maintain that record, STA must replace aging transportation assets and communication systems for convoy safety and security. The Safeguards Transporter (SGT) fleet is beyond its design life. STA is sustaining its capability by implementing a risk-reduction initiative to extend the life of the SGT until its replacement, known as the Mobile Guardian Transporter (MGT), becomes operational. Nuclear weapon life extension programs; limited life component (LLC) exchanges; surveillance, dismantlement, and nonproliferation activities; and experimental programs rely on transport of weapons, components, and SNM on schedule and in a safe and secure manner. STA supports the DOE/NNSA goals of consolidating storage of nuclear material and reducing the dangers and environmental risks posed by domestic transport of nuclear cargo.

Armored Tractor

5.1 Status

5.1.1 Major Elements of the Secure Transportation Asset

This section discusses the various property assets and personnel elements that comprise STA.

5.1.1.1 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 vehicles to extend their useful life, and procuring of new vehicles.

The process of identifying, designing, procuring, and manufacturing these vehicles takes several years. The vehicle fleet is currently being updated with replacement armored tractors, escort, and support vehicles. The STA program 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.

5.1.1.2 Trailers

The trailer fleet is a critical asset for transporting nuclear weapons, weapon components, and SNM 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 second-generation trailers began reaching their end-of-design life cycle in 2018, years before the first MGT will enter production. STA implemented risk-reduction initiatives to maintain current capability until the new MGTs are produced and operational.

5.1.1.3 Aviation

The fleet of government-owned aircraft provides 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 4-hour response time to nuclear incidents. STA must also support evacuation and relocation of key personnel to maintain continuity of government operations.

These aircraft provide emergency response in support of the Nuclear Emergency Support Teams, which include the Joint Technical Operations Team, Accident Response Group, and Radiological Assistance Program. Two of the aircraft are Boeing 737 models manufactured in 1996. With both aircraft more than 20 years old, a plan must be developed to replace them. STA also operates one McDonnell Douglas DC-9 aircraft that was manufactured in 1969 and is 50 years old.

A Business Case Analysis was performed that supports replacement of the aging DC-9. This replacement acquisition is planned for FY 2021. Replacement of the two 737 aircraft is planned in FY 2025 and FY 2029, respectively.

5.1.1.4 Communications

Reliable, secure, real-time communication is crucial to ensure 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 cyber security to ensure system reliability and integrity.

5.1.1.5 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 offerings for Federal agents, including special weapons, tactical scenarios, initial Nuclear Material Courier Basic (NMCB) training program for Federal agent candidates, and other general training, covering all aspects of convoy operations. The Federal Law Enforcement Training Center, at Glynco, Georgia, is an integral part of STA's training curriculum. The center provides basic law enforcement authority, tactics, and other specialized training for Federal agents. Federal agent law enforcement authority and specialized training are continually evaluated to respond to the dynamic operational environment.

5.1.1.6 Safety and Security

Validation Force-on-Force exercises are assessments designed to test STA's Active Security Doctrine and determine system effectiveness for 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. 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 and NNSA.

5.1.1.7 Liaison

STA maintains a liaison program with agencies and organizations that may be in contact with a convoy or have to respond to an STA emergency. This interface extends across the 48 continental states, with the 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.

5.1.2 Changes from the FY 2019 SSMP

- As previously mentioned, STA has completed the Business Case Analysis to review options to replace its aging DC-9. The analysis supports the purchase of a new aircraft for planned inclusion in the FY 2021 budget. Replacement of the two 737s is planned for FY 2025 and FY 2029, respectively.
- The SGTs' operational life has been extended to FY 2031.
- DOE/NNSA will begin first production units of the next-generation Armored Tractor (T4) and Escort Vehicle 4 (EV4) in FY 2020.
- The milestone/objective for Advanced Radio Enterprise System (ARES) II deployment was removed. STA will update the current ARES as software becomes available, eliminating the need for redesign.
- In response to staffing issues and long clearance wait times, modifications were implemented to position qualifications, level of risk acceptance associated with the Human Reliability Program,

and a change in clearance requirements for Federal agent candidates to allow participation in NMCB training without a clearance.

- Additionally, STA introduced a modular training program allowing Federal agent candidates to be brought on board and placed into Federal agent training once psychological and medical screenings are complete.

5.2 Challenges and Strategies

Table 5–1 provides a high-level summary of STA's program challenges and strategies.

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

Challenges	Strategies
The SGT fleet is beyond its design life SGT sustainment faces challenges associated with obsolete parts, including difficulty finding new manufacturers and the high cost of limited-run production.	Develop the MGT to replace the aging SGT.
SGT Degradation SGT structural degradation occurs due to water intrusion, corrosion, and stress cracks.	Conduct SGT risk-reduction initiatives to address issues related to the aging SGT fleet. To ensure safe SGT operation, STA inspects the welds on all SGTs and conducts scanning to measure bolster plate thickness and wear from corrosion.
Sustainment of SGT Sustainment issues may outpace STA's capacity to mitigate its ability to meet Nuclear Explosive Safety Study requirements.	Work with partners to identify mitigation strategies to address Nuclear Explosive Safety Study requirements and sustain the capability.
Aircraft Aircraft performance and payload restrictions render STA unable to consistently support mission-related cargo, security operations, and Office of Counterterrorism and counter proliferation requirements.	Procure a DC-9 replacement aircraft (FY 2021).
Lengthy Security Clearance Processing	Modified position qualifications, level of risk acceptance associated with the Human Reliability Program, and a change in clearance requirements for Federal agent candidates to allow participation in the NMCB basic training without a clearance. Maintain a modular training program that allows Federal agent candidates to be hired and placed into training once psychological and medical screening are successfully completed. Manage the lengthy security clearance process for staff by providing alternative workspaces outside limited access areas.

MGT = Mobile Guardian Transporter
NMCB = Nuclear Material Courier Basic
SGT = Safeguards Transporter
STA = Secure Transportation Asset

Chapter 6
Security

The Defense Nuclear Security (DNS) and Information Technology (IT) and Cybersecurity Programs ensure the security of the Nation's nuclear materials, physical infrastructure, workforce, and information assets at NNSA Headquarters and its field offices, national security laboratories, nuclear weapons production facilities, and the Nevada National Security Site. The Chief of Defense Nuclear Security is responsible to the NNSA Administrator and the Secretary of Energy for developing and implementing safeguards and security programs and activities. That responsibility includes protection, control, and accountability of special nuclear material (SNM) to prevent loss, theft, diversion, unauthorized access, misuse, or sabotage of radioactive materials and the physical security of all facilities in the NNSA nuclear security enterprise. Similarly, the NNSA Office of the Chief Information Officer (OCIO) is responsible for managing and protecting all electronic information and information assets created, processed, transmitted, and stored by NNSA and its management and operating (M&O) partners. OCIO also coordinates with DoD, other government agencies, and allied nations to maintain strong cybersecurity defenses to ensure information is not compromised or subjected to unauthorized access or malicious acts.

6.1 Defense Nuclear Security

DNS leads, develops, and implements NNSA's security program to enable the NNSA's nuclear security enterprise missions by protecting materials, information, and people. DNS also has the critically important responsibility for adjudicating the personnel security clearances of the workforce at the NNSA field offices and the eight M&O partner sites. Beginning in FY 2019, NNSA assumed responsibility for funding the clearances of NNSA Headquarters personnel, consistent with direction provided in the Joint Explanatory Statement accompanying the *Energy and Water Development and Related Agencies Appropriation Act*, 2017. To carry out its mission to protect NNSA 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, DNS coordinates with other programs (e.g., Counterintelligence and Insider Threat). DNS also provides facility clearances for contractor organizations performing classified work for NNSA and administers the classification program to ensure information is properly identified for appropriate handling and protection. Dedicated and specially trained security professionals using an array of weapons and technologies to address general and site-specific threats, carry out the physical security mission at each field location. The programs and capabilities of DNS are arrayed against a broad range of threats to DOE/NNSA Headquarters and field offices, national security laboratories, nuclear weapons production facilities, and the Nevada National Security Site. 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.

6.1.1 Accomplishments

Safeguards and security personnel, layers of physical security systems and technologies, and sophisticated cybersecurity systems protect and carry out DOE/NNSA's missions in secure environments. Together, this approach protects DOE/NNSA's facilities, SNM, employees, networks, and information. In FY 2018, DOE/NNSA's DNS Program implemented 42 of the 56 key initiatives contained in the DOE/NNSA Security Roadmap, along with other activities that contribute to program effectiveness:

- The Security Management Improvement program helps ensure continuous improvement of the physical security program, relying on Headquarters and field collaboration to prioritize and implement risk-based solutions within an effective oversight regimen. Visits have been completed at all DOE/NNSA sites, and the results were compiled in a final report disseminated to all field office managers in December 2018.
- An intensive test and evaluation program assessed alternatives for a system to address the threat posed by unmanned aircraft vehicles. Initial deployment and operational testing of the system have been completed. DNS completed all required consultation engagements with the Federal Aviation Administration in December 2018 and issued the final authority to operate at that time.
- An enterprise-wide security culture campaign was executed with site-by-site visits and awareness presentations to the workforce that emphasized an individual commitment to the goal of "Protecting What is Ours."
- Security Infrastructure Revitalization program documentation was completed in 2017. In 2018, substantial progress was made in executing these activities. This plan is the implementing document for a 10-year effort to refresh and replace vital security technology and infrastructure. The Security Infrastructure Revitalization Plan provides a time-phased, prioritized approach to system refresh requirements that is anticipated to provide more viable funding projections.
- Six Tactical Casualty Care Instructor courses were completed, yielding 96 trained and certified Protective Force members. To date, approximately 90 percent of DOE/NNSA's Protective Force have been trained in hemorrhage control and have been issued individual first aid kits. This standardized first aid course is a crowning achievement in DOE/NNSA's Protective Force Training Reform initiative.

The Headquarters Security Operations organization implements all aspects of the DOE security program for DOE/NNSA Headquarters operations, including overseas offices, which serve approximately 2,500 partners. The organization also manages the newly established DOE/NNSA Headquarters Facility Survey and Approval program and assists all DOE/NNSA Headquarters offices in preparing for third-party security assessments and surveys. Activities included facilitating approximately 300 VIP and foreign national visits to Headquarters offices in FY 2018.

DOE/NNSA continues to provide comprehensive support in the areas of personnel and facility clearance processing. In FY 2018, over 27,000 adjudicative actions were performed, and three national-level requirements were implemented on schedule. In support of critical DOE/NNSA classified work, over 50,000 pages were reviewed. DOE/NNSA leadership selected the Clearance Action Tracking System Stabilization and Enhancement automated clearance workflow system for all DOE cognizant personnel security offices. Five of the eight offices, comprising over 90 percent of DOE clearances, are now operating on this system.

6.1.2 Status

DOE/NNSA has a network of programs and technical capabilities that are integrated to achieve graded levels of protection for personnel, sensitive information, weapons-grade SNM, and mission-critical facilities, calibrated by threat and asset importance. DOE/NNSA deploys various technologies at M&O partner sites for alarm management and control, intrusion detection and assessment, access controls, barriers and locks, secure storage, material control and accountability, package inspection, communications, Protective Forces, and technical surveillance countermeasures. These technologies are described below.

Alarm Management and Control Systems. DOE/NNSA sites with Category I or II quantities of SNM are expected to use the proprietary Argus system that meets all DOE/NNSA requirements for intrusion detection and access control to protect these materials. Three Category I sites have fully implemented the system, and the fourth site will complete installation in the fourth quarter of FY 2019. Three of the four non-Category I sites employ non-Argus, commercial systems. Two of these sites are scheduled to replace legacy systems with Argus in the near future.

Intrusion Detection Systems. An integrated, multi-layered suite of barriers, sensors, and assessment systems, including the Perimeter Intrusion Detection and Assessment System for Category I or II quantities of SNM protects NNSA assets.

Access Control Systems. Access control systems use a combination of entry and exit control, combined with multifactor authentication technologies and contraband detection technology to ensure authorized entry and exit. NNSA is in various stages of implementing the Identity, Credential, and Access Management (ICAM) program according to the Federal ICAM Roadmap.

Barriers and Lock Systems. State-of-the-art barrier technologies are used at some facilities, along with low-technology barriers such as concrete blocks or razor wire.

Secure Storage Systems. These systems provide additional barriers when practical for specific materials.

Material Control and Accountability. NNSA has deployed specific technologies (e.g., accounting software, tamper-indicating devices and dispensers, measurement devices, and barcode readers) at sites with SNM. NNSA manages a project to modernize the software application that serves as the standard core nuclear material accountability system. This software application provides sites and facilities with basic nuclear material accountability capabilities and can be enhanced to accommodate site- or facility-specific requirements.

Package Inspection Systems. Multiple sites have deployed x-ray inspection equipment at shipping and receiving facilities to augment their capability to prevent introduction of contraband into protected or material access areas.

Communication Systems. These systems facilitate secure communication among members of NNSA's Protective Force with system redundancy.

Protective Force Training Reform Initiative. Pursuant to review of multiple external audit reports spanning the last two decades and 2012 congressional hearings in which Protective Force training program deficiencies were identified, DNS worked closely with DOE's National Training Center and Protective Force training subject matter experts from all DOE and NNSA sites to initiate a comprehensive analysis of the training program's construct and effectiveness. The objective was to define a desired end state for a "corporately developed" configuration that would optimally support the nuclear security enterprise's ability to improve the focus, effectiveness, and efficiency of the Protective Force sustainment training program. Exhaustive analyses revealed that clear, nuclear security-focused training objectives and performance expectation parameters common to all NNSA Protective Force mission areas had not been sufficiently established to assist Protective Force training managers in defining sustainment training content, appropriate annual training hours, or methods of instructional delivery. Overall, the analysis showed Protective Force training programs had little apparent consistency in program planning, management, and execution among the eight sites.

Informed by these audit reports, internal analyses, and studies, the first Training Reform Initiative effort was development of the Enterprise Mission Essential Task List (EMETL) Sustainment Training program. This effort involved several planning and development working group sessions and benefited from extensive collaboration among multiple entities.

Enterprise Mission Essential Task List. All DOE/NNSA field sites have implemented the EMETL program, which fundamentally restructures Protective Force training with a primary focus on critical tasks that directly contribute to mission success. The EMETL program identifies real-time training focused on improving performance and provides a clear picture of the best options for using precious resources (time, money, and personnel) for making needed improvements. EMETL requires sites to conduct rigorous, formal, eyes-on assessments of the Protective Force's ability to perform specific individual, collective, and leadership tasks to identify areas in which improvement is needed. Local site training departments; operations, performance testing, and vulnerability assessment groups; and field offices are all participant organizations within the construct of the EMETL program. This mission-focused approach improves partners' understanding of actual performance capabilities, promotes finite resources to be targeted at areas with the highest priority for improvement, and ultimately improves mission performance. The EMETL program requires both on- and off-post training and performance testing of various tasks with continuous assessment by partners each quarter.

Protective Force Tactical Systems. NNSA tactical systems increase Protective Force lethality and survivability. These systems include hardened vehicles and fighting positions, Protective Force tracking systems, friend or foe identification systems, shooter detection systems, non-explosive mechanical and thermal breaching equipment, and remotely operated weapons systems.

Technical Surveillance Countermeasures. Technical surveillance countermeasures are the systematic physical and electronic examinations of designated areas by federally trained, qualified, and equipped persons to discover electronic eavesdropping devices and electronic security hazards and weaknesses. DNS recently implemented a consolidated enterprise approach that will result in substantial cost savings.

Enterprise Safeguards and Security Planning and Analysis Program (ESSPAP). The ESSPAP is the strategic process that NNSA uses to conduct vulnerability assessments and risk analyses to meet the intent of DOE's Design Basis Threat, which sets the safeguards and security standards for protecting Departmental operations and assets, including SNM and classified information. This process provides managers at all levels of the organization who have authority to accept risk with a consistent approach to guiding and managing safeguards and security programs throughout NNSA's nuclear security enterprise. The ESSPAP Supplemental Directive standardizes vulnerability assessment methodology, modeling and simulation tools, and data analytics into a comprehensive enterprise security risk management process. The directive provides NNSA sites with programmatic technical guidance on conducting security analysis and planning activities to aid identification and communication of security risks in clear, concrete, and consistent terms.

Physical Access Controls (PACS) and Intrusion Detection Systems (IDS) Depot and Modernization. NNSA has established a PACS and IDS equipment depot to centrally fund, procure, and manage all security system-related parts for six of the eight field sites. NNSA is also developing a standardized security systems training program for operators and system maintainers. Commercially available off-the shelf (COTS) IDS is being utilized at the other two sites. The COTS equipment has been determined to meet the protection needs, is readily available, and is a more cost effective alternative.

Security Management Improvement Program (SMIP). SMIP facilitates continuous, enterprise-wide improvement of the DNS program through consistent, effective, and efficient execution and program integration. SMIP enhances the ability of field security programs to oversee and understand security conditions, enabling better-informed decisions on oversight and execution activities and the allocation of finite resources. The SMIP does this through program management, establishing a baseline profile of policies, practices, procedures, and capabilities with a focus on Federal field oversight.

6.1.3 Challenges and Strategies

A major challenge for NNSA and 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 programs to meet security challenges. As systems age and technology advances, meeting current and future challenges remains difficult. **Table 6–1** provides a high-level summary of DNS challenges and the strategies developed to address them.

Table 6–1. Summary of Defense Nuclear Security Program challenges and strategies

Challenges	*Strategies*
Identifying emerging threats and ensure capabilities are developed and implemented to counter threats	• Defense Nuclear Security (DNS) participates in collaboration with numerous internal and external entities • Departmental Collaboration is described in the Center for Security Technology, Analysis, Response, and Testing (CSTART) program
Developing time-phased maintenance programs and a master schedule for upgrades and replacements at all DOE/NNSA nuclear security enterprise sites	The *10-Year Physical Security Systems Refresh Plan* has been provided to Congress and is described in the next section
Integrating and standardizing policies and procedures for a single safeguards and security program that is consistently executed at all DOE/NNSA nuclear security enterprise sites	DNS has a multipronged approach to standardize policies and procedures, including the DNS Strategic Plan, CSTART, Enterprise Safeguards and Security Planning and Analysis Program, and a Technical Surveillance Countermeasures consolidated enterprise approach
Ensuring security is considered in planning all new construction and any adjustments to facilities at the national security laboratories and nuclear weapons production sites	The Enterprise Safeguards and Security Planning and Analysis Program is the strategic process that NNSA uses to conduct vulnerability assessments and risk analyses to meet the intent of DOE's Design Basis Threat, which sets the safeguards and security standards for protecting Departmental operations and assets, including special nuclear material and classified information
Assessing and addressing the full range of threats, from protestor incursions to active, violent insiders or intruders	DNS has created a Security Analysis Cell to interface with the intelligence community and law enforcement agencies across the nuclear security enterprise for devising strategies to identify and counter the full range of current and evolving threats

Recent changes in nuclear policy have prompted an expansion of the nuclear security enterprise mission, especially in the areas of weapon modernization and infrastructure investment and recapitalization. This mission growth increases site staffing needs which will cause increases in clearances, reinvestigations, personnel security reporting, personnel verification (new personal identification verification for uncleared hires), and security awareness briefings. Increases in square footage (buildings) have two effects: (1) standing up new facilities through installation, commissioning, inspections, documentation, and approvals and (2) ongoing day-to-day operational programs. These effects entail additional access control systems; intrusion detections; surveillance (cameras); Protective Force requirements (patrols, responses to alarms/incidents, training and testing of staff); incidents of security concerns; classified material protection and control (setting up classified areas, approvals, and ongoing oversight); technical surveillance and countermeasures (inspecting new equipment and classified areas); classification program, programmatic management (risk assessments, plans, oversight); and vendor support. Modernization efforts have an even larger impact on cybersecurity programs, as more equipment, building controls, and security systems are computer-based, and the emerging threat continues to increase in sophistication.

6.1.3.1 Long-Term Vision and Strategy

The strategies for responding to physical security challenges are described below.

Center for Security Technology, Analysis, Response, and Testing (CSTART). DNS is continuing its efforts with CSTART to enhance standardization, integration, and cost-effectiveness across the DOE/NNSA nuclear security enterprise. This initiative uses a collaborative approach that includes working with SNL, LANL, and LLNL, other DOE national laboratories, DoD, and the Nuclear Regulatory Commission to achieve enterprise-wide solutions to security challenges. DNS uses CSTART to address the challenges of managing security risks for nuclear weapons and related programs, including the Security Infrastructure Revitalization Program.

Counter Unmanned Aircraft System (UAS). In 2015, the NNSA Administrator tasked DNS to develop and implement an enterprise-wide program to protect NNSA facilities against an unauthorized UAS. DNS rigorously tested and evaluated competing technology platforms, which led to the decision to develop and deploy an integrated system comprised of mature, commercial off-the-shelf components to meet this threat.

Like other government agencies, NNSA has encountered numerous incursions, adding a degree of urgency to the DNS effort to field a viable Counter UAS capability and policy for its use.

10-Year Physical Security Systems Refresh Plan. Historically, DOE's implementation of physical security technology has been site-centric, offering no corporate direction regarding selection, installation, operation, and maintenance of technologies at all sites. This approach has led to solutions at each site that increase the funding requirements to manage multiple systems performing similar functions. NNSA has worked to address these issues and, in August 2017, sent the *10- Year Physical Security Systems Refresh Plan* to Congress detailing security system priorities over the next 10 years. The execution of this 10-year plan is codified in the Security Infrastructure Revitalization Program.

DNS Strategic Plan. The priorities in the DNS Strategic Plan include sustaining the security enhancements implemented at the sites since September 11, 2001; continuing reduction of physical security vulnerabilities; leading efforts to integrate security initiatives with DOE program offices, government agencies, and international partners; and assisting NNSA sites in applying risk management principles and processes to achieve cost-effective physical security.

Layered Protection Areas. NNSA applies its physical security technology capabilities by using a "layered protection strategy" beginning at the boundaries of designated property protection areas, protected areas, and within material access areas. Barriers of various types are used within these areas, along with personnel identification and verification procedures.

Departmental Collaboration. DNS participates in the Capital Acquisition (CapAx) process, the Integrated Planning Group, and the Management Council to maintain close collaboration with other parts of NNSA, including Defense Programs. Under one of the Security Roadmap initiatives, DNS revitalized collaboration with the Nuclear Regulatory Commission, Department of Homeland Security, the United Kingdom's Ministry of Defense, and DoD to identify opportunities for collaborating on respective nuclear security programs. DNS also provides specialized nuclear security support for NNSA partners that are involved in nuclear nonproliferation, emergency response, homeland security, intelligence work, and the work of other U.S. Government agencies in these areas.

6.2 Information Technology and Cybersecurity

NNSA's Office of the Associate Administrator for Information Management and Chief Information Officer (NNSA OCIO) is the principal organizations for Federal information management, IT, and enterprise-wide cybersecurity for NNSA. The office has the responsibility for oversight, operations, modernization, and enhancement of IT and cybersecurity that are necessary to ensure the safety, security, and reliability of NNSA's nuclear security enterprise.

NNSA's OCIO executes and governs the complex and dynamic program of value-added and mission-enabling secure services, which span both classified and unclassified environments across Headquarters, national laboratories, plants, and field offices (see Chapter 3 of the classified Annex for a detailed map). The NNSA OCIO takes a risk management approach to developing IT applications and networks to ensure that cybersecurity is embedded in the IT fabric of the agency. Using an effective mix of technology, policy, and risk management practices enables NNSA to enhance information management across the NNSA enterprise.

6.2.1 Contributions to NNSA's Nuclear Security Enterprise Goals

The mission of the NNSA IT and Cybersecurity Program is to ensure that sufficient management, operational, and technical cybersecurity safeguards are implemented throughout NNSA's nuclear security enterprise to maintain adequate protection of information and information assets. As such, this program has several responsibilities:

- Fostering a culture of information sharing
- 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, the Clinger-Cohen Act, the *Federal Information Security Management Act* (FISMA), E-Government Initiative of the President's Management Agenda, and the *Federal Information Technology Acquisition and Reform Act* (FITARA)
- Based on the goals and priorities set forth by the NNSA Administrator and the Secretary of Energy, the NNSA OCIO contributes to the enterprise by ensuring execution of these activities:
  - Enabling classified and unclassified collaborative solutions for weapons activities throughout the enterprise
  - Providing the technology infrastructure and protections for all collateral classified networks within NNSA and DOE
  - Informing and advising incident responders from other government organizations about known threats
  - Coordinating with other Federal agencies (i.e., DoD and Department of Homeland Security) and government programs (i.e., Intelligence) to establish and maintain strong cybersecurity defenses to ensure that electronic information and information assets are performing necessary operations and are protected from compromise, unauthorized access, and malicious actors that could adversely affect national and economic security and operational readiness

- Fostering collaboration and coordination with international partners
- Defending electronic information and information assets from current and evolving threats to business and mission operations
- Maintaining the integrity and availability of Internet-based functions and transactions that are essential to NNSA's mission, operational needs, and Federal obligations
- Providing dedicated and specially trained professionals and employing an array of technologies to address general and site-specific threats to business and mission operations

IT and cybersecurity have become ubiquitous with the functions of everyday business. This trend is expected to continue as the Federal Government mandates that agencies automate and reshape the way services are provided to the taxpayer and to other government agencies.

Today, the efficient and effective management of IT and cybersecurity is one of the most crucial factors in supporting the NNSA enterprise. The highly complex and global nature of the NNSA enterprise, coupled with resource priorities, makes it critically important that information and information assets are secured, managed, and protected using a risk-management approach. NNSA's OCIO leadership recognizes that well-informed management decisions require a systematic understanding of the risks inherent in the use of information systems; thus, it is vital to ensure those systems are properly protected. Full integration of management processes organization-wide will reduce risk by providing greater degrees of security, privacy, reliability, and cost-effectiveness for core missions and business functions.

Building on past organizational successes to modernize and strengthen an aging infrastructure, NNSA is moving toward a managed services model which, for a fixed rate, would provide reliable, comprehensive, and continuous IT network security and support for the enterprise. With the managed services model, NNSA's networks will benefit from industry best practices, receive ongoing patching and monitoring, hardened configurations from a security perspective, fine-tuned settings for performance, and dynamic configurations to meet evolving business environments.

Enhancing the IT environment increases NNSA's capacity to support an ever-evolving and ever-expanding set of mission priorities and defend against adversarial threats. It is important that NNSA renew its commitment to consolidate and enhance the IT and cybersecurity services provided to the mission user and partners to maintain this capability. NNSA will strive to continue delivery of IT and cybersecurity modernization efforts for long-term program implementation and success. These efforts will transform NNSA's ability to manage the full life cycle of the nuclear stockpile and ensure nuclear security goals are completed.

IT and Cybersecurity. The IT and Cybersecurity Program manage the implementation and maintenance of IT assets within the NNSA classified and unclassified environments (excluding indirect funded M&O assets). The office provides NNSA with enterprise cybersecurity capabilities and assists with detection, analysis, and mitigation of cybersecurity threats and incidents. The IT and Cybersecurity Program also coordinates and supports DOE functions, including the integrated Joint Cybersecurity Coordination Center (iJC3), Telecommunications Electronics Material Protected from Emanating Spurious Transmissions (TEMPEST)/Protected Transmission System, and serves as the Cybersecurity Service Provider. Additionally, the NNSA OCIO directs the design, development, and maintenance of all aspects of NNSA computing activities including but not limited to, application development, integration, and deployment; application hosting; desktop provisioning; video teleconferencing; and provisioning voice and data resources. The office also oversees IT processes and services to provide NNSA staff with the IT resources necessary to achieve mission goals and objectives.

DOE uses a fully inclusive enterprise-wide approach to meet its cybersecurity goals. The DOE Cyber Strategy and corresponding implementation plan guide these efforts. Information Technology and Cybersecurity has established an innovative enterprise-wide cyber governance structure involving our Headquarters, 17 DOE/NNSA national laboratories, and multiple sites across the country. This collaborative approach has enabled DOE to make substantial progress on cyber information-sharing and safeguarding priorities. A critical priority currently under implementation, DOE's Enterprise Cyber Distributed Shared Risk Management Framework, is designed to provide enterprise-wide cyber situational awareness to support cyber risk decisions on investments, policy, capabilities, and operations.

Office of Policy and Governance. The Office of Policy and Governance is responsible for providing leadership, policy, direction, guidance management, integration, and governance in support of the Chief Information Officer and other NNSA senior managers on the strategic use of IT and cybersecurity resources to support core business processes and achieve mission-critical goals. The office focuses on the development, dissemination, and oversight of NNSA's IT and cybersecurity architecture policies, standards, and procedures to address internal and external requirements. The office uses an industry standard governance model to provide the appropriate degree of management oversight to ensure investments deliver the desired results within cost and schedule thresholds and comply with applicable regulations and best practices.

6.2.2 Accomplishments

Major accomplishments contributing to program effectiveness in FY 2020 include:

- NNSA's OCIO collaborated with Microsoft to develop an IT Modernization Architecture that identified 14 areas of specific improvement to current NNSA IT capabilities that align with business goals and objectives. In partnership with Microsoft NNSA continues to refine the desired modernization outcomes, began planning for a production pilot program, and completed an independent analysis.
- NNSA has completed Phase 1 of the iJC3 implementation for Federal networks. NNSA has complete coverage of the NNSA environment, including unclassified, classified, and mission space. NNSA has developed the approach and standards to provide situational awareness of the nuclear security enterprise to the DOE OCIO.
- NNSA's OCIO worked in collaboration with DOE's OCIO to establish DOE's Data Taxonomy Framework. This effort was used to expand DOE Headquarters visibility across the DOE enterprise in relation to the response to cybersecurity incidents.
- In partnership with SNL, NNSA's OCIO created a Center of Excellence to improve and enhance the situational awareness, incident response, and incident management throughout the nuclear security enterprise.
- NNSA's OCIO has made significant strides in meeting Department of Homeland Security's binding operational directive requirements, substantially reducing the potential attack surface, and improving overall scores for DOE. NNSA's OCIO continues to work, through continuous monitoring and continuous diagnostic monitoring activities, to determine what tools across the enterprise currently meet the core requirements and where additional tools may be needed to improve performance.

- NNSA's OCIO led the cybersecurity and IT Mission Focus Areas for the Plutonium Pit Production Project. NNSA's OCIO also provided the cybersecurity Mission Focus Areas Implementation Plan Pit Production content and ensured alignment with the goals and objectives of the Plutonium Pit Production Program Office. The Cybersecurity Mission Focus Areas will highlight the approach, requirements, design, and implementation of unclassified and classified wired and wireless infrastructure, to include cybersecurity, IT, and operational technology components to support the 80 pits per year mission.
- NNSA's OCIO partnered with the Office of Nonproliferation and Arms Control to develop an e-licensing and case management web portal specific to the 10 CFR Part 810 licensing process that has both Internet and intranet components.
- NNSA's OCIO completed its enterprise solution for email and document marking. Known as TITUS, this solution was in accordance with the policy requirements outlined in the July 26, 2017, memorandum titled, *Enterprise Standard for Email and Document Marking*. OCIO successfully implemented TITUS on the Enterprise Secure Network (ESN), NNSA's Secret Network, and all site-connected networks.

6.2.3 Status

6.2.3.1 Information Technology Modernization

Secure, reliable, well-managed, and accessible IT solutions are critical components to executing the NNSA mission. Modernized IT systems are easier to secure from a cybersecurity standpoint. NNSA currently relies on the DOE model, which poses challenges with regard to communication, collaboration, and security capabilities. This is why NNSA's OCIO is moving toward an NNSA-managed service model, which will greatly improve these capabilities between Headquarters, M&Os, and other partners.

NNSA's OCIO manages and protects all electronic information that is processed, transmitted, and stored by NNSA, and it is OCIO's mission to ensure cybersecurity and information security are embedded into the fabric of the agency. Therefore, NNSA is undertaking an aggressive 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.

OCIO's focus on a managed service model will enable NNSA to take advantage of new and emerging technologies, provide opportunities to participate in economies of scale, and rely on industry's rapid development and testing practices to ensure the use of safe, secure, and modern technology.

NNSA's OCIO is in the process of implementing Phase 1 of the IT Modernization effort. Within Phase 1, OCIO will lead the development and implementation of the pilot program, which will support Microsoft Office 365, SharePoint Online, Skype for Business, and email. OCIO will maintain a hosting environment that contains tools, applications, and programs. OCIO will also be responsible for securing tools, applications, and programs and protecting information, along with login and access controls. Managed services also include offerings like analytics, data storage, and the increased ability to share data between users when necessary. The IT Modernization effort will improve the network infrastructure by updating and enhancing networking equipment through public/private cloud services, managed services, and software and hardware enhancements.

In addition to the implementation of Phase 1, NNSA's OCIO is in the process of launching the production pilot for desktop services, commodity applications, and cybersecurity architecture.

Finally, NNSA's OCIO will work with DOE's OCIO to complete modernization of the current IT infrastructure provided to Departmental elements and move to a managed service model.

6.2.3.2 Enterprise Secure Network

NNSA is pursuing a strategic initiative for its ESN as part of its larger Enterprise Secure Computing program. The project will:

- Increase operational effectiveness through a shared services model
- Lower security risks by providing an enhanced protection strategy for information and information assets
- Increase visibility of the nuclear security enterprise software portfolio to promote enhanced integration across the nuclear security enterprise
- Upgrade and enhance the secure logical infrastructure

The 2018 *Nuclear Posture Review* emphasizes the importance of an effective, responsive, and resilient nuclear weapons stockpile for U.S. national security interests. It goes on to state that the United States will pursue initiatives to ensure the necessary capability, capacity, and responsiveness of the nuclear weapons infrastructure. This initiative directly 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.

6.2.3.3 Restricted Data

NNSA's OCIO continues to work 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) by:

- Providing a list of current cyber protection requirements and methodologies for RD
- Explaining the current congressional statutes that control dissemination of RD outside the DOE/DoD environment
- Assessing the current state of the Federal Bureau of Investigation cybersecurity controls in correlation with RD protection requirements and assisting in the formulation of an official memorandum from the Associate Director of the Render Safe Program to the NNSA OCIO, requesting access to host RD

6.2.3.4 Multifactor Authentication and Federal Information Technology Acquisition Reform Act Implementation Framework

NNSA's OCIO worked with DOE to provide input on behalf of NNSA on the DOE FITARA and MFA implementation plans. NNSA OCIO supplemental plans outline NNSA's strategy for effectively implementing and overseeing the FITARA and MFA activities.

6.2.3.5 Collaboration Efforts with DOE Partners

- **Involvement in development and implementation of Physical Security Systems.** NNSA's OCIO is working to apply technology to improve physical security. While this technology is improving operations across DOE, it does introduce a new complexity to the way NNSA's OCIO thinks about cybersecurity in reference to physical space. It is necessary to shift the current physical security approach to mitigate cyber threat vectors aimed at information security and safeguarding.

- **iJC3.** NNSA's OCIO completed Phase 1 of the iJC3 implementation for Federal networks. NNSA has complete coverage of the NNSA environment, including unclassified, classified, and mission space. NNSA has developed the approach and standards to provide situational awareness of the nuclear security enterprise to the DOE OCIO.
- **TEMPEST Management.** NNSA's OCIO is responsible for implementing a TEMPEST program to establish control of any authority requirements introduced by the approved risk management model.

6.2.3.6 Technologies Deployed to Address Cybersecurity Threats

NNSA's IT and Cybersecurity Programs maintain management, operations, and technical security safeguards throughout the nuclear security enterprise for adequate protection of information assets. The workforce that develops, deploys, and uses the security tools listed in **Table 6–2** provides the first lines of defense against known adversaries and emerging threats.

Table 6–2. Technologies deployed to address 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
Respond	Incident Response
	Enterprise Forensics

6.2.3.7 Investment Prioritization Methodology

Strong IT governance and oversight ensures that NNSA is capitalizing on its IT and cybersecurity budget to deliver a strong, secure set of tools. Effective IT governance empowers program offices to make decisions about their IT requirements, while providing guidance and support to ensure their success.

NNSA uses the continuous Planning, Programming, Budgeting, and Evaluation process that establishes an overall approach to enabling the mission of each individual program to be accomplished through mutually supportive budget inputs and outputs from appropriate partners. NNSA's OCIO works closely with its internal Requirements Overview Council to appropriately align itself with the NNSA Planning, Programming, Budgeting, and Evaluation process, and to focus on vetting the rigorous and efficient budget planning and submission inputs that are required on an annual basis. This process is conducted between Headquarters and the field, thus addressing the risks and effectively accomplishing the cyber and IT specific missions from an operational planning standpoint.

During the planning and programming process, NNSA's OCIO coordinates with the field offices to communicate strategic program initiatives they are desire to be reach over the next 3 to 5 years. The field offices then collaborate and provide the necessary cost inputs required to support strategic initiatives through an annual brief that includes all programmatic funded priorities in a formal budget planning meeting. During these briefs, all of the appropriate risks are captured so that OCIO Headquarters staff can consolidate and submit their inputs to support the unified NNSA OCIO budget submission across each NNSA site in the form of the Integrated Priority List for the Administrator's consideration.

During the budgeting process, NNSA's OCIO provides necessary briefing information to external partners, including the Office of Management and Budget (OMB) and the designated congressional appropriations committees, to successfully represent, inform, justify, and defend their program's budget submission.

During the evaluation phase, NNSA's OCIO executes appropriated funding for a given fiscal year while constantly evaluating, monitoring, and overseeing the IT, cybersecurity, and operational activities that the OCIO provides to the NNSA enterprise.

The Requirements Overview Council is the primary decision-making body employed to ensure that NNSA has efficient IT project management and oversight. The Council uses mature project management processes to gain efficiencies and improve customer and partner interaction across the enterprise.

FISMA requires agencies to develop and implement an organization-wide information security program to address identification and prioritization of threats as they apply to information security. NNSA's IT and Cybersecurity Program meets the FISMA threat-based requirements through application of the National Institute of Standards and Technology risk management framework influenced by DOE Order 205.1B, *Department of Energy Cyber Security Program*, and further outlined in NNSA Baseline Cybersecurity Program policy.

NNSA's cyber program and IT managers use results from multiple ongoing activities to identify and prioritize needed investments based on threats and the degree of risk posed to NNSA information assets and business operations. Activities include:

- Intelligence analyses
- System authorization activities
- FISMA Performance Reports
- Program reviews, audits, and inspections
- Performance Evaluation and Measurement Plan
- Technical impact assessments
- Operational impact assessments

6.2.4 Challenges and Strategies

The cyber threat landscape constantly evolves, with the most sophisticated threats changing to adapt to whatever defenses face them. NNSA is committed to providing an IT infrastructure to protect the highly complex, global nature of the stockpile stewardship and management missions using a collaborative, intelligence-informed approach to cyber operations and a response that employs the full capabilities of the nuclear security enterprise, DOE, and the Federal Government. **Table 6–3** provides a high-level summary of the cybersecurity challenges and the strategies developed to address them.

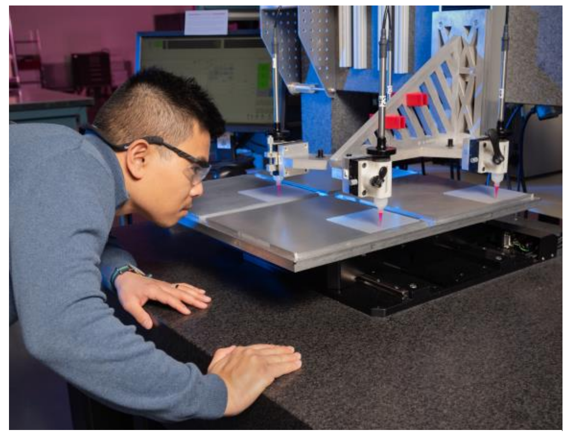
Table 6–3. Summary of Information Technology and Cybersecurity challenges and strategies

Challenges	***Strategies***
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
Insider Threat	Work with counterintelligence on implementation of an insider threat program, concentrating first on the classified arena
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
Current network monitoring services restrictions	Upgrade sites across the enterprise through deployment of new cybersecurity solutions
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
Program effects from 2018 *Nuclear Posture Review* Implementation	• Resource requirements for IT and cybersecurity that are required to support the nuclear security enterprise mission will vary directly with any increases in weapons program workloads • Additional work locations, increasing workforce numbers, and adding shifts will result in additional demand for IT and cybersecurity resources to ensure a secure, protected, and innovative work environment
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: "Principle 6: Invest in employee development to cultivate a high-performing workforce that will support NNSA's mission today and into the future"
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

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

Chapter 7
Sustaining the Workforce

DOE/NNSA's ability to meet nuclear security missions depends on a unique, diverse, and highly skilled workforce, requiring expertise across a broad array of disciplines, including science and engineering specialties that can only be exercised within the weapons programs. The technical staff and managers working in these areas possess advanced science, technology, engineering, and math degrees and years of experience working directly for DOE/NNSA or its management and operating (M&O) partners. The need to recruit and retain highly skilled staff with unique expertise will continue to grow, given DOE/NNSA's major modernization programs and workforce demographics.



KCNSC Advanced Manufacturing Facility

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 not only by current mission needs, activities are designed to anticipate future challenges and developments that will require skills that are not currently in demand.

This chapter provides an overview of the status, accomplishments, and challenges of the workforce, as well as the approaches and strategies that DOE/NNSA and its M&O partners use to mitigate those challenges. Appendix D of this report, "Workforce and Site-Specific Information," includes the mission, capabilities, and workforce data for DOE/NNSA and each of the eight nuclear security sites.

Workforce Snapshot (Enterprise-Wide)
(as of September 30, 2018)

- *Total Headcount: 42,690*
- *Average Age: 46.9*
- *Average Years of Service: 13*
- *Average Retirement-Eligible Population: 25.9%*
- *Hires (as of September 30, 2016): 9,219*
- *Separations (as of September 30, 2016): 5,813*
- *Net Change (as of September 30, 2016): 3,406*

7.1 Status

7.1.1 Workforce Size and Composition

The overall workforce has three basic components: the Federal workforce, the M&O partners,[1] and the non-M&O entities. The M&O partners that conduct DOE/NNSA's stockpile activities consist of the three national security laboratories that operate as Federally Funded Research and Development Centers, the four nuclear weapons production facilities, and the Nevada National Security Site. This government-owned, contractor-operated, nuclear weapons enterprise is assisted by non-M&O entities (support

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

service contracting firms, members of academia with technical expertise in specific areas, and industrial suppliers).

7.1.1.1 Overall Workforce

At the end of FY 2018, the combined Federal and M&O partner workforce included 42,690 employees.[2] Collectively, the M&O partners reported a total of 40,518 employees. The sites reported 8,860 hires and 5,459 separations over the last 2 fiscal years, resulting in a net increase of 3,401 employees. KCNSC reported the largest net population change, with an increase of 1,079 employees. No sites reported a net decrease in personnel during this period. While the largest amount of separations came from retirements, there is a notable, continuing trend of large numbers of separations occurring among employees with 0 to 5 years of service.[3]

7.1.1.2 Federal Workforce

NNSA's Federal workforce is responsible for program and project management, as well as Federal contractor assurance oversight of the national security missions across the nuclear security enterprise, and includes significant numbers in the Office of Secure Transportation. The Federal workforce is accountable to the President, Congress, and the public in performing inherently governmental functions such as[4] key planning functions, fiduciary oversight, risk prioritization, product acceptance, and environmental, safety, and health oversight duties. At the end of FY 2018, the NNSA Federal workforce consisted of 2,172 employees.[5] Given the growing number of life extension programs (LEPs) and major projects NNSA is pursuing legislation to enable removal of the overall artificial cap on full-time equivalents (FTEs).

The Federal workforce is augmented by officers in the military services on rotational assignments. The senior military leader in Defense Programs[6] is a flag officer whose position is established by the *Atomic Energy Act of 1954*, as amended. In addition to this position, a small cadre of active-duty military members serve on rotation at DOE/NNSA.

> ***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 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, 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 (i.e., production sites embedding employees at the laboratories to learn design changes or site personnel advising Defense Programs' leadership at Headquarters). Several M&O employees are currently on assignment in DOE/NNSA, DoD, and other Federal agencies, sharing their expertise while broadening their strategic perspective in national security.*

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[2] This total excludes the Federal Naval Reactors workforce and excludes significant contractor populations on site and at Headquarters serving either as subcontractors or as support service contractors to the Federal workforce. For the SSMP, NNSA does not collect Naval Reactors numbers.

[3] Among the M&O contractors, as of January 2018, the median years of tenure with a current employer for total industry was 4.2 years (data include age 16 and above). While half have less tenure, a median of 4.2 years matches up separations in the 0 to 5 category; this becomes problematic given the many aspects of the nuclear security enterprise that require sustained work and "learning by doing" and the long clearance times, which affect retention.

[4] 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.

[5] The *National Defense Authorization Act for Fiscal Year 2015* capped the total number Federal employees under NNSA's Federal Salaries and Expenses at 1,690 FTEs. Current numbers include Secure Transportation Asset couriers, but exclude the Office of Naval Reactors, whose data is not collected for the SSMP. This is headcount.

[6] Defense Programs is the office within NNSA with the responsibility for most of the Weapons Activities work.

These military personnel bring a service perspective to Weapons Activities, assisting DOE/NNSA in better meeting DoD requirements and, in turn, giving military personnel a deeper understanding of the DOE/NNSA nuclear security enterprise.

The Federal workforce resides at DOE/NNSA Headquarters (Washington, DC; Germantown, Maryland; and Albuquerque, New Mexico) and at the field offices across the eight nuclear security sites.

7.1.1.3 Management and Operating Workforce

The M&O workforce resides at eight government-owned or leased nuclear security enterprise sites. An analysis of the composition of the M&O workforces at these sites shows differences in the types of labor at the laboratories versus the production sites. A breakdown by Common Occupational Classification System (COCS) categories of the national laboratory population (including the Nevada National Security Site) and the production facility population can be found in **Figures 7–1** and **7–2**.

Although professional administrative and general management percentages are lower for the M&O partners than for the Federal staff, they still represent a substantial portion of the M&O workforce. This is a byproduct of the COCS code definitions. The COCS codes are established by job function, not by degree held, and the COCS categories mask the number of scientists and engineers functioning as technical managers or as program or project managers. Detailed site discussions and site-specific workforce data can be found in Appendix D, "Workforce and Site-Specific Information."

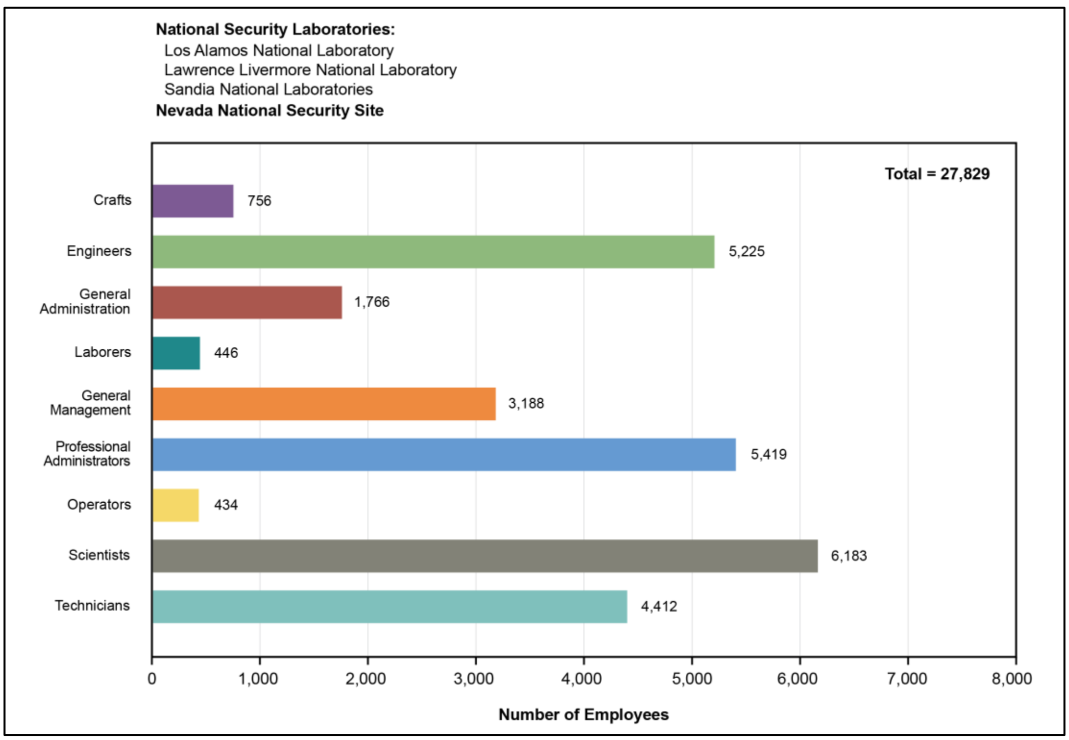


Figure 7–1. Total workforce of national security laboratories and the Nevada National Security Site by Common Occupational Classification System[7] (as of September 30, 2018)

[7] The SSMP reports workforce data using the Common Occupational Classification System (COCS). Federal and M&O workforce data are reported in the standardized COCS categories to allow consistent comparison among the sites. However, 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.

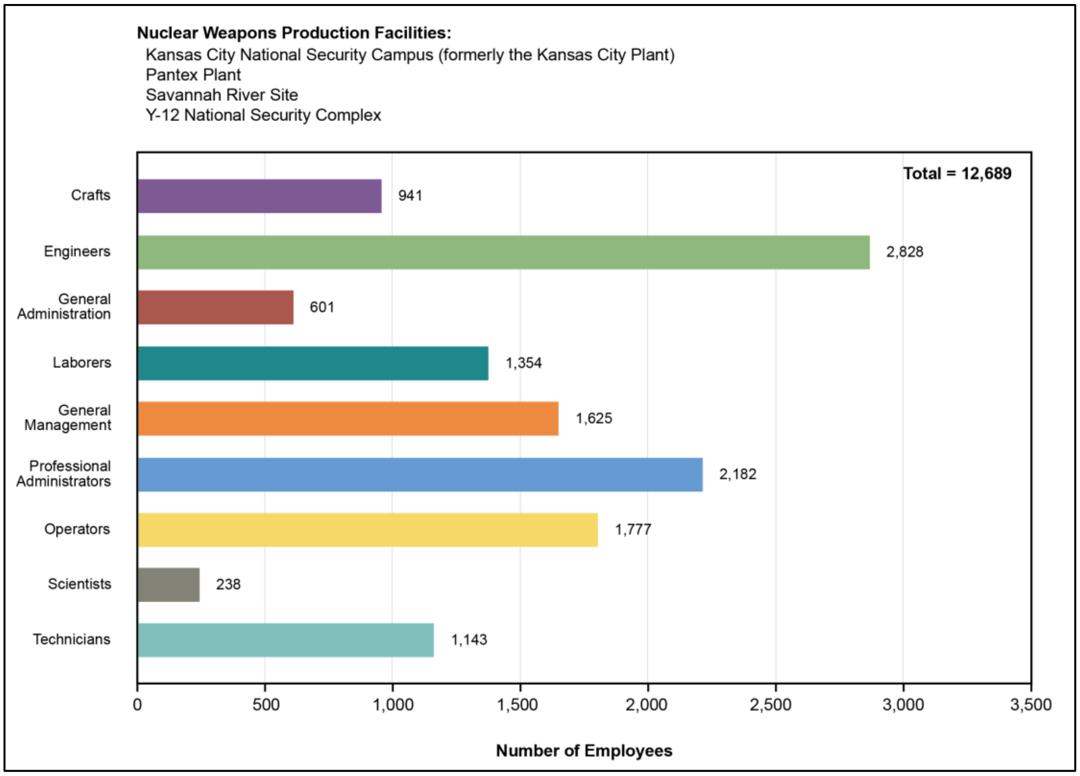


Figure 7–2. Total workforce of nuclear weapons production facilities[8] by Common Occupational Classification System (as of September 30, 2018)

7.1.1.4 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 nuclear security enterprise. These include, but are not limited to:

- Support service contractors providing advisory and technical support and services
- Vendors providing the specific parts necessary to fulfill a key production mission
- Academic institutions supporting DOE/NNSA by providing a pipeline of highly skilled and educated talent to the nuclear security enterprise

Institutions operated by major research universities are a key component of the non-M&O workforce and are heavily used in providing talent for the nuclear security enterprise. DOE/NNSA's M&O partners continue to build connections with these institutions through academic alliances to maintain a skilled, versatile, knowledgeable, and experienced workforce. Several universities have partnered with the sites to form a wide array of student internship and other outreach programs.

[8] This does not account for production functions at SNL and LANL. While these sites have significant production missions, for SSMP data reporting they are included in Figure 7–3.

DOE/NNSA's nuclear security enterprise also requires outside vendors and producers to supply certain materials and services. Two diverse examples of non-M&O vendors are the firms that fabricate tritium-producing burnable absorber rods and the Laboratory for Laser Energetics at the University of Rochester. Support service contracting companies in the non-M&O workforce at Headquarters provide advice and support to program and project managers responsible for infrastructure, systems, operational readiness, budgets, and policy; independent cost estimating, independent project review, and analyses of alternatives; and nuclear facility operations and asset management, and nuclear engineering and analysis services. These companies are a blend of both large and small businesses. DOE/NNSA continues to develop long-term vendor relationships and to identify additional suppliers, researchers, and technical and management consultants to reduce the risk of relying on single-source providers with capabilities that are not duplicated or retained within the M&O workforce.

In an effort to develop hard to find resources in the General Machinist and Toolmaker areas, KCNSC has developed a partnership with the Metropolitan Community Colleges of Kansas City to develop a training and certification program in these specialized fields. The General Machinist program allows employees with a manufacturing background, but no machining experience, to learn technical skills and shadow machinists in a manufacturing setting. The more specific Toolmaker program is similar, but requires at least 2 years of machining experience. The jointly developed custom curriculum provides employees with certifications and enough credits to receive associate degrees. KCNSC has also adopted a new strategy to add relocation benefits for certain non-exempt classifications to allow national recruitment of toolmakers and technicians.

7.1.2 Age and Other Demographics of the Workforce

Age

Eighty-four percent of the nuclear security enterprise workforce is between the ages of 31 and 60, with 16 percent in the 56 to 60 demographic alone. Sites are reporting rates of retirement eligibility from 15 percent to 44 percent, which will likely increase over the next 5 years as the 56 to 60 group ages into the 61 to 65 age range. The average age among the sites ranges from 45 to 49, a slight reduction from the average reported in the FY 2018 SSMP.

Both the laboratories and plants exhibit bimodal age distributions, with large numbers of employees in the 36 to 40 and 56 to 60 age ranges. Some sites have seen their bimodal age distribution peaks lessen over the years. Comparing the data reported in the FY 2018 SSMP to this data, the higher age categories have remained relatively constant, while there is a noticeable increase in personnel from ages 31 to 45. **Figure 7–3** provides an illustration of the M&O workforce distribution by age for the entire nuclear security enterprise.

Stewardship Science Academic Alliances Program

Four universities were selected to operate new centers of excellence fostering collaboration between DOE/NNSA and academia. This collaboration strengthens the nuclear security enterprise by advancing relevant science within the stockpile stewardship mission and ensures a pipeline of future scientists and engineers to carry out that mission.

The M&O partner sites closely monitor their populations and are focused on planning to mitigate the impacts. For individual site reports, please see Appendix D, "Workforce and Site-Specific Information."

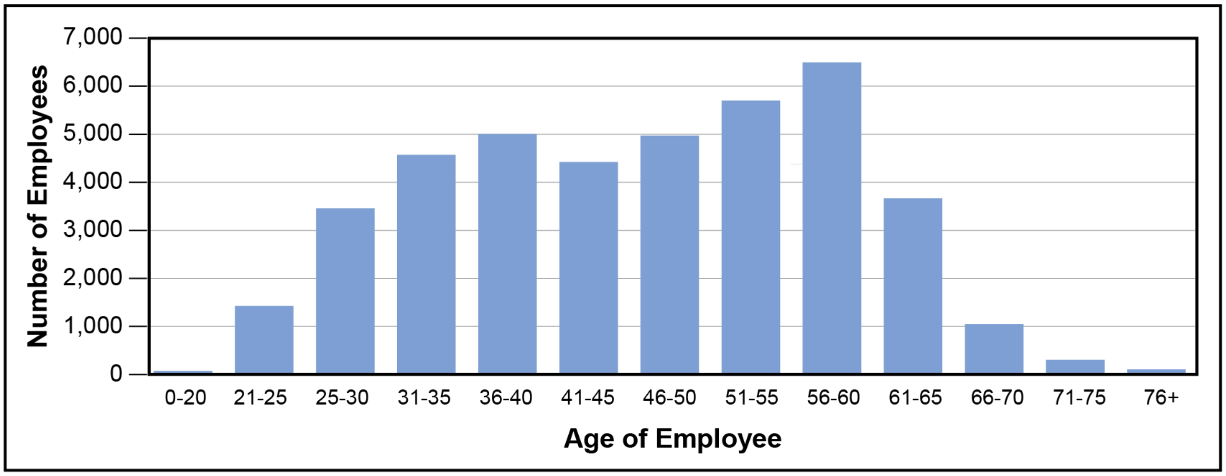


Figure 7–3. Management and operating partner headcount distribution by age (as of September 30, 2018)

Years of Service

Out of the reported M&O partner headcount of 40,518 employees, the 1 to 5 years of service category contains the largest number, with a headcount of 11,382. This holds true for the laboratories, the Nevada Nuclear Security Site, and the production plants. There is a noticeable drop beyond 20 years of service, with 70 percent of the workforce having 1 to 20 years of experience. Only 20 percent of the workforce has more than 20 years of experience. The average length of service at the nuclear security sites ranges from 11 to 14 years. **Figure 7–4** illustrates NNSA's M&O workforce distributed by years of service.

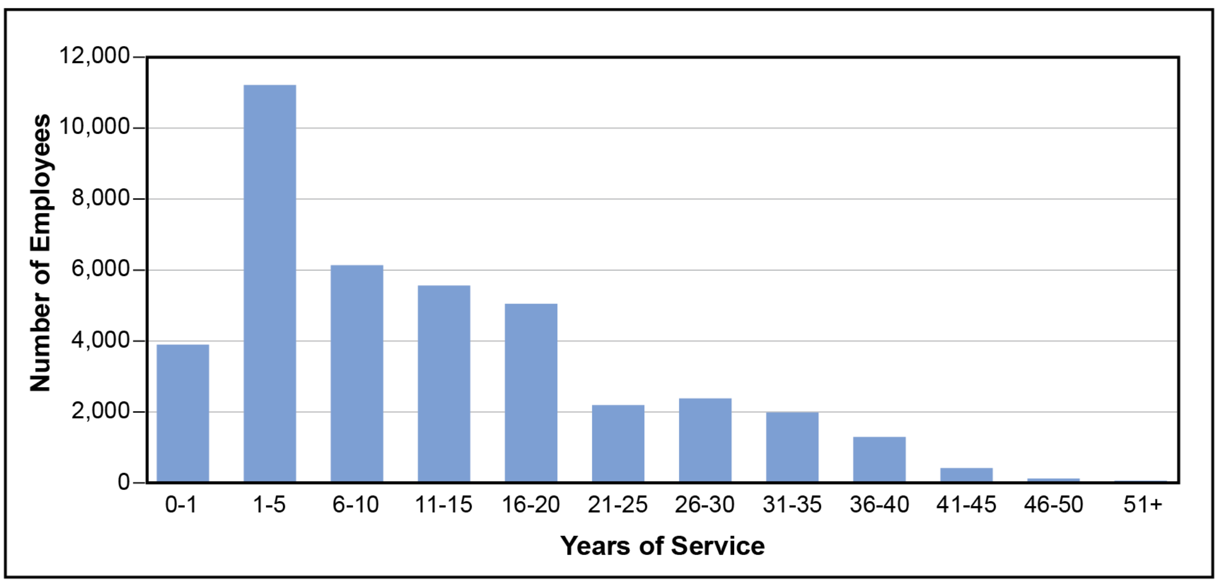


Figure 7–4. Management and operating partner headcount distribution by years of service (as of September 30, 2018)

Separations

Since publication of the FY 2018 SSMP, the M&O workforce had 5,459 separations. Of these 2,071 were voluntary separations, 600 were involuntary separations and 2,788 were retirements. Among the voluntary separations, more than 82 percent were in the 1 to 10 years of service range. Sixty-four percent of voluntary separations were within 1 to 5 years of service. While the sites have strategies to mitigate the number of separations within 1 to 5 years of service, the employee separation data show a noticeable and troubling challenge concerning the ability to retain early-career professionals in the workforce. Some major components of this trend include security clearance processing time, staff having to forego personal electronic devices for the majority of the day, location, and competition from other technical industries. The percentage of the workforce in the later-career stage has remained relatively stable or even decreased as a result of increased hiring combined with retirements, shifting the distribution toward early-career employees. This trend is accurate for every site. **Figure 7–5** illustrates M&O partner site separations distributed by years of service.

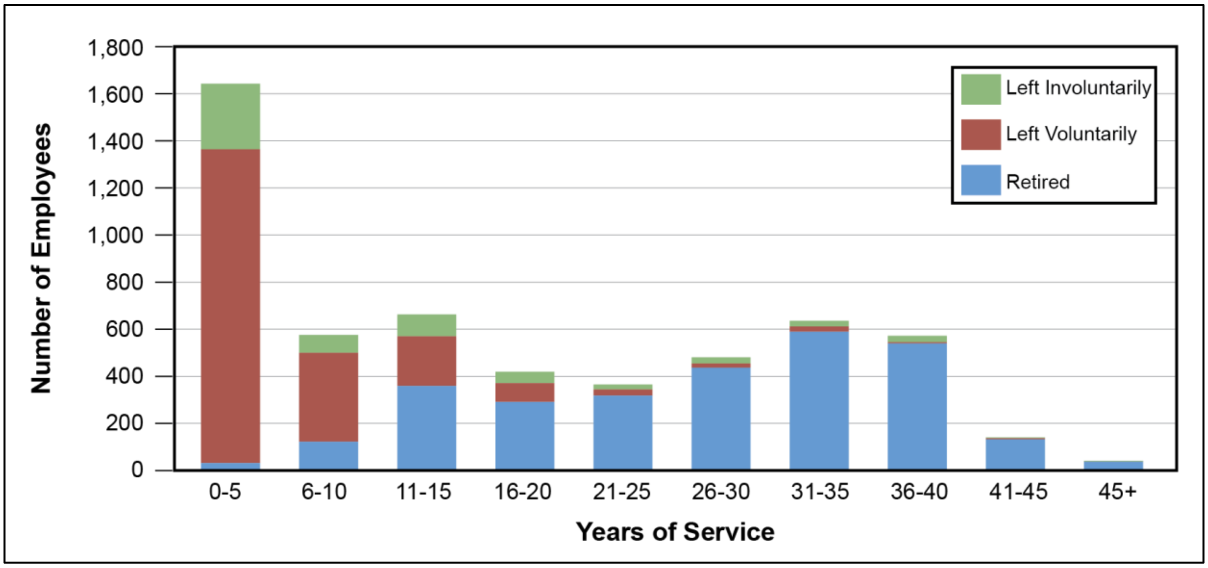


Figure 7–5. Total management and operating separations by years of service

7.2 Workforce Planning

As DOE/NNSA continues its modernization programs, DOE/NNSA Headquarters and M&O partners face emerging challenges in planning, managing, and sustaining the specialized workforce, especially in critical skills and key areas of expertise. Shortages in key sectors of the workforce and high demand from the private sector will make it difficult to recruit, hire, and retain such a high-tech workforce. The role of NNSA Headquarters in workforce planning is focused on five areas:

- Planning for the Federal workforce
- Providing annual work scope guidance
- Enabling and monitoring the M&O partners' management of the workforce in executing work scope
- Collecting NNSA workforce demographics for annual reports to Congress
- Working with the M&O partners to identify and resolve cross-cutting issues affecting multiple sites

NNSA is currently developing a more coordinated and collaborative effort across the nuclear security enterprise, including a more comprehensive recruitment plan and strategy. To accomplish this, the NNSA Administrator has launched a team that will focus on attracting and retaining the best and brightest for the nuclear security enterprise.

7.2.1 Federal Workforce Planning

DOE/NNSA has a bimodal distribution in terms of experience; fewer employees have advanced experience (25 or more years of service) compared to many more employees with 6 to 15 years of service (see **Figure 7–6**). The potential experience gap is a risk; however, while some employees have fewer years of service, they are still fairly experienced and represent an opportunity to manage risk through development and training. Retirements, which have represented more than 60 percent of separations in the past few years, are still of particular concern as DOE/NNSA's workload is expected to increase (see **Figure 7–7**).

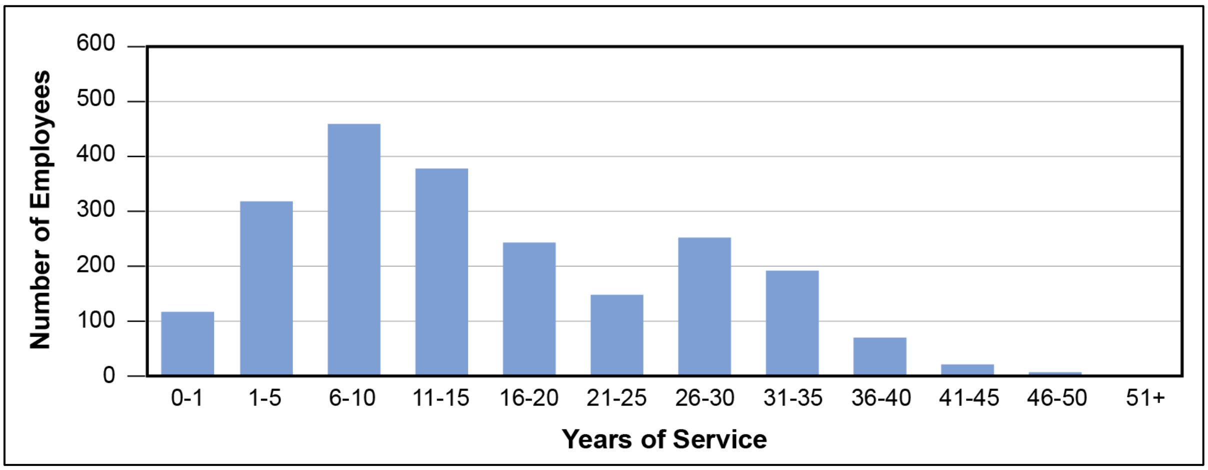


Figure 7–6. Federal employees by years of service (as of September 30, 2018)

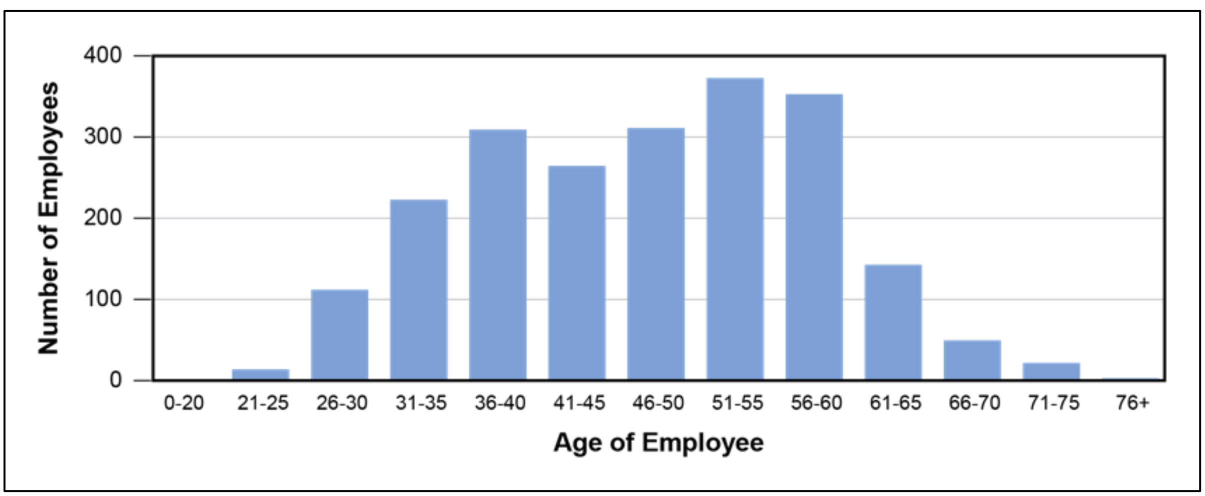


Figure 7–7. Federal employees by age (as of September 30, 2018)

Independent studies conducted by the Office of Personnel Management and the NNSA Office of Cost Estimating and Program Evaluation, in 2017 and 2018, identified the need to significantly increase NNSA Federal staffing by an additional 250 FTEs. As these studies were conducted before the 2018 *Nuclear Posture Review* and NNSA's plutonium engineering assessment and workforce analysis, NNSA will need to conduct additional workforce planning to determine the actual, optimal NNSA workforce end-state level.

This potential increase in staffing provides DOE/NNSA an opportunity to reshape the workforce to both handle the increased workload and balance the skill mix in the future workforce. DOE/NNSA has increased its training budget to prepare for mission growth. DOE/NNSA will continue using excepted service authorities, and the pay-for-performance NNSA Demonstration Project's alternate personnel system to recruit, hire, and retain the appropriate skill sets needed for DOE/NNSA's national security missions. DOE/NNSA plans to use these personnel systems to obtain the right mix of skills needed to support evolving mission requirements.

NNSA supports efforts to formulate a comprehensive government-wide reform plan to create an accountable, efficient government workforce; to effectively and efficiently deliver NNSA programs; and to align the NNSA Federal workforce to meet the needs of today and the future. For more information on the Federal workforce, please see Appendix D, "Workforce and Site-Specific Information."

7.2.2 M&O Workforce Planning

Concurrent with DOE/NNSA planning, M&O partner sites develop and implement workforce plans and approaches to manage staffing to maintain a stable workforce across the full spectrum of nuclear weapon capabilities.

Each NNSA site has workforce planning processes tailored to its unique needs:

- Long-term workforce hiring and staffing plans
- Training and qualification of workforce
- Modeling and planning to address attrition
- Robust student and postdoctoral programs
- Strategies with local, regional, and state communities to recruit and retain the workforce
- Limited-term and staff augmentation employment
- Leveraging resources from other programs (e.g., the Strategic Partnership Projects)
- Parent company reach-back[9]
- Deferring purchases, maintenance, travel, etc., to preserve headcount

Current M&O workforce projections reflect minimal growth over the Future Years Nuclear Security Program period (see **Figure 7–8**).

[9] Parent company reach-back is the ability of operating contractors to leverage certain knowledge, skills, abilities, and business practices to respond to M&O partner needs, such as best practices, technical capabilities, or access to specialized resources and talent.

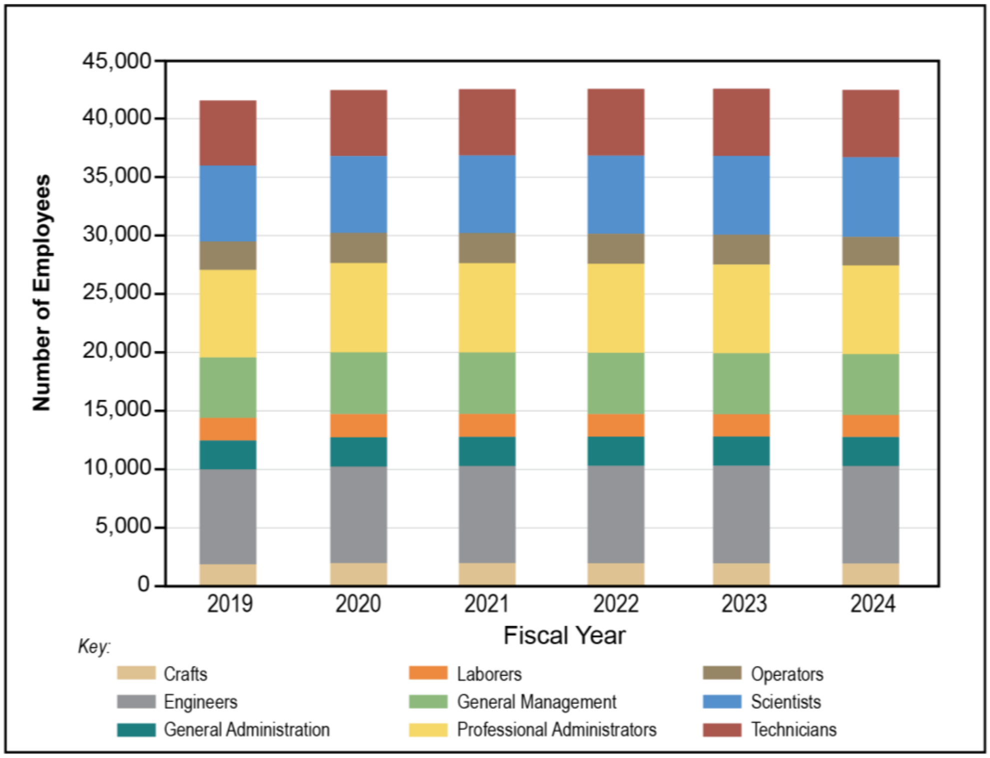


Figure 7–8. Management and operating partner workforce projections by Common Occupational Classification System for the current Future Years Nuclear Security Program period[10] (as of September 30, 2018)

7.2.3 Additional Elements in Workforce Planning

The nuclear security enterprise must address multiple aspects in workforce planning, given the specialized and challenging nature of the mission:

- Sites need to provide for knowledge transfer to new employees amid separations.
- Sites also need to plan for security clearance processing times, including hiring in advance of requirements and handling uncleared employees awaiting clearances that, in some cases, take around 18 to 24 months.
- As the workforce continues to grow at various M&O partner sites, requirements for supporting infrastructure will increase accordingly. Workforce planning must include increased office space for both cleared and uncleared personnel, parking, training facilities, cafeterias, etc.
- As DOE/NNSA modernizes the enterprise, infrastructure requirements such as space, associated with a temporary workforce for construction will need to be addressed.
- Inter-site exchanges need to be increased to better facilitate enterprise understanding and provide additional learning experiences.
- The impact of Nuclear Enterprise Assurance on the workforce as vendor/supply chain issues are uncovered will require new solutions and increased vetting.

[10] COCS categories are detailed in *Environmental Restoration/Waste Management Activities Common Occupational Classification System*, Revision 3, May 1996, by Pacific Northwest National Laboratory.

7.2.4 Unique Set of Essential Skills for Nuclear Weapons Work

Essential skills are necessary to successfully provide capabilities to support the nuclear weapons mission. While DOE/NNSA and the M&O partners monitor and manage the workforce providing these skills, they must closely manage certain essential skills that can only be obtained from disciplined experience. These skills cannot be learned in the classroom and are nontransferable from other industries. For example, the DOE/NNSA capability in simulation codes and modeling requires skill sets in nuclear weapon design, production, and certification; such as:

- materials behavior subject matter experts working with software developers to create models that describe weapon effects in certain environments;
- plutonium physicists working with software developers to develop nuclear implosion models;
- engineering analysis and modeling subject matter experts producing integrated design codes to advance predictive capability; and
- manufacturing process subject matter experts working with software developers to simulate, design, and refine processes and perform failure analysis for the production of weapon components.

Other essential skills include, but are not limited to, nuclear criticality safety engineering, high explosives manufacturing and surveillance, weapon design, radiation effects sciences, welding, radar, and optics applications.

Examples of Programs to Attract and Retain Personnel

- *M&O partner sites have partnered with top universities to offer graduate degrees and certification programs in high-demand disciplines such as systems engineering and data science.*
- *KCNSC is implementing a formalized Career Path Model and tools to help employees own and manage their careers.*
- *SNL has five on-campus Academic Alliance programs to identify promising candidates at top universities before graduation and promote joint technology development research between graduate students and SNL researchers, pursuing topics with national security applications.*
- *Pacific Northwest National Laboratory administers the NNSA Graduate Fellowship Program (NGFP). NGFP accepts graduate-level students from technical and policy backgrounds and provides hands-on experience in a variety of nuclear security missions. NGFP fellows have contributed to nuclear security for over 20 years and many serve in the Federal Government or at the nuclear sites.*

7.3 Challenges and Strategies

Building and retaining a workforce capable of maintaining the current stockpile and planning for an uncertain future poses many challenges for the Federal, M&O, and non-M&O workforce. Workforce planning efforts are focused on both the near- and long-term challenges in managing the increased workload necessary to support weapons modernization, while also backfilling key skills and transferring institutional knowledge as significant numbers of the workforce retire. These challenges are articulated for specific disciplines and areas of expertise in many of the challenge/strategy sections in Chapters 2, 3 and 6 of this SSMP.

Through a variety of approaches and strategies, the Federal, M&O, and non-M&O components ensure a competent and sustained workforce that will provide the knowledge, skills, and experience needed to maintain the current and future stockpile while being able to respond to dynamic needs and expectations.

The remainder of this section is organized by the talent management life cycle depicted in **Figure 7–9**.

7.3.1 Recruiting and Hiring

NNSA and its M&O partners continue to increase hiring to meet mission requirements. Each site employs mitigation strategies that address its unique recruiting and hiring challenges. **Table 7–1** provides a high-level summary of DOE/NNSA's recruitment and hiring challenges and strategies.

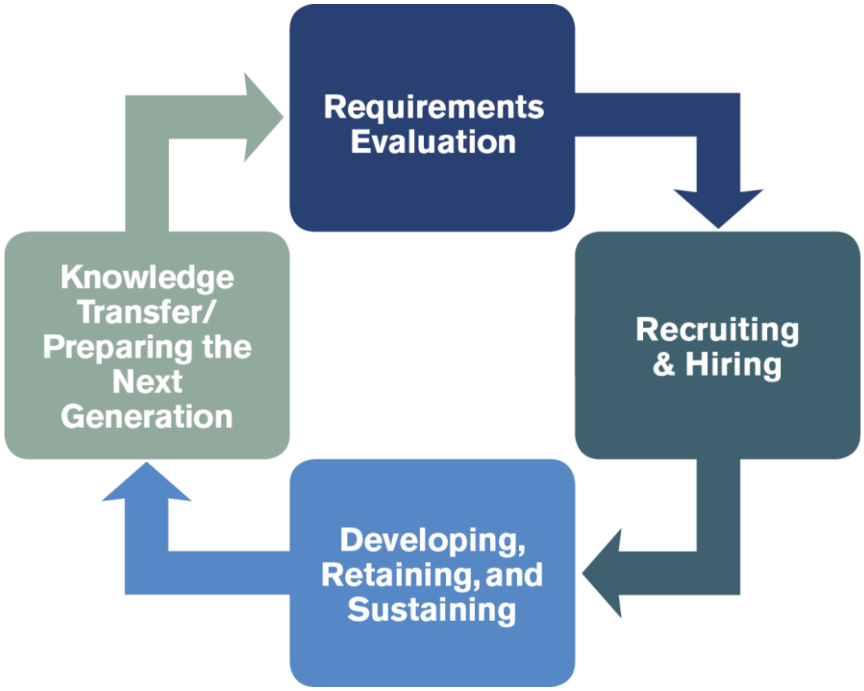


Figure 7–9. A simplified model of the talent management life cycle

Table 7–1. Summary of recruitment and hiring challenges and strategies

Challenges	***Strategies***
• Limited awareness of career opportunities in the nuclear security enterprise • Demonstrating the differentiating advantages of a national security career to prospective employees	• Increase outreach programs • Recruit at career fairs and universities/colleges • Increase social media presence • Establish and leverage long-term university partnerships; hire employees that are alumni to these institutions • Capture interest through initial student internships and post-doc appointments, with subsequent conversion to permanent employee status • Use specialized, third-party recruiting services • Increase the emphasis on the uniqueness and state-of-the-art research opportunities at NNSA sites via outreach programs • Develop and market a distinct nuclear security enterprise "brand"
• Competition for high-demand disciplines, such as electrical engineering and computer science • Proximity to high-tech industries, sparking intense competition for high-demand disciplines	• Promote access to unique, world-class R&D, science, technology, and engineering capabilities and facilities • Develop postdoctoral programs with opportunities to become career employees. • Emphasize stable employment, even during economic downturns, with long-term financial stability and higher quality of life • Introduce hiring bonus programs • 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) • Investigate methods to increase compensation for hard to fill roles

Challenges	*Strategies*
• Difficulty finding and hiring technical specialists in emerging disciplines, such as nanotechnologies, advanced manufacturing technologies, and high performance computing • Limited availability of U.S. citizens earning advanced engineering and science degrees	• Develop partnerships with universities that offer specialization in these emerging disciplines • Introduce students and early-career professionals to computing facilities via unclassified projects • Increase military and veteran recruitment • Target U.S. citizen students in university partnerships • Use specialized, third-party recruitment services • Use internships and special hiring programs to capture candidates' interest before graduation
• 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 technologists and craft workers, particularly at the nuclear weapons production facilities • Emphasize internal facility community
• Loss of candidates because of extended hire cycle time	• Work on processes to decrease hire cycle time, including consolidating Human Resource systems and transitioning to applicant tracking systems • Use innovative hiring strategies (e.g., hiring on the spot, hiring pools)
• Lower quality work environment because of aging infrastructure issues	• Continue efforts to increase capital investments in modern facilities with modern amenities, collaborative space, and enhanced digital communications access

7.3.2 Developing, Retaining, and Sustaining the Workforce

Many aspects of nuclear weapons work require sustained and extensive experience and knowledge, which can be difficult to achieve when most non-retirement separations occur within the first 5 years of employment. Today's workforce leans toward being increasingly mobile and desires more authority, more responsibility, and quicker advancement. These changes in expectations found in today's workforce make it difficult to keep staff engaged, given lengthy security clearance wait times, multi-year training periods, and constantly changing workloads and priorities.

As a means to increase workforce engagement, DOE/NNSA offers Laboratory Directed Research and Development (LDRD), Site Directed Research and Development (SDRD), and Plant Directed Research and Development (PDRD) programs to the national security laboratories, Nevada National Security Site, and nuclear weapons production facilities. These programs provide the nuclear security workforce with opportunities to collectively form the foundation of NNSA's strategy for developing science and technology tools and capabilities to meet future national security challenges.

KCNSC completed implementation of a new 100-workstation Mock Factory, an evolution from the original Manufacturing Innovation Center, which is focused on the onboarding of direct hourly employees who support development, production, and other projects for the nuclear security enterprise. The Mock Factory provides uncleared employees with a better understanding of business processes and requirements at KCNSC, including work instructions, Enterprise Resource Planning functions, Calibration Management, and other business operating systems. Performing this training up front reduces the burden on cleared factory employees who would otherwise spend time training newly cleared employees on the business systems critical to success in the factory. This increases efficiency for employees already working on the B61, W88, and other weapon programs in the factory.

There are five key objectives of the LDRD/SDRD programs:

- Maintain the scientific and technical vitality of the laboratories
- Enhance the laboratories' ability to extend LDRD work to address current and future DOE/NNSA missions
- Foster creativity and stimulate exploration of forefront areas of science and technology
- Serve as a proving ground for new concepts in research and development (R&D)
- Support high-risk, potentially high-value R&D

There are three key objectives of the PDRD program:

- Fund conceptual or preliminary designs of technology applications that hold a high potential payoff for their mission applications
- Fund capital expenditures for acquisition of general-purpose equipment if the equipment is required for PDRD projects
- Train, recruit, or retain essential personnel in critical engineering and manufacturing disciplines

The highly innovative and cutting edge nature of LDRD/SDRD/PDRD attracts high-quality candidates to the enterprise, while also providing those awaiting a clearance with a mechanism to work on mission-relevant basic R&D.

NNSA and its partners employ a number of strategies for development and retention, especially for early- and mid-career employees.[11] **Table 7–2** provides a high-level summary of DOE/NNSA's challenges and strategies associated with developing, retaining, and sustaining the workforce.

Table 7–2. Summary of workforce development, retention, and sustainment challenges and strategies

Challenges	***Strategies***
• New hires must wait extended time periods for security clearances – currently greater than 1 year for Q clearance • Perceived isolation while awaiting clearance	• Increase pre-clearance training programs • Offer opportunity to work on unclassified R&D or other projects • Use priority and interim clearance processes to shorten clearance times for new hires with essential skills
• Increasing attrition rates for early-career employees • Retaining new hires in mid-career, especially those in high-demand disciplines and in locations with a large high-tech base and high cost of living • Ensuring Federal technical employees possess the necessary knowledge, skills, and abilities to perform their duties and responsibilities (e.g., safe operation of defense nuclear facilities) • Making the wide range of programmatic and technical oversight tasks to advance NNSA's mission available to Federal employees across the nuclear security enterprise • Maintain critical skills during and outside of LEPs across the entire weapon life cycle	• Offer advanced education, training, leadership, and mentoring • Emphasize total compensation benefits (i.e., flexible work arrangements, royalty sharing, educational assistance, and work and life balance) • Emphasize stable employment with long-term financial stability. • Provide rotational development opportunities • Explore possibilities for specific skill incentives (e.g., bonuses and pay for market differential) • Offer broadening rotational assignments between the sites and NNSA, DoD, the White House, and other appropriate agencies • Analyze exit interviews and employee satisfaction surveys to obtain additional insight • Use the Technical Qualification Program, a structured training and development program, to identify the competencies that

[11] This section includes examples of programs that have been implemented by at least one site, but may not be available or feasible at other sites because the sites are operated under seven different M&O contracts; moreover, each M&O partner has its own business model, which may or may not be compatible with a particular approach.

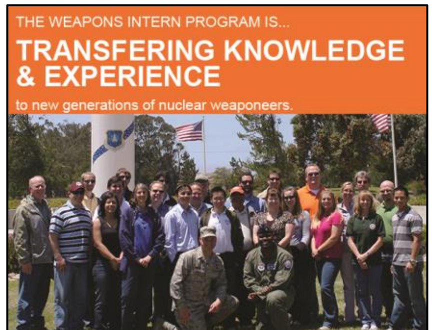
Challenges	*Strategies*
	employees must possess, and ensure that employees maintain those technical competencies • Use the Nuclear Weapon Acquisition Professional Certification Program, which was established to combine education, training, and mentoring, to ensure the workforce meets current Federal program management standards in key technical areas (i.e., engineering, program management and science, and technology) • Implement the Stockpile Responsiveness Program

7.3.3 Training and Knowledge Transfer to the Next Generation

Implementing training and knowledge transfer programs that are robust enough to stay ahead of the wave of retirement-eligible employees continues to be an area of emphasis for DOE/NNSA and its M&O partners.

The heavy stockpile modernization workloads provide an opportunity for new employees to learn on the job, although this must be accompanied by sufficient mentoring and guidance to be optimal. Many sites, especially the national security laboratories, have mentoring systems in place as part of an employee's career development. These mentoring systems provide new employees opportunities to learn from experienced professionals while enabling the experienced employees, including retirees, to pass on their knowledge.

Aside from active mentorship, the knowledge and expertise of seasoned employees approaching retirement has to be documented and preserved for future weapon designers. DOE/NNSA and the M&O partners recognize 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.



Created in 1998 with nominations for a new class each year, the Weapons Intern Program (WIP) is a formal way to transfer weapons-related knowledge, experience, and increase the understanding of those new to the nuclear weapons field. WIP graduates have come from all areas of the nuclear security enterprise and the United States military.

The DOE/NNSA nuclear security enterprise sites have deployed a variety of approaches that reflect their strategies to address knowledge transfer challenges. **Table 7–3** provides a high-level summary of challenges and strategies for training and transferring knowledge to the next generation.

Table 7–3. Summary of knowledge transfer and next-generation workforce training challenges and strategies

Challenges	*Strategies*
• Transferring knowledge and skills prior to the expected retirement wave	• Provide programs to transfer the experience of weapon mentors and leaders to new hires, such as lunch and learn sessions and "Bombs 101" courses • Digitize and catalogue weapon system-specific artifacts • Design and implement education and training programs for weapons engineers and scientists • Implement increased internship and postdoctoral opportunities for students and recent graduates • Provide formal mentoring in weapon programs and in R&D, testing, and evaluation to accelerate on-the-job training • Utilize recent retirees as consultants and mentors • Initiate succession planning to identify personnel with critical skills and recruit replacement candidates for key positions
• Amount of time required to bring early-career scientists and engineers to technical and leadership competency	• Incorporate introductory live and web-based self-study modules • Design education and training programs for weapons engineers and scientists • Implement new hire orientation programs • Design programs specifically for new employees within 6 months of hire
• Documenting, managing, and preserving subject matter expertise, critical technical skills, and key processes prior to an expected wave of retirements	• Develop or expand programs to identify, track, and manage mission-critical subject areas, essential skills, and key processes • Develop data virtualization and interactive online tools to capture knowledge, improve collaboration, and expand the weapons knowledge base • Enhance video and process documentation of weapon surveillance, annual assessment, LEP, and alteration expertise and processes and role descriptions for designers and engineers

7.4 Workforce Accomplishments

The nuclear security enterprise workforce continues to possess a track record of outstanding achievement of scientific, technical, and professional excellence. The collective workforce includes dedicated individuals that not only contribute to DOE/NNSA's mission, but also take great pride in contributing to their professions and communities. This is demonstrated through the numerous awards and accolades earned by members of the workforce. More detailed site-by-site accomplishments can be found in each site's section of Appendix D, "Workforce and Site-Specific Information."

- Over the past 2 years, the three national security laboratories and the Nevada National Security Site earned or partnered in over 30 R&D 100 awards. The sites have had impressive representation in these awards for several years.
- The national security laboratories jointly published over 7,000 peer-reviewed, highly cited technical publications over a variety of fields in 2017 and 2018.
- In 2017 and 2018, DOE/NNSA sites were collectively issued more than 400 patents and copyrights; additional patent applications and more than 300 invention disclosures were also submitted.
- DOE/NNSA sites collectively worked to implement efficiency improvements in a variety of areas such as security, human resources, and productivity. Some examples of these achievements include allowing employees to report to work earlier through improved security clearance processes; consolidating human resource processes to use best practices and enhance the ability to recruit and retain top talent; increasing efficiency through actions such as improving product

loading, review, and shipping availability times and reducing single point failure; and completing multiple projects without safety issues.

- Several employees used their scientific, technical, and professional expertise to contribute while on assignment or detail supporting NNSA and other agencies in national security missions. Examples of these assignments include advising Defense Programs' leadership by serving on the Defense Programs Science Council; serving in other positions at DOE/NNSA Headquarters; participating at another nuclear enterprise site; advising DoD; serving at another government agency; and as detailees to congressional staffs.
- A number of employees and high-performing teams across the enterprise won diverse, distinguished, and prestigious awards. These include, but are not limited to, several 2018 Defense Programs Awards of Excellence; the Significant Technical Achievement Reward and Recognition award; DOE Early-Career Awards; five 2018 Black Engineer of the Year Awards; three 2018 Women of Color Awards; the National Organization of Gay and Lesbian Scientists and Technical Professionals' Scientist of the Year award; multiple Asian American of the Year awards; and the 2017 George Cotter Award for vision and leadership in the field of data analytics.
- Personnel at several sites were recognized for professional excellence through fellowship appointments to the American Physical Society, American Chemical Society, American Society of Mechanical Engineers, American Institute of Aeronautics and Astronautics, American Association for the Advancement of Science, and Institute of Electrical and Electronics Engineers.
- The FY 2019 update to the Government Accountability Office High Risk List identified progress in contract, project, and program management in its biannual update to Congress.

Chapter 8
Budget and Fiscal Estimates

This chapter provides an overview of the key programmatic elements proposed in the Weapons Activities budget request for FY 2020. The chapter displays budgetary information based on the current program of record, including the Future Years Nuclear Security Program (FYNSP), for FY 2020 through FY 2024. Each programmatic section in this chapter compares the FY 2020 budget request to the FY 2019 enacted budget and presents key milestones representing progress toward program goals. Milestones have been updated from the FY 2019 SSMP to reflect the milestones listed in the *Department of Energy FY 2020 Congressional Budget Request*. Specific information on the status and accomplishments of each program can be found in Chapters 2 through 6. This chapter also includes a section that describes cost projections beyond the FYNSP and the basis of those cost projections. The chapter concludes with an analysis of the affordability of Weapons Activities program costs.

8.1 Future Years Nuclear Security Program Budget

Table 8–1 outlines program budget requests for Weapons Activities for FY 2020 – FY 2024.

Table 8–1. Overview of Future Years Nuclear Security Program budget request for Weapons Activities in fiscal years 2020 through 2024[a]

Activity	*Fiscal Year (dollars in millions)*					
	2019 Enacted	*2020 Request*	*2021 Request*	*2022 Request*	*2023 Request*	*2024 Request*
Directed Stockpile Work	4,658.3	5,426.4	5,986.7	6,279.1	6,534.0	6,312.9
Research, Development, Test and Evaluation	2,014.2	2,277.9	2,295.9	2,376.2	2,390.6	2,430.4
Science	*480.5*	*586.6*	*656.8*	*691.1*	*695.8*	*684.9*
Engineering	*190.1*	*234.0*	*257.4*	*263.8*	*273.4*	*289.9*
Inertial Confinement Fusion Ignition and High Yield	*544.9*	*480.6*	*492.0*	*504.8*	*517.1*	*530.7*
Advanced Simulation and Computing	*717.1*	*839.8*	*774.6*	*799.5*	*782.3*	*794.0*
Advanced Manufacturing Development	*81.6*	*136.9*	*115.0*	*117.1*	*122.1*	*130.9*
Secure Transportation Asset	278.6	317.2	356.8	292.7	285.5	310.1
Infrastructure and Operations	3,087.9	3,208.4	3,033.3	2,938.8	2,767.7	3,165.3
Defense Nuclear Security	690.6	778.2	773.1	773.9	785.1	800.8
Information Technology and Cybersecurity	221.2	309.4	281.2	290.2	311.7	315.8
Legacy Contractor Pensions	162.3	91.2	66.9	66.9	69.4	69.4
Adjustments	(13.1)	0.0	0.0	0.0	0.0	0.0
Weapons Activities Total	**11,100.0**	**12,408.6**	**12,793.8**	**13,017.9**	**13,143.9**	**13,404.5**

[a] Totals may not add because of rounding.

The FY 2020 Weapons Activities budget request provides an 11.8 percent increase over the FY 2019 enacted level to support the current stockpile, life extension programs (LEPs), enterprise modernization efforts, and the scientific tools necessary for these efforts. The FY 2020 budget request is consistent with the 2018 *Nuclear Posture Review* and positions DOE/NNSA to support *Nuclear Posture Review* initiatives while continuing to work within the Nuclear Weapons Council to define military requirements and strategic direction. As military requirements are refined, the Administration will work with Congress to obtain the required adjustments in funding.

DOE/NNSA's plan to meet the objectives and strategies outlined in the 2018 *Nuclear Posture Review* consists of the 42 explicit and implicit tasks outlined in DOE/NNSA's *Nuclear Posture Review Implementation Plan*.[1] DOE/NNSA will continue to work with DoD through the Nuclear Weapons Council to translate *Nuclear Posture Review* policy into requirements that may impact future budget requests.

The figures that follow in each section enumerate the FY 2020 budget request. The tables compare the FY 2020 request to the FY 2019 enacted budget.

8.2 Directed Stockpile Work

Directed Stockpile Work (DSW) encompasses five major subprograms that sustain the nation's nuclear weapons stockpile. These subprograms are: (1) LEPs, which extend the lifetime of the Nation's nuclear stockpile while addressing defects and enhancing security and safety features, as well as alterations (Alts) and modifications (Mods), which address aging or obsolete components to ensure continued service life; (2) Stockpile Systems, which directly performs sustainment activities for all enduring weapons systems in the stockpile, including surveillance for each weapon system; (3) Weapons Dismantlement and Disposition, which dismantles retired weapons and disposes of retired components from the stockpile; (4) Stockpile Services, which provides the foundation and capabilities for DOE/NNSA's research, development, production, maintenance, and surveillance activities; and (5) Strategic Materials, which ensures sustainment of nuclear material processing capabilities and funds stabilization, consolidation, disposition, tracking, and accounting of nuclear materials. Research and development (R&D) in Stockpile Services is managed through the technology maturation R&D program and develops technologies from design concept through simulated environmental tests to support LEPs and future stockpile systems, which is distinct from the work done as part of the research, development, test and evaluation (RDT&E) portfolio.

8.2.1 Budget

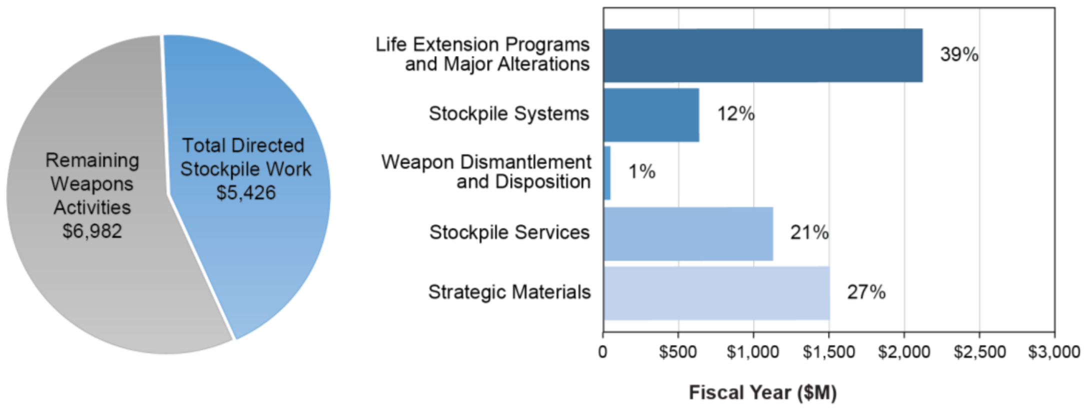
The funding schedule for DSW is illustrated in **Figure 8–1**. The budget request for DSW increased 17 percent from the FY 2019 enacted budget. The Stockpile Systems and Stockpile Services lines in Figure 8–1 include the surveillance program funding listed in **Table 8–2**.

8.2.2 Accomplishments

Major DSW accomplishments since the FY 2019 SSMP, in addition to the Annual Assessment Reports, Laboratory Director Letters to the President, and scheduled replacements of limited life components (LLCs), are discussed in Chapter 2, "Stockpile Management."

[1] NNSA *Nuclear Posture Review Implementation Plan* Report to Congress, February 2018.

Directed Stockpile Work Funding for FY 2020
(Dollars in Millions)



Fiscal Year ($M)	2019	2020	2021	2022	2023	2024
Life Extension Programs and Major Alterations	1,920.0	2,117.4	2,387.2	2,354.0	2,360.8	2,248.4
Stockpile Systems	599.5	635.8	605.4	633.9	638.8	655.3
Weapon Dismantlement and Disposition	56.0	47.5	50.0	51.0	51.0	51.0
Stockpile Services	1,048.7	1,124.5	1,150.3	1,199.1	1,215.7	1,281.7
Strategic Materials	1,034.1	1,501.2	1,793.8	2,041.1	2,267.7	2,076.6
Total Directed Stockpile Work	4,658.3	5,426.4	5,986.7	6,279.1	6,534.0	6,312.9

Note: Numbers may not add due to rounding

Figure 8–1. Funding schedule for Directed Stockpile Work, fiscal years 2019 through 2024

Table 8–2. Core Surveillance Program funding for fiscal years 2013 through 2024

	Fiscal Year (dollars in millions)											
	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*
Core Surveillance Program Funding [a]	217	225	236	217	213	231	264	264	274	279	294	298

[a] Core surveillance program numbers for FY 2019 through FY 2024 represent current planning estimates for Stockpile Systems and Management, Technology, and Production. Prior-year numbers reflect actual expenditures. The FYNSP estimates include increases to support retention of the B83 in the stockpile.

8.2.3 FY 2020 Budget Request Compared to FY 2019 Enacted

8.2.3.1 Life Extension Programs and Major Alterations

- The budget request for the B61-12 LEP had no substantive changes from the FY 2019 enacted budget.
- No FY 2020 funding was requested for the W76-1 LEP due to the completion of the remaining W76 warhead refurbishments and associated deliveries to the Navy.
- The budget request for the W76-2 Modification Program decreased 85 percent from the FY 2019 enacted budget because of strong program performance and production efficiencies. This funding directly supports 2018 *Nuclear Posture Review* implementation.
- The budget request for the W88 Alt 370 had no substantive changes from the FY 2019 enacted budget.
- The budget request for the W80-4 LEP increased 37 percent from the FY 2019 enacted budget to continue performing Phase 6.3 activities. This increase reflects revised cost estimates resulting

from the Weapon Design and Cost Report (WDCR) process.[2] The WDCR process captures higher-fidelity cost estimates based on site-specific analysis.

- The budget request for the W87-1 Modification Program (formerly IW1) increased 111 percent from the FY 2019 enacted budget to continue Phase 6.2 activities. This request supports 2018 *Nuclear Posture Review* implementation.

8.2.3.2 Stockpile Systems

- The budget request for B61 Stockpile Systems increased 10 percent from the FY 2019 enacted budget due to electronic neutron generator production for the B61-11 and transition costs associated with the B61-12 entering the stockpile.
- The budget request for W76 Stockpile Systems increased 7 percent from the FY 2019 enacted budget due to a ramp-up in development of the Joint Test Assembly 3 flight test body.
- The budget request for W78 Stockpile Systems had no substantive changes from the FY 2019 enacted budget.
- The budget request for W80 Stockpile Systems increased 7 percent from the FY 2019 enacted budget to support the 2018 *Nuclear Posture Review* sea-launched cruise missile study.
- The budget request for B83 Stockpile Systems increased 47 percent from the FY 2019 enacted budget to implement continued surveillance and assessment activities to support the 2018 *Nuclear Posture Review*.
- The budget request for W87 Stockpile Systems increased 18 percent from the FY 2019 enacted budget due to growth in component development and production to support joint test flight requirements, Ground-Based Strategic Deterrent integration, and ramp-up of component production to support rebuild and retrofit schedules.
- The budget request for W88 Stockpile Systems decreased 8 percent from the FY 2019 enacted budget due to reduced design and development costs for neutron generators and gas transfer systems.

8.2.3.3 Weapons Dismantlement and Disposition

- The budget request for Weapons Dismantlement and Disposition decreased 15 percent from the FY 2019 enacted budget due to a reduction in legacy component disposition and canned subassembly activities consistent with the material and component needs of the stockpile and external customers. The Weapons Dismantlement program of record remains unchanged.

8.2.3.4 Stockpile Services

- The budget request for Production Support increased 7 percent from the FY 2019 enacted budget to ensure production base capabilities and capacities are sufficiently resourced to support an increased workload as LEPs reach full-scale production rates.
- The budget request for Research and Development Support increased 9 percent from the FY 2019 enacted budget to enhance production agency and design agency interactions in early technology development.
- The budget request for Research and Development Certification and Safety increased 17 percent from the FY 2019 enacted budget to further invest in early development of new technologies, to

[2] More information about the WDCR can be found in Section 8.7.3.7.

advance existing technologies for the W87-1 and other future LEPs, and to support demonstration activities for flight test and ground-based capabilities.

- The budget request for Management, Technology, and Production increased 1 percent from the FY 2019 enacted budget in multi-weapon activities to support fielding the LEPs following first production unit, surveillance activities, and development of surveillance testers for weapons.

8.2.3.5 Strategic Materials

- The budget request for Uranium Sustainment increased 8 percent from the FY 2019 enacted budget to continue phasing out mission dependency on Building 9212 and executing ramp-up activities related to full-scale equipment prototyping for future uranium processes.
- The budget request for Plutonium Sustainment increased 97 percent from the FY 2019 enacted budget to support the 2018 *Nuclear Posture Review* requirement for a responsive nuclear weapons infrastructure that provides "the enduring capability and capacity to produce pits at a rate of no fewer than 80 pits per year (ppy) by 2030." In May 2018, the DOE/NNSA Administrator provided Congress with DOE/NNSA's recommended alternative to meet this requirement, which includes, repurposing SRS's Mixed Oxide Fuel Fabrication Facility, renaming it the Savannah River Plutonium Processing Facility, to produce 50 ppy by 2030 and concurrently continuing to invest in LANL to produce a minimum of 30 ppy beginning in 2026.
- The budget request for Tritium Sustainment decreased 7 percent from the FY 2019 enacted budget due to movement of funds to the Domestic Uranium Enrichment line; however, this program supports ramp-up of tritium production in the Watts Bar Unit 1 reactor and commencement of irradiation of tritium-producing burnable absorber rods (TPBARs) in the Watts Bar Unit 2 reactor. Funding supports increased extractions at the Tritium Extraction Facility and for down-blending highly enriched uranium (HEU) per the *Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019*. This request directly supports 2018 *Nuclear Posture Review* implementation.
- The budget request for Lithium Sustainment had no substantive changes from the FY 2019 enacted budget.
- The budget request for Domestic Uranium Enrichment increased 180 percent from the FY 2019 enacted budget largely due to the increased cost for down-blending activities to provide unobligated low-enriched uranium (LEU) fuel for tritium production and movement of those funds back into the Domestic Uranium Enrichment line from Tritium Sustainment.
- The budget request for Strategic Materials Sustainment increased 19 percent from the FY 2019 enacted budget to meet increased tritium and plutonium mission requirements through additional capability investment at SRS and the Plutonium Facility vault de-inventory, storage optimization, and transuranic waste process supply chain efforts at LANL.

8.2.4 Key Milestones

This section details key milestones for DSW. **Figure 8–2** illustrates key milestones for LEPs, major Alts, component production, and dismantlement.

8.2.4.1 Life Extension Programs and Major Alterations

Key milestones for LEPs and major Alts include:

- Carry out Phase 6.4 activities for the B61-12 LEP. The B61-12 schedule is under revision, see section 2.5.4 (B61-12 LEP) for details. A decision on first production unit and Initial Operational Capability dates is being jointly coordinated with the Air Force.
- Complete project closeout activities and production of arming, fuzing, and firing (AF&F) assemblies for the W76-1 LEP to support W76-1 life of program hardware provisioning in FY 2020.
- Complete remaining production of W76-2 warheads and execute program closeout activities in FY 2020.
- Carry out Phase 6.4 activities for the W88 Alt 370. The W88 Alt 370 schedule is under revision, see section 2.5.3 (W88 Alt 370) for details.
- Carry out Phase 6.3 activities in support of the Air Force Long Range Standoff cruise missile program in FY 2020 and FY 2021.
- Begin Phase 6.4 activities for the W80-4 LEP in FY 2022; deliver first production unit in FY 2025; and deliver last production unit in FY 2031.
- Complete Phase 6.2 activities for the W87-1 Modification Program and transition to Phase 6.3 activities in FY 2022.
- Deliver first production unit of the W87-1 Modification Program in FY 2030.
- Execute feasibility studies for the Next Navy Warhead in FY 2020 as part of the Stockpile Responsiveness Program.
- Deliver first production unit of the Next Navy Warhead in FY 2034.[3]
- Deliver first production unit of the Future Strategic Missile Warhead in FY 2037.

8.2.4.2 Stockpile Systems

Key milestones for Stockpile Systems include:

- Complete a sea-launched cruise missile study in the early 2020s as identified in the NNSA *Nuclear Posture Review Implementation Plan.*

8.2.4.3 Weapons Dismantlement and Disposition

Key milestones for Weapons Dismantlement and Disposition include:

- Complete dismantlement of weapons consistent with material and disposition needs for the stockpile and external customers.

8.2.4.4 Stockpile Services

Key milestones for Stockpile Services include:

- Complete the Manufacturing Modernization Project to support digital product production and acceptance, specifically the upgrade for the detonator manufacturing line completing in FY 2021.

[3] The Nuclear Weapons Council continues to evaluate deterrence requirements from the 2018 *Nuclear Posture Review* that will be resolved in the next several months. Among these are the first production units for the Next Navy Warhead and the Future Strategic Missile Warhead. The costs and updated delivery dates, once approved by the Nuclear Weapons Council, will be reflected in next year's SSMP.

- Complete demonstration studies for the Joint Technology Demonstrator for the Mk21 ground test unit by FY 2020 and United States/United Kingdom-developed systems by FY 2022.
- Evaluate and implement re-entry concepts/environments within the High Operational Tempo Sounding Rocket (HOT SHOT) initiative by FY 2024.
- Complete the Weapons Reliability Report in FY 2020.

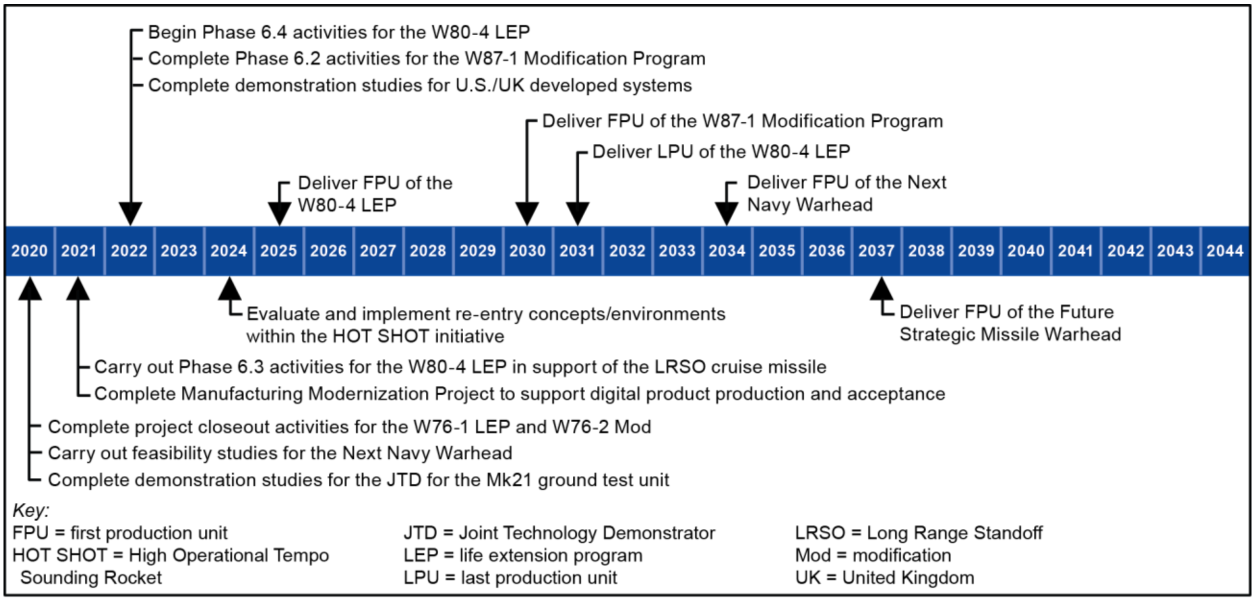


Figure 8–2. Key milestones for life extension programs and major alterations, Stockpile Systems, and Stockpile Services

8.2.4.5 Strategic Materials

As illustrated in **Figure 8–3**, key milestones[4] for Strategic Materials include:

- Obtain Critical Decision 4 (CD-4) approval for the Uranium Processing Facility[5] by the end of FY 2025.
- Accomplish and certify the W87-like pit design, including production of development pits each year to sustain fabrication capability, according to the timeline:
  - 1 W87-like War Reserve ppy in FY 2023
  - 10 W87-like War Reserve ppy in FY 2024
  - 20 W87-like War Reserve ppy in FY 2025
  - 30 W87-like War Reserve ppy in FY 2026
  - 80 W87-like War Reserve ppy in FY 2030

[4] The Critical Decision process is outlined in Chapter 4, "Physical Infrastructure," Figure 4–5.
[5] The Uranium Processing Facility project is funded under Infrastructure and Operations.

- Begin irradiation of TPBARs in a second reactor in FY 2021.
- Begin increasing TPBAR irradiation cycles to begin producing 2,800 grams of tritium per reactor cycle by FY 2025.
- Re-establish a lithium chloride conversion and purification process in FY 2020.
- The Lithium Processing Facility[6] is scheduled to:
  - Obtain Technology Readiness Level-7 for selected technologies for insertion into the Lithium Processing Facility in FY 2021.
  - Obtain CD-2/3 approval in FY 2022.
  - Obtain CD-4 approval in FY 2027.
- The Domestic Uranium Enrichment program is scheduled to:
  - Complete Analysis of Alternatives (AoA) in FY 2020.
  - Obtain CD-1 approval by the end of FY 2023.
  - Complete down-blending of identified HEU to extend the need date for LEU fuel for tritium production in FY 2025.
  - Obtain CD-4 approval in FY 2039.

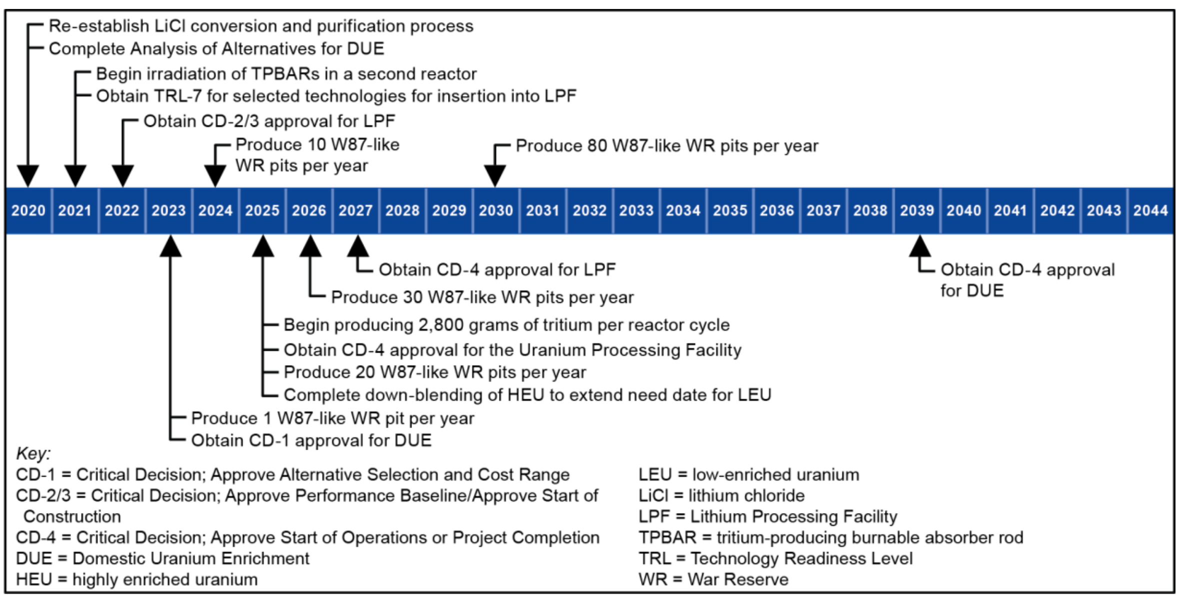


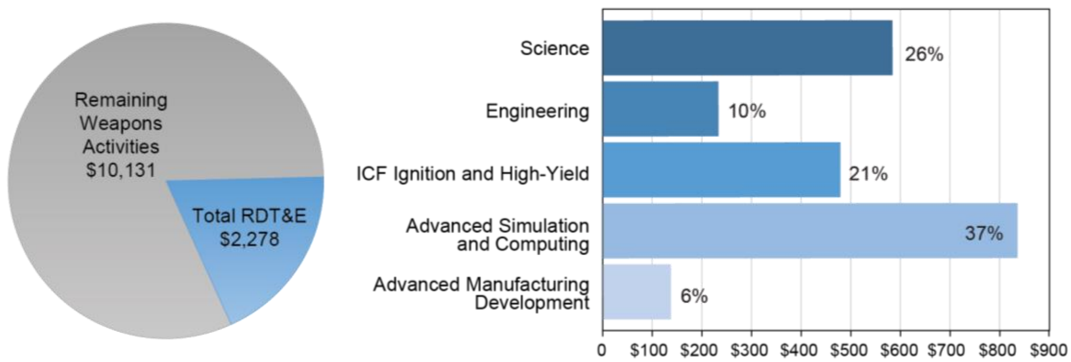
Figure 8–3. Key milestones for Strategic Materials

[6] The Lithium Processing Facility project is funded under Infrastructure and Operations.

8.3 Research, Development, Test and Evaluation

The RDT&E programs develop and maintain the critical capabilities, tools, and processes needed to support science-based stockpile stewardship, refurbishment, and continued certification of the stockpile without additional explosive nuclear testing. The funding schedule for the RDT&E portfolio is illustrated in **Figure 8–4**.

RDT&E Program Funding for FY 2020
(Dollars in Millions)



Fiscal Year ($M)

	2019	2020	2021	2022	2023	2024
Science	480.5	586.6	656.8	691.1	695.8	684.9
Engineering	190.1	234.0	257.4	263.8	273.4	289.9
ICF Ignition and High-Yield	544.9	480.6	492.0	504.8	517.1	530.7
Advanced Simulation and Computing	717.1	839.8	774.6	799.5	782.3	794.0
Advanced Manufacturing Development	81.6	136.9	115.0	117.1	122.1	130.9
Total RDT&E	2,014.2	2,277.9	2,295.9	2,376.2	2,390.6	2,430.4

Key:
ICF = Inertial Confinement Fusion RDT&E = Research, Development, Test and Evaluation
Note: Numbers may not add due to rounding

Figure 8–4. Funding schedule for Research, Development, Test and Evaluation, fiscal years 2019 through 2024

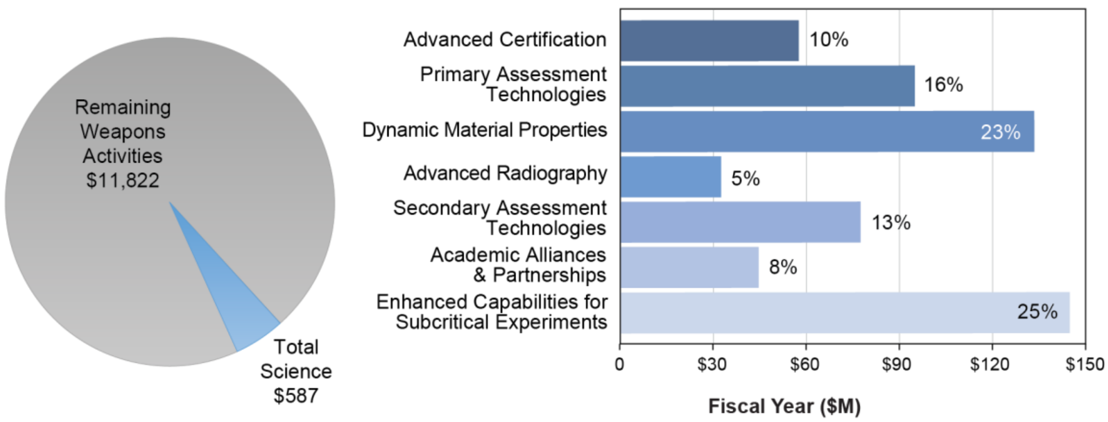
8.3.1 Science

The Science Program provides the knowledge and expertise needed to maintain confidence in the nuclear stockpile without additional underground nuclear explosive testing. Capabilities developed and maintained in the Science Program provide: (1) the scientific underpinnings required to conduct annual assessments of weapon performance and certification of LEPs; (2) the information required to understand the effects of surveillance findings to assure that the nuclear stockpile continues to remain safe, secure, and effective; and (3) the core technical expertise required to be responsive to technical and geopolitical developments. Science deliverables also facilitate the assessment of current weapon and component lifetimes, development and qualification of modern materials and manufacturing processes, concepts for component reuse, and modern safety concepts for sustainment.

8.3.1.1 Budget

The funding schedule for Science is illustrated in **Figure 8–5**. The budget request for Science increased 22 percent from the FY 2019 enacted budget.

Science Program Funding for FY 2020
(Dollars in Millions)



Fiscal Year ($M)	2019	2020	2021	2022	2023	2024
Advanced Certification	57.7	57.7	60.7	64.1	66.1	67.4
Primary Assessment Technologies	89.3	95.2	106.8	117.0	127.4	130.1
Dynamic Material Properties	120.0	133.8	147.8	159.9	134.4	137.3
Advanced Radiography	32.5	32.5	36.0	37.4	38.8	42.7
Secondary Assessment Technologies	77.6	77.6	82.1	84.0	85.8	87.6
Academic Alliances & Partnerships	53.4	44.6	53.1	56.0	56.7	57.9
Enhanced Capabilities for Subcritical Experiments	50.0	145.2	170.4	172.8	186.5	161.8
Total Science	480.5	586.6	656.8	691.1	695.8	684.9

Note: Numbers may not add due to rounding

Figure 8–5. Funding schedule for Science, fiscal years 2019 through 2024

8.3.1.2 Accomplishments

Major accomplishments and significant contributions from the Science Program and its subprograms since the FY 2019 SSMP are detailed in Chapter 3, “Stockpile Stewardship Science, Technology, and Engineering.”

8.3.1.3 FY 2020 Budget Request Compared to FY 2019 Enacted

- The budget request for Advanced Certification had no substantive changes from the FY 2019 enacted budget.
- The budget request for Primary Assessment Technologies increased 7 percent from the FY 2019 enacted budget to support design and development of an inner containment vessel at the Los Alamos Neutron Science Center (LANSCE) proton radiography (pRad) facility and expanded nuclear science initiatives based on recent findings.
- The budget request for Dynamic Materials Properties increased 12 percent from the FY 2019 enacted budget to support an increased rate of subcritical experiments with improved diagnostics, plutonium characterization, advanced manufacturing, and new high explosive formulation for future stockpile options.
- The budget request for Advanced Radiography had no substantive changes from the FY 2019 enacted budget.
- The budget request for Secondary Assessment Technologies had no substantive changes from the FY 2019 enacted budget.

- The budget request for Academic Alliances and Partnerships decreased 16 percent from the FY 2019 enacted budget to reflect priorities of other programs.
- The budget request for Enhanced Capabilities for Subcritical Experiments (ECSE) increased 190 percent from the FY 2019 enacted budget to support: (1) the technical maturation and design activities needed in support of the Advanced Sources and Detectors (ASD) accelerator CD-3A submittal (FY 2020; long lead acquisitions); (2) development of the source and detectors associated with Neutron Diagnosed Subcritical Experiments; and (3) staff to support the overall preliminary and final designs needed to support an ASD accelerator FY 2021 CD-2/3 submittal. The ASD accelerator is an ~$800 million, multi-pulse (at least 4-pulses) x-ray machine being built at the Nevada National Security Site U1a Complex in Nevada.[7]

8.3.1.4 Key Milestones

This section details key milestones for Science. The Stewardship Capability Delivery Schedule (SCDS) (formerly known as the Predictive Capability Framework) pegposts and objectives previously included in this section were adjusted to better align with the needs of the current and future U.S. nuclear stockpile and are described in Chapter 3. Note that SCDS is an organizational framework for ongoing initiatives in the RDT&E program and has no internal budget and makes no capital investments. **Figure 8–6** illustrates the key milestones for Science, including:

- Conduct two subcritical experiments per year beginning in FY 2020.
- Reinstitute the capability for examining plutonium-bearing material at the LANSCE pRad facility in FY 2021.
- Develop the ability to fabricate plutonium thin films supporting target fabrication and surface studies by FY 2023.
- Develop updated lifetime assessment of aging based on new, experimental data by FY 2024.
- Execute ramp-compression experiments, providing equation of state data for high Z materials in a relevant pressure regime in FY 2023.
- Conduct six experiments to deliver high-pressure plutonium data using the Joint Actinide Shock Physics Experimental Research (JASPER) capability at the Nevada National Security Site in FY 2020.
- Complete R&D for the next-generation Dual-Axis Radiographic Hydrodynamic Test (DARHT) and Flash X-Ray replacement accelerator architectures by FY 2024.
- Provide a pulsed neutron source that supports radiographic and reactivity measurements by FY 2024.
- Deliver opacity data on multiple elements from the Z pulsed power facility (Z) and National Ignition Facility (NIF) experiments to improve and validate first-principles opacity models in FY 2020.
- Obtain CD-3A approval for long lead ECSE procurements in FY 2021 and approval of CD-2/3 for the ASD accelerator in FY 2022.
- Begin installation of ASD accelerator special equipment in the U1a Complex in FY 2021.

[7] This x-ray machine is somewhat analogous to the 4-pulse second axis of DARHT at LANL. However, the design requirements are more stringent so as to be able to fit the ASD accelerator within the tunnel structure of the U1a Complex, and more importantly, the ASD accelerator system will be able to diagnose the late time behavior of plutonium, to eliminate the paucity of plutonium data that exist within this extreme regime of temperature and pressure.

- Complete the ASD accelerator injector testing at the integrated test stand in FY 2023.
- Establish sustainable ECSE capability at the Nevada National Security Site in FY 2025.

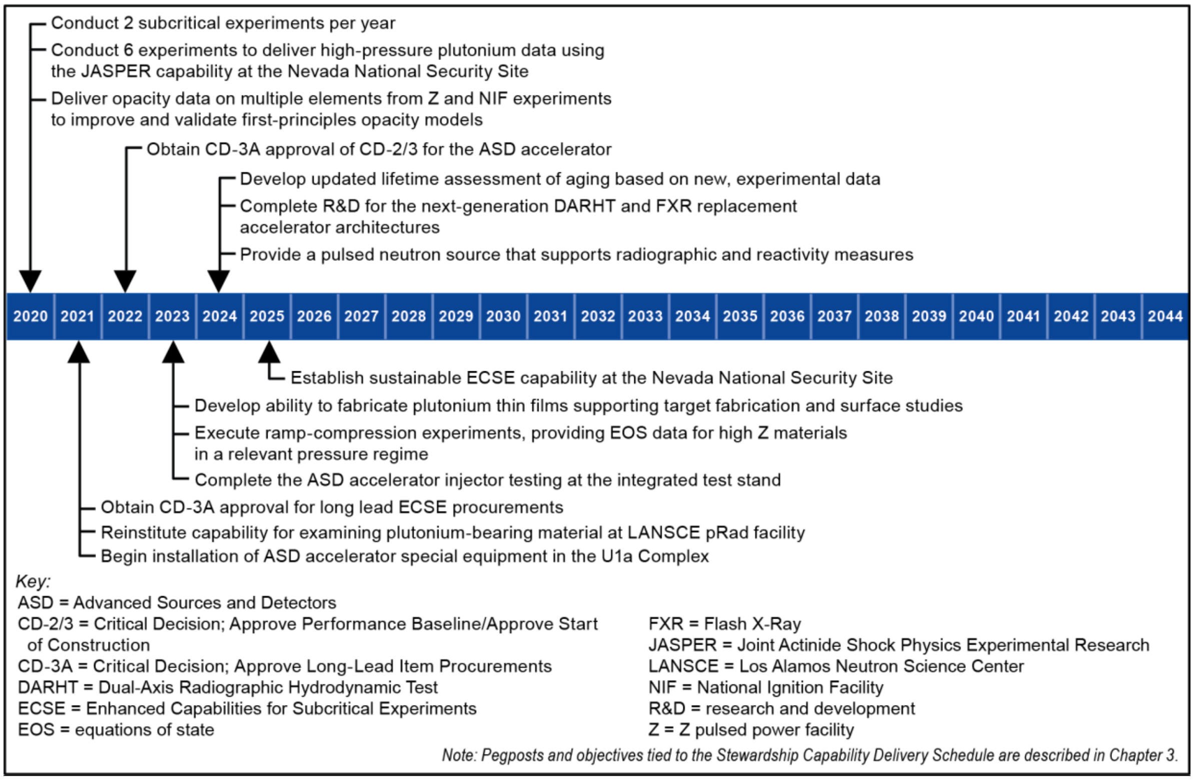


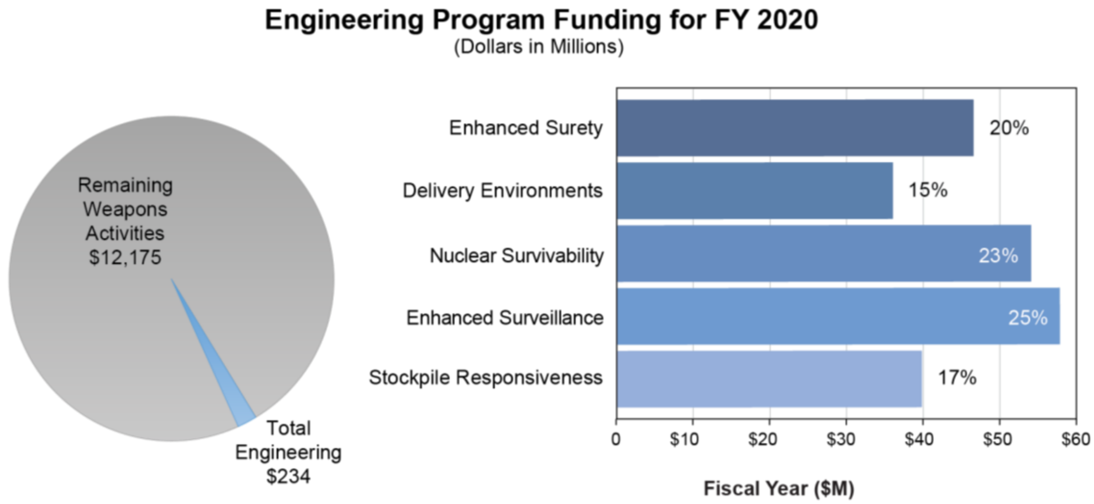
Figure 8–6. Key milestones for Science

8.3.2 Engineering

The Engineering Program is responsible for providing the engineering tools and capabilities for evaluating the stockpile of today and enabling the future deterrent. This program supports five key mission areas: (1) strengthening the science, technology, and engineering base by maturing advanced technologies to improve weapon surety; (2) providing tools for qualifying weapon components to hostile environments without underground nuclear explosive testing; (3) providing tools for qualifying weapon components to a range of delivery environments, to include accident scenarios; (4) supporting annual stockpile assessments through improved weapons surveillance technologies and warhead component aging assessments; and (5) exercising all phases of the joint nuclear acquisition process through Stockpile Responsiveness.

8.3.2.1 Budget

The funding schedule for Engineering is illustrated in **Figure 8–7**. The budget request for Engineering increased 23 percent from the FY 2019 enacted budget.



	2019	2020	2021	2022	2023	2024
Enhanced Surety	39.7	46.5	52.6	53.7	54.6	60.2
Delivery Environments	23.0	35.9	39.2	39.5	42.6	44.1
Nuclear Survivability	48.2	53.9	59.5	61.0	63.7	66.7
Enhanced Surveillance	45.1	57.7	62.3	63.5	64.9	66.2
Stockpile Responsiveness	34.0	39.8	43.8	46.1	47.7	52.8
Total Engineering	190.1	234.0	257.4	263.8	273.4	289.9

Note: Numbers may not add due to rounding

Figure 8–7. Funding schedule for Engineering, fiscal years 2019 through 2024

8.3.2.2 Accomplishments

Major accomplishments and significant contributions from Engineering and its subprograms since the FY 2019 SSMP are detailed in Chapter 3, "Stockpile Stewardship Science, Technology, and Engineering."

8.3.2.3 FY 2020 Budget Request Compared to FY 2019 Enacted

- The budget request for Enhanced Surety increased 17 percent from the FY 2019 enacted budget to produce flight test hardware to validate and qualify system performance for next-generation technologies and multi-point safety initial design concepts, and to support the simultaneous development of technologies at the design and production agencies.
- The budget request for Delivery Environments (formerly Weapons Systems Engineering Assessment Technology) increased 56 percent from the FY 2019 enacted budget to support joint DOE/NNSA-DoD interagency projects on delivery environments, provide diagnostics for sounding rocket experiments, and prepare for a planned hydrodynamic flight test in FY 2023.
- The budget request for Nuclear Survivability increased 12 percent from the FY 2019 enacted budget to support x-ray radiation environment testing (Saturn) recapitalization, evaluations of new strategic radiation-hardened microelectronics, development of cold x-ray surrogate test capability, and radiation transport in advanced materials.
- The budget request for Enhanced Surveillance increased 28 percent from the FY 2019 enacted budget to maintain characterization of high-risk stockpile components and materials.
- The budget request for Stockpile Responsiveness increased 17 percent from the FY 2019 enacted budget to begin work with the production agencies to explore new technology concepts. This funding supports 2018 *Nuclear Posture Review* implementation.

8.3.2.4 Key Milestones

This section details key milestones for Engineering. The SCDS pegposts and objectives previously included in this section were adjusted to better align with the needs of the current and future U.S. Nuclear Stockpile and are described in Chapter 3. **Figure 8–8** illustrates key milestones for Engineering, including:

- Provide advanced surety options for the W87-1 weapon system by FY 2022.
- Assure advanced surety options are available for the Next Navy Warhead system by FY 2024.
- Develop integrated use control and physical security subsystems developed for Air Force weapon storage by FY 2023.
- Develop enhanced capability shipping configurations for current stockpile systems by FY 2023.
- Develop and apply experimental modeling capabilities and diagnostics to assess effects of delivery environments and accidents by FY 2024.
- Increase the fidelity of simulated weapons environments in predictive models using validation data from scaled experiments in FY 2023.
- Develop progressive methodologies for measuring engineering performance of materials, components, and systems needed for future qualification by FY 2022.
- Perform ground testing and model validation for reentry environments and flight test diagnostics in FY 2021.
- Extend nuclear environment test capabilities at the Z machine, Hermes, Saturn, and NIF through FY 2024.
- Provide the initial tools and technologies necessary to design and qualify components and subsystems to meet requirements to withstand radiation environments associated with hostile encounters by FY 2020 and provide advanced tools and technologies by FY 2023.
- Evaluate performance damage to non-nuclear components and evaluate damage modes to the nuclear explosive package yield by FY 2023.
- Develop and refine understanding of stockpile aging and age-aware models for weapon materials, components, and subsystems by 2024.
- Provide assessments of aging model status for highest-risk materials by FY 2022.
- Qualify and deploy a new scintillator for the Confined Large Optical Scintillator Screen and Imaging System (CoLOSSIS) I and II in FY 2021.
- Complete assembly of a 10-megaelectronvolt neutron imaging machine at LLNL for plant installation in FY 2023.
- Conduct design competition associated with potential future strategic missile warheads exploring different manufacturing approaches and potentially different stockpile-to-target sequence environments compared to today’s systems in FY 2020.
- Develop several design options to inform future strategic programs by FY 2024.

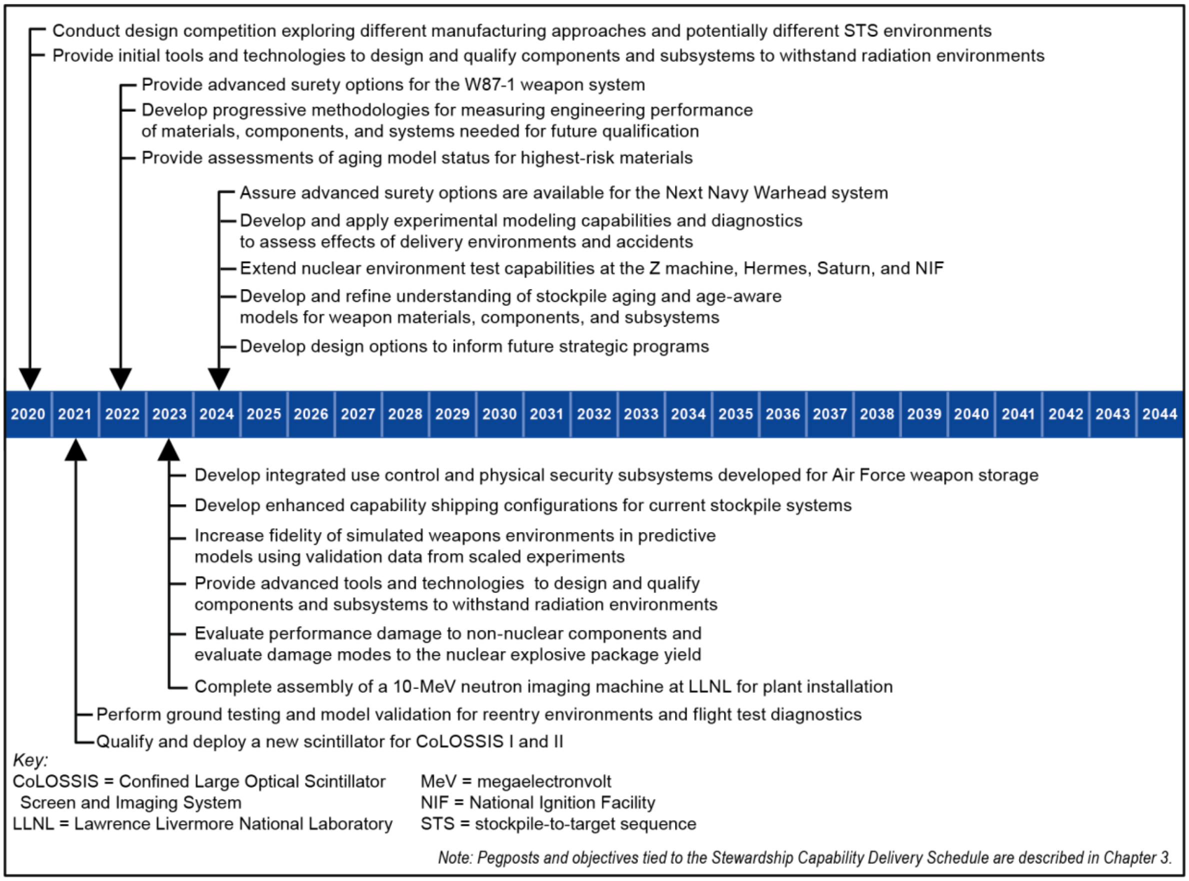


Figure 8–8. Key milestones for Engineering

8.3.3 Inertial Confinement Fusion Ignition and High Yield

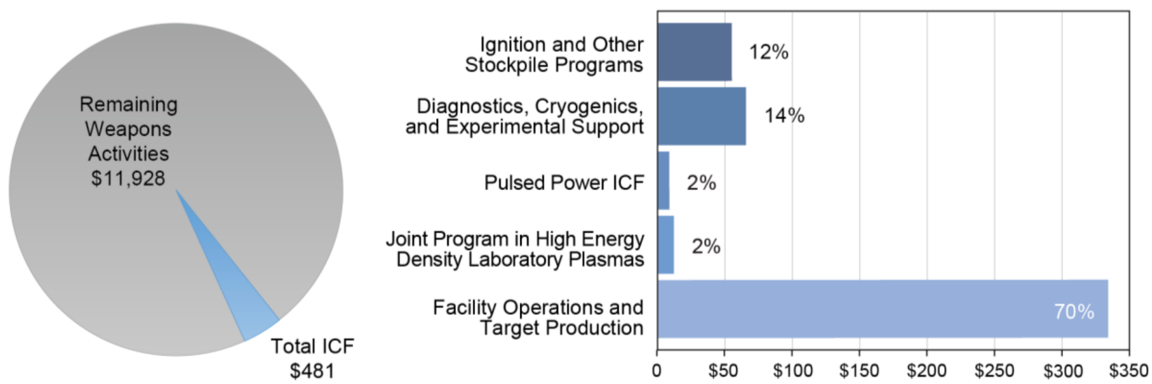
The Inertial Confinement Fusion Ignition and High Yield (ICF) Program provides data, experimental tools, and supporting expertise required for the ongoing assessment and certification of the nuclear weapons stockpile. As warheads proceed through the LEP process, new materials and components must be qualified and accepted. The United States no longer conducts underground tests that allow these materials and components to be tested at extreme temperatures and densities. Instead, the unique facilities funded by the ICF Program can be used to generate the weapon-relevant environments that improve confidence in their certification. The capabilities provided by ICF for Stockpile Stewardship include experimental diagnostics, computational models, national high energy density (HED) facilities, experimental platforms, and target engineering and production.

8.3.3.1 Budget

The funding schedule for ICF is illustrated in **Figure 8–9**. The budget request for ICF decreased 12 percent from the FY 2019 enacted budget.

Inertial Confinement Fusion Ignition and High Yield (ICF) Program Funding for FY 2020

(Dollars in Millions)



Fiscal Year ($M)	2019	2020	2021	2022	2023	2024
Ignition and Other Stockpile Programs	101.1	55.6	57.0	58.3	59.5	61.6
Diagnostics, Cryogenics, and Experimental Support	77.9	66.1	67.2	69.5	71.2	73.0
Pulsed Power ICF	6.6	8.6	8.8	9.0	9.2	9.5
Joint Program in High Energy Density Laboratory Plasmas	8.5	12.0	12.3	12.6	12.9	13.2
Facility Operations and Target Production	350.8	338.2	346.7	355.4	364.3	373.4
Total ICF	544.9	480.6	492.0	504.8	517.1	530.7

Note: Numbers may not add due to rounding

Figure 8–9. Funding schedule for Inertial Confinement Fusion Ignition and High Yield, fiscal years 2019 through 2024

8.3.3.2 Accomplishments

Major accomplishments and significant contributions from ICF and its subprograms since the FY 2019 SSMP are detailed in Chapter 3, "Stockpile Stewardship Science, Technology, and Engineering."

8.3.3.3 FY 2020 Budget Request Compared to FY 2019 Enacted

The *Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019* combined Ignition with Support of Other Stockpile Programs into a single program: Ignition and Other Stockpile Programs.

- The budget request for Ignition and Other Stockpile Programs decreased 45 percent from the FY 2019 enacted budget to reflect a shift to higher priority DOE/NNSA efforts. DOE/NNSA will support highest-priority non-ignition HED stockpile experiments and delivery of the ICF 2020 Report.
- The budget request for Diagnostics, Cryogenics, and Experimental Support decreased 15 percent from the FY 2019 enacted budget to reflect a shift to higher-priority DOE/NNSA efforts. Execution of the National Diagnostics Plan will continue with a focus on diagnostics needed for key materials and radiation effects platforms.
- The budget request for Pulsed Power Inertial Confinement Fusion increased 30 percent from the FY 2019 enacted budget to continue its comprehensive experimental investigation of Magnetic Direct Drive.

- The budget request for Joint Program in High Energy Density Laboratory Plasmas increased 41 percent from the FY 2019 enacted budget to expand national participation in HED science research.
- The budget request for Facility Operations and Target Production decreased 4 percent from the FY 2019 enacted budget to support higher DOE/NNSA priorities. A reduction is consistent with the proposed reduction in ignition science work scope. Operations at the Omega Laser Facility and Z are unaffected.

8.3.3.4 Key Milestones

This section details key milestones for ICF. The SCDS pegposts and objectives previously included in this section were adjusted to better align with the needs of the current and future U.S. nuclear stockpile and are described in Chapter 3. **Figure 8–10** illustrates key ICF milestones based on experiments at the different facilities, including:

- Complete an independent study in FY 2020 to determine the efficacy of NIF for ignition and credible physics-scaling to multi-mega joule yields for all ignition approaches.
- Increase energy coupled from the driver to the fusion fuel by FY 2023.
- Reduce uncertainties in yield scaling based on the 2010 ICF assessment by FY 2023.
- Perform thermonuclear burn experiments to inform understanding of primary boost by FY 2024.
- Establish mission need for a high-yield platform to support LEP and long-term stockpile stewardship requirements by FY 2024.
- Conduct major program review to assess the facility investments needed to meet future stockpile stewardship requirements by FY 2025.
- Experimentally constrain complex hydrodynamic models used in stockpile assessments by FY 2022.
- Support the national plutonium aging and manufacturing assessment effort through cross-platform HED experiments by FY 2024.
- Reduce discrepancies between opacity experiments and models through a systematic study of high-temperature cross-platform measurements by FY 2024.
- Develop x-ray platforms for measuring thermo-mechanical shock to inform future LEP options in FY 2020.
- Enable system-generated electron magnetic pulse model validation using new warm x-ray capabilities by FY 2023.
- Measure the response of weapon-related components under high neutron fluence irradiation by FY 2024.

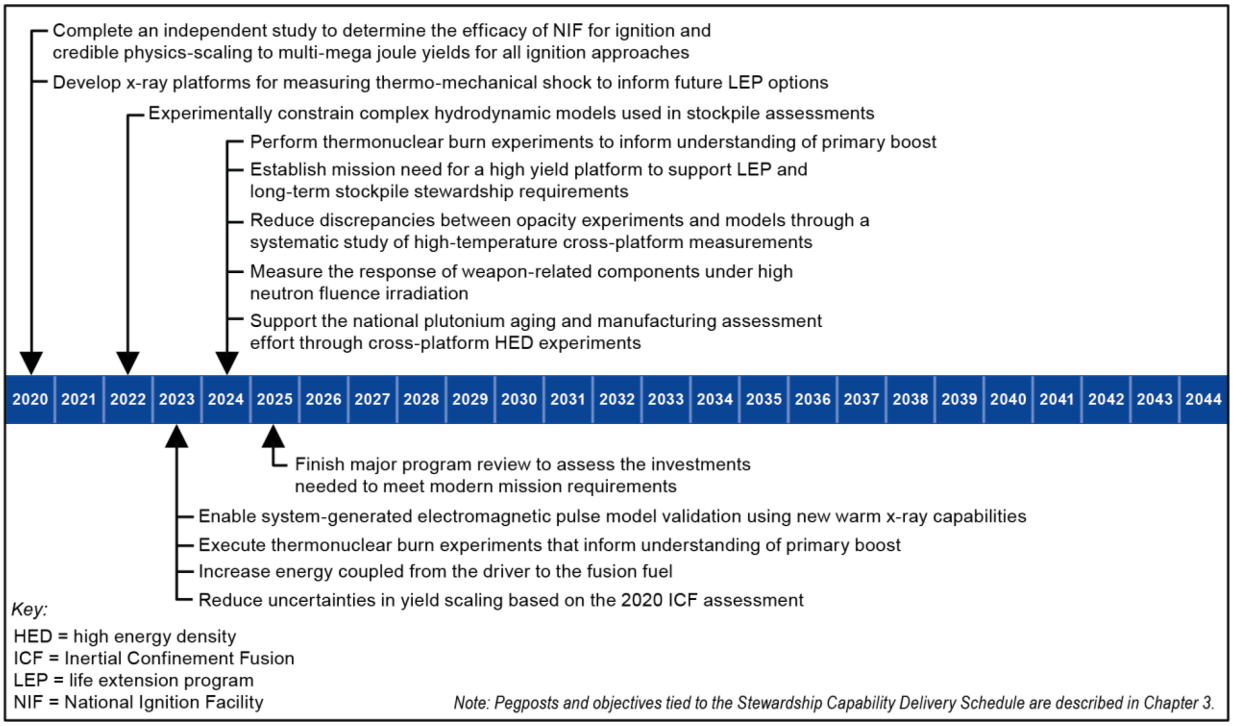


Figure 8–10. Key milestones for Inertial Confinement Fusion Ignition and High Yield

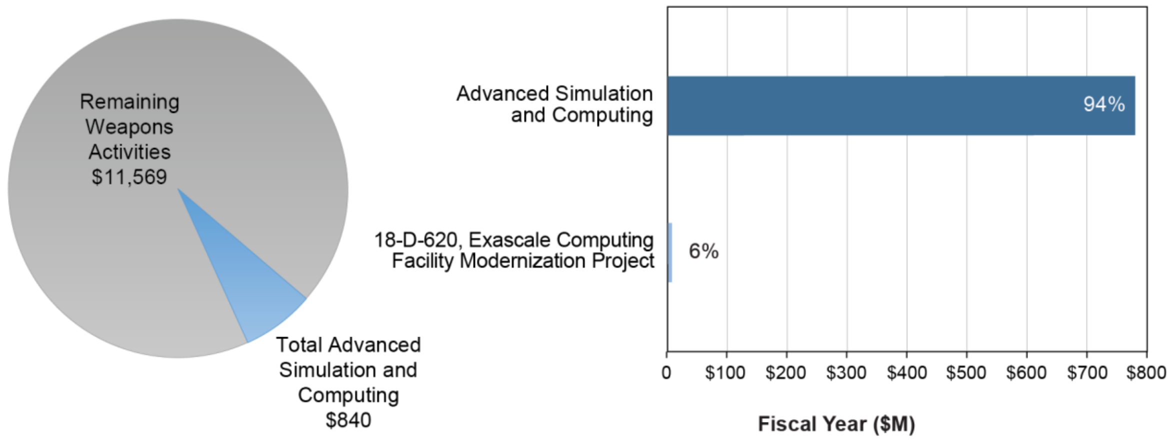
8.3.4 Advanced Simulation and Computing

To meet the requirements of the Stockpile Stewardship Program, the Advanced Simulation and Computing (ASC) Program provides high-end simulation capabilities, including modeling and computing platforms and their supporting infrastructure. Modeling the complexity of nuclear weapons systems is essential to maintaining confidence in the performance of our stockpile without additional underground nuclear explosive testing. ASC provides the weapon codes that provide the integrated assessment capability supporting annual assessment and future sustainment program qualification and certification for the stockpile. ASC capabilities also inform decision-making related to the sustainment of the nuclear stockpile and future stockpile reductions in support of U.S. nonproliferation objectives.

8.3.4.1 Budget

The funding schedule for the ASC Program is illustrated in **Figure 8–11**. The funding schedule for the DOE/NNSA Exascale Computing Initiative, which is executed with ASC's budget, is presented in Appendix C, Table C–1. The budget request for the ASC Program increased 17 percent from the FY 2019 enacted budget.

Advanced Simulation and Computing Program Funding for FY 2020
(Dollars in Millions)



	2019	2020	2021	2022	2023	2024
Advanced Simulation and Computing	670.1	789.8	747.6	786.5	782.3	794.0
18-D-670, Exascale Class Computer Cooling Equipment	24.0	0.0	0.0	0.0	0.0	0.0
18-D-620, Exascale Computing Facility Modernization Project	23.0	50.0	27.0	13.0	0.0	0.0
Total Advanced Simulation and Computing	717.1	839.8	774.6	799.5	782.3	794.0

Note: Numbers may not add due to rounding

Figure 8–11. Funding schedule for Advanced Simulation and Computing, fiscal years 2019 through 2024

8.3.4.2 Accomplishments

Major accomplishments and significant contributions from ASC and its subprograms since the FY 2019 SSMP are detailed in Chapter 3, "Stockpile Stewardship Science, Technology, and Engineering."

8.3.4.3 FY 2020 Budget Request Compared to FY 2019 Enacted

- The budget request for ASC increased 18 percent from the FY 2019 enacted budget to reflect the transition of the integrated design codes to new architectures, the development and evaluation of new computing technologies and algorithms against advanced prototype hardware, and support for integration between platform procurement/deployment and computing center operations. These funding levels are necessary for delivering an exascale system in FY 2023.
- The budget request for ASC – Construction increased 6 percent from the FY 2019 enacted budget to continue construction of the Exascale Computing Facility Modernization Project. This project will provide the infrastructure necessary to support advanced technology systems at LLNL.

8.3.4.4 Key Milestones

This section details key milestones for ASC. The SCDS pegposts and objectives previously included in this section were adjusted to better align with the needs of the current and future U.S. nuclear stockpile and are described in Chapter 3. **Figure 8–12** illustrates key milestones for ASC, including:

- Transition current integrated weapon design codes to the exascale system architecture in FY 2020.
- Accept Advanced Technology System (ATS)-3/Crossroads in FY 2021.
- Demonstrate performance portability for all integrated design codes on ATS-3 in FY 2023.

- Accept ATS-4/El Capitan in FY 2023.
- Complete analysis of Large Scale Calculation Initiative Phase I in FY 2020.
- Conduct final review of the Production Simulation Initiative in FY 2024.
- Assess machine learning for turbulent flow in the Cognitive Simulation Initiative in FY 2024.
- Demonstrate a Hostile Survivability Baseline Code capability in FY 2020.
- Complete Exascale Class Computer Cooling Equipment project in FY 2021.
- Complete the Exascale Computing Facility Modernization Project in FY 2022.

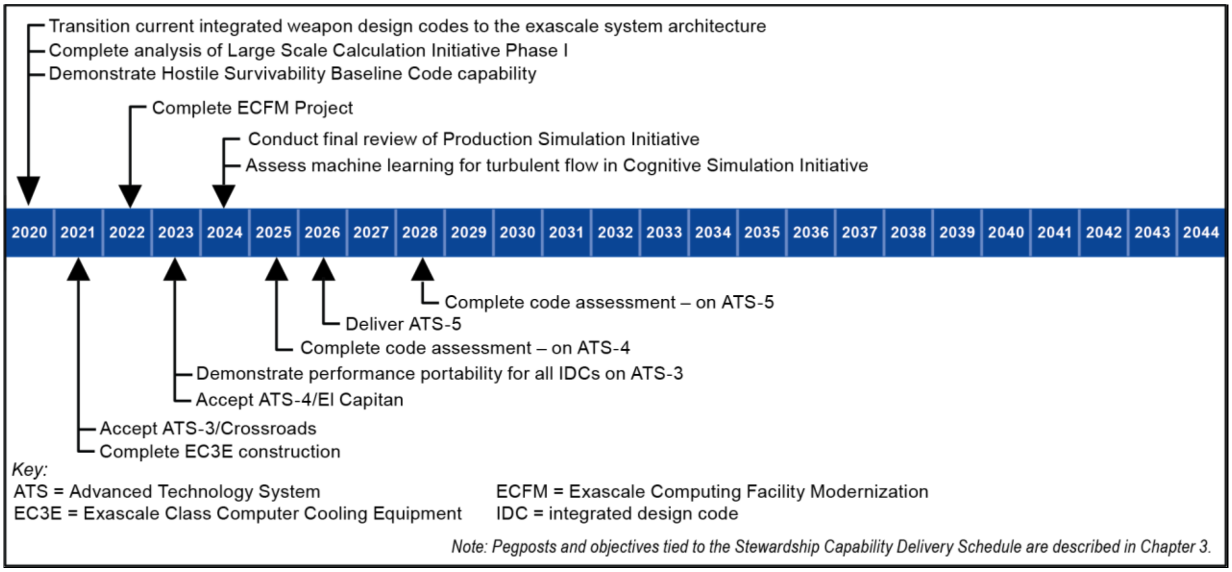


Figure 8–12. Key milestones for Advanced Simulation and Computing

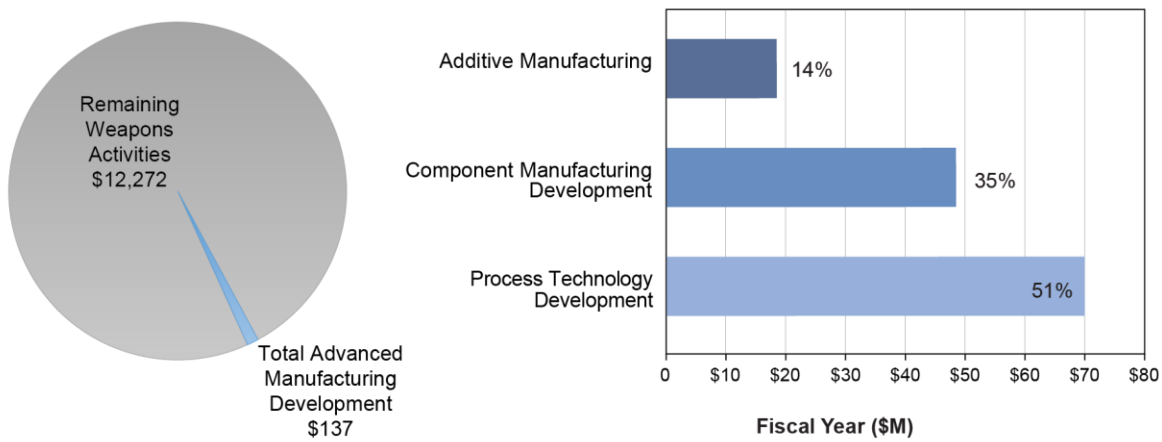
8.3.5 Advanced Manufacturing Development

The Advanced Manufacturing Development Program directly affects the future agility and responsiveness of DOE/NNSA's manufacturing infrastructure by providing capable, efficient, and effective manufacturing solutions to address technical challenges and respond to a changing geopolitical environment. The Program is focused on developing needed improvements that support future stockpile insertion opportunities. The Advanced Manufacturing Development Program conducts development in areas such as additive manufacturing (AM), automation, intelligent production systems, and high-precision manufacturing processes to reduce production time, waste, and floor space requirements. In accomplishing its mission, the Program enables the DOE/NNSA to accelerate the development of manufacturing technologies prior to Phase 6.3 of a future weapon program, which increases DOE/NNSA's confidence in schedules and costs.

8.3.5.1 Budget

The funding schedule for Advanced Manufacturing Development is illustrated in **Figure 8–13**. The budget request for Advanced Manufacturing Development increased 68 percent from the FY 2019 enacted budget.

Advanced Manufacturing Development Program Funding for FY 2020
(Dollars in Millions)



	2019	2020	2021	2022	2023	2024
Additive Manufacturing	12.0	18.5	19.8	19.8	20.2	20.6
Component Manufacturing Development	38.6	48.4	63.6	67.6	70.8	78.1
Process Technology Development	30.9	70.0	31.7	29.8	31.0	32.2
Total Advanced Manufacturing Development	81.6	136.9	115.0	117.1	122.1	130.9

Note: Numbers may not add due to rounding

Figure 8–13. Funding schedule for Advanced Manufacturing Development Program, fiscal years 2019 through 2024

8.3.5.2 Accomplishments

Major accomplishments and significant contributions from Advanced Manufacturing Development and its subprograms since the FY 2019 SSMP are detailed in Chapter 2, "Stockpile Management."

8.3.5.3 FY 2020 Budget Request Compared to FY 2019 Enacted

- The budget request for AM increased 54 percent from the FY 2019 enacted budget to support expanded use of AM for specific stockpile components, to develop a qualified AM process for metal components, to replace inefficient conventional polymer processes with more agile and responsive methodologies, and to invest in advanced technology for future weapon systems.
- The budget request for Component Manufacturing Development increased 25 percent from the FY 2019 enacted budget to accelerate development of new manufacturing processes to replace hazardous and obsolescent processes and critical technologies to support the W87-1 Modification Program.
- The budget request for Process Technology Development increased 126 percent from the FY 2019 enacted budget to accomplish the Building 9212 calciner and electrorefiner projects, the completion of uranium activities for the direct chip melt furnaces, and activities to replace the uranium oxide to metal capability.

8.3.5.4 Key Milestones

This section details key milestones for Advanced Manufacturing Development. **Figure 8–14** illustrates key milestones for Advanced Manufacturing Development, including:

- Transition AM machine capabilities to a production environment to deliver AM parts to the stockpile in FY 2020.
- Place filled AM gas bottles into long-term storage to gather material and component performance data in FY 2021.
- Investigate the applicability and viability of additively manufactured energetics and new types of plastics by FY 2022.
- Develop trusted and secure manufacturing diagnostics to support advanced manufacturing processes to assure supply chain integrity by FY 2022.
- Develop methodologies required to qualify and certify AM for metal lattices by FY 2023.
- Transition direct casting technology from prototype facilities to the production facility in FY 2020.
- Develop and implement solutions to produce useable magnesium oxide for thermal batteries by FY 2021.
- Introduce several new manufacturing process control diagnostics by FY 2023 (e.g., defect detection capabilities).
- Accelerate development of new manufacturing processes to replace hazardous and obsolescent processes by Phase 6.3 of the W87-1 Mod in FY 2023.
- Complete installation and start-up of the Building 9212 calciner in FY 2022.
- Complete installation and start-up of electrorefiner process line in FY 2022.
- Begin installation of direct chip melt furnaces in FY 2020.

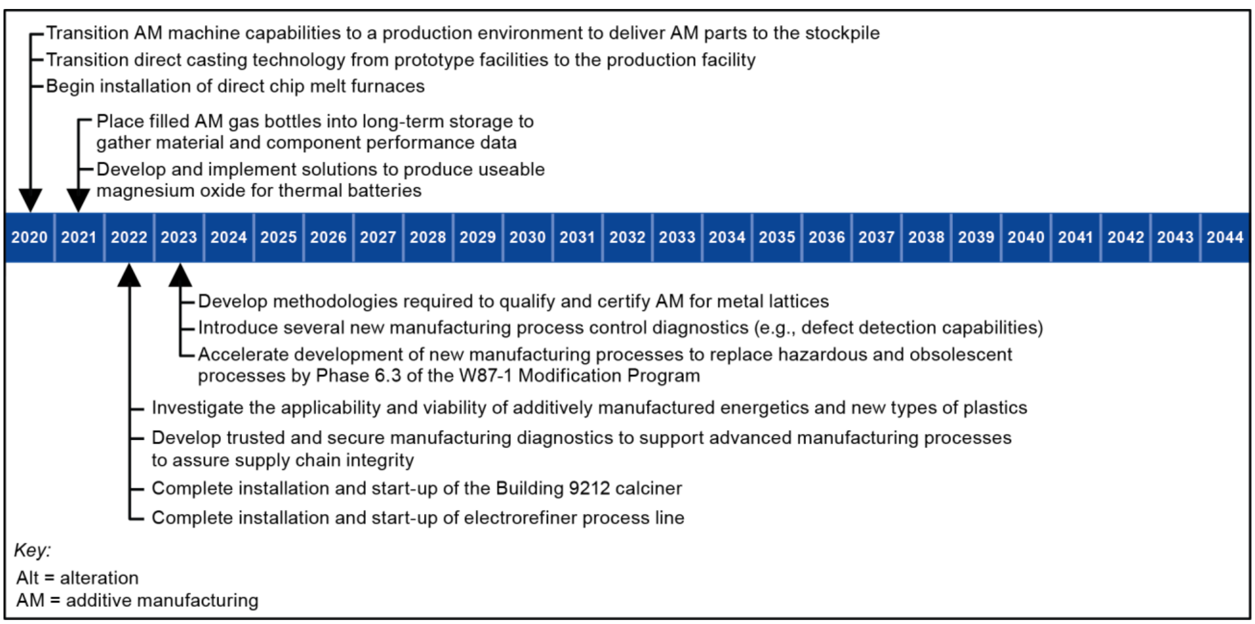


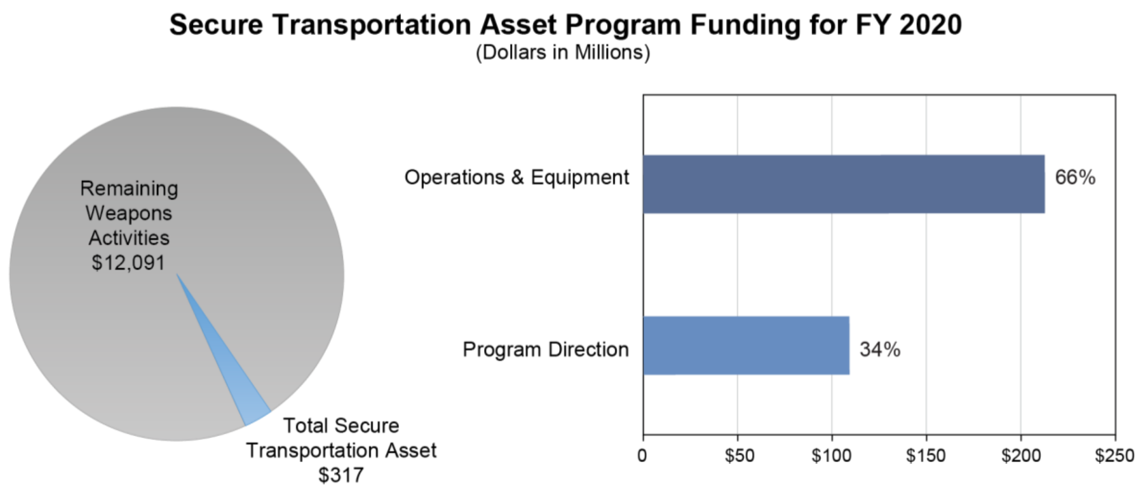
Figure 8–14. Key milestones for Advanced Manufacturing Development

8.4 Secure Transportation Asset

The Secure Transportation Asset (STA) Program safely and securely transports nuclear weapons, weapons components, and special nuclear material (SNM) to meet mission requirements. The STA Program includes the Operations and Equipment and Program Direction subprograms. The Operations and Equipment subprogram provides the transportation service infrastructure required for STA to meet DOE/NNSA's national security mission. The Program Direction subprogram provides salaries, travel, and other related expenses for Federal agents and the secure transportation workforce.

8.4.1 Budget

The funding schedule for Secure Transportation Asset is illustrated in **Figure 8–15**. The budget request for STA increased 14 percent from the FY 2019 enacted budget.



Fiscal Year ($M)	2019	2020	2021	2022	2023	2024
Operations & Equipment	176.6	209.5	246.9	180.6	170.8	193.2
Program Direction	102.0	107.7	110.0	112.1	114.7	116.9
Total Secure Transportation Asset	278.6	317.2	356.8	292.7	285.5	310.1

Note: Numbers may not add due to rounding

Figure 8–15. Funding schedule for Secure Transportation Asset, fiscal years 2019 through 2024

8.4.2 Accomplishments

Major accomplishments and significant contributions from STA and its subprograms since the FY 2019 SSMP are detailed in Chapter 5, "Secure Transportation Asset."

8.4.3 FY 2020 Budget Request Compared to FY 2019 Enacted

- The budget request for Operations and Equipment increased 19 percent from the FY 2019 enacted budget to support long lead material purchases, development and testing of the Mobile Guardian Transporter (MGT), life extension and risk reduction efforts for the Safeguards Transporter (SGT), and first production unit of the next generation armored tractor and Escort Vehicle 4.
- The budget request for Program Direction increased 6 percent from the FY 2019 enacted budget to support increases to the Federal agent workforce and support service contracts.

8.4.4 Key Milestones

This section details key milestones for STA. **Figure 8–16** illustrates key milestones for STA, including:

- Begin first production unit of the next generation armored tractor and Escort Vehicle 4 in FY 2020.
- Begin MGT production in FY 2025.
- Begin procurement of a new aircraft to replace the aging DC-9 aircraft in FY 2021.
- Intend to replace the two aircraft in the remaining 737 fleet in FY 2025 and FY 2029.
- The last SGT will reach its end of design life cycle in FY 2031.
- Complete MGT production in FY 2034.

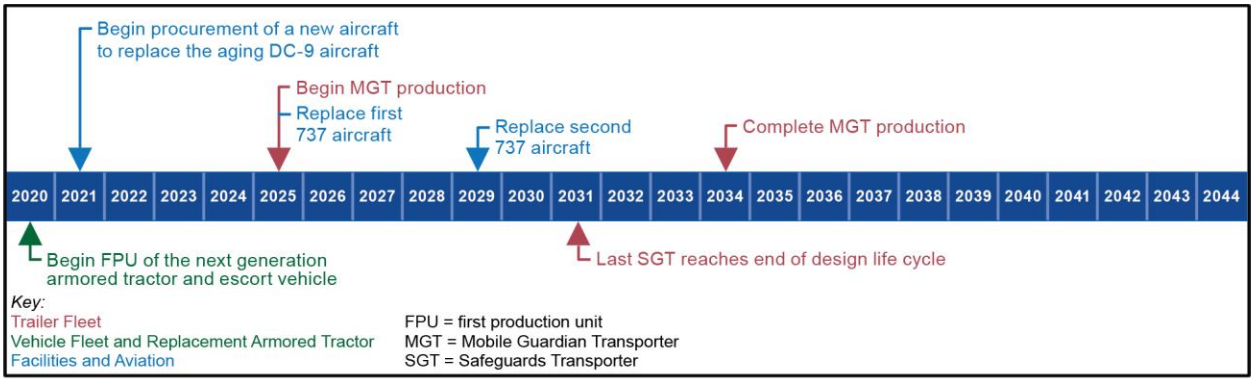


Figure 8–16. Key milestones for Secure Transportation Asset

8.5 Infrastructure and Operations

The Infrastructure and Operations (I&O) Program maintains, operates, and modernizes the DOE/NNSA infrastructure in a safe, secure, and cost-effective manner to maximize return on investment, enable program results, and reduce enterprise risk. The program also plans, prioritizes, and constructs state-of-the-art facilities, infrastructure, and scientific tools.

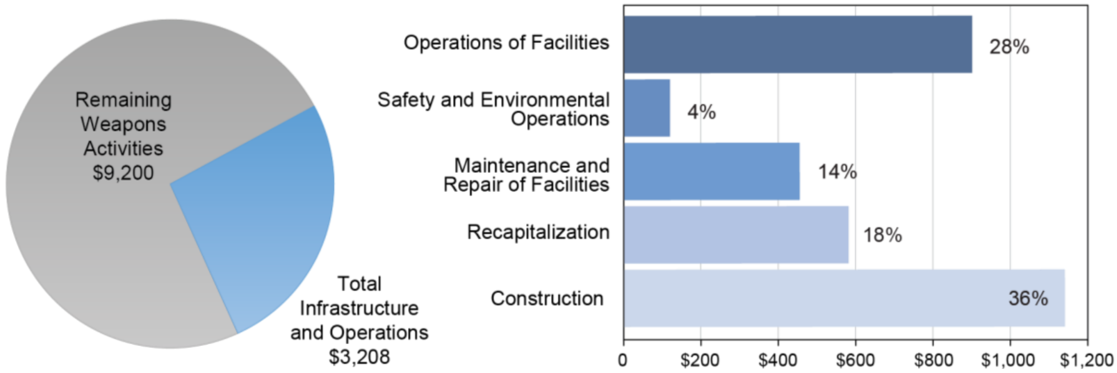
The success of DOE/NNSA's unique national security mission is dependent upon safe, reliable, and modern infrastructure. However, the current state of DOE/NNSA's infrastructure poses increasing risk to availability, capacity, and reliability for weapons activities capabilities, as well as the safety of the workforce, the public, and the environment.

While there has been strong support for several specific actions to ensure the safety, security, and reliability of the nuclear weapons stockpile, funding for sustaining key infrastructure in support of program deliverables has not kept pace. Upgrading or replacing aging facilities will require significant and sustained investment.

8.5.1 Budget

The funding schedule for I&O is illustrated in **Figure 8–17**. The budget request for I&O increased 4 percent from the FY 2019 enacted budget.

Infrastructure and Operations Program Funding for FY 2020
(Dollars in Millions)



	Fiscal Year ($M)					
	2019	2020	2021	2022	2023	2024
Operations of Facilities	870.0	905.0	915.0	925.0	935.0	960.0
Safety and Environmental Operations	110.0	119.0	124.0	125.0	127.0	127.0
Maintenance and Repair of Facilities	515.0	456.0	480.0	490.0	510.0	525.0
Recapitalization	559.1	583.0	506.8	527.3	533.2	543.8
Construction	1,033.8	1,145.4	1,007.4	871.5	662.5	1,009.4
Total Infrastructure and Operations	3,087.9	3,208.4	3,033.3	2,938.8	2,767.7	3,165.3

Note: Numbers may not add due to rounding

Figure 8–17. Funding schedule for Infrastructure and Operations, fiscal years 2019 through 2024

Based on the total funding request shown in Figure 8–17, investments in I&O appear to decline during portions of the FYNSP. However, there is significant funding for Plutonium Sustainment in the DSW portfolio throughout the FYNSP for infrastructure investments to support efforts to produce pits at a rate of no fewer than 80 ppy by FY 2030. When combined, these reflect increased infrastructure investments throughout the FYNSP. DOE/NNSA continues to balance risk across portfolio investments to ensure resources are being properly applied to sustain and modernize infrastructure across the enterprise.

8.5.2 Accomplishments

Major accomplishments and significant contributions from I&O and its subprograms since the FY 2019 SSMP are detailed in Chapter 4, "Physical Infrastructure."

8.5.3 FY 2020 Budget Request Compared to FY 2019 Enacted

- The budget request for Operations of Facilities increased 4 percent from the FY 2019 enacted budget to sustain an increasing workload supporting the W80-4 at SNL and B61-12 and W88 flight tests at Tonopah Test Range; increase hiring of critical skill employees at LLNL; increase resources at nuclear and high-hazard facilities to meet increased mission needs at the Nevada National Security Site and Y-12; and provide the additional resources needed to support safe and effective execution in the tritium facilities at SRS.
- The budget request for Safety and Environmental Operations increased 8 percent from the FY 2019 enacted budget to reflect transfer of scope from Operations of Facilities for five facilities at Y-12 that treat waste streams associated with the Long-Term Stewardship program and to fund the performance of required retained obligations at the Bannister Federal Complex in Kansas City.
- The FY 2020 budget request for Maintenance and Repair decreased 12 percent from the FY 2019 enacted budget, allowing the sites to absorb the significant increases from the past 2 years by

increasing staffing levels to address the long-standing deficiency of a robust maintenance program. Overall funding for maintenance has grown significantly, but appropriately, over the last several budget cycles. This will address carryover balances and provide increased maintenance staffing levels to maintain and preserve facilities in a condition that is suitable to meet an increasing mission demand.

- The budget request for Recapitalization: Infrastructure and Safety had no substantive changes from the FY 2019 enacted budget.
- The budget request for Recapitalization: Capability-Based Investments increased 24 percent from the FY 2019 enacted budget to include other project cost funding to develop new programmatic line item construction projects, as well as funding to continue the conceptual design for the Material Staging Facility. This increase also supports growth in programmatic equipment recapitalization requirements for the W80-4 LEP.
- The budget request for I&O: Construction increased 11 percent from the FY 2019 enacted budget to support construction of the Uranium Processing Facility at Y-12, the High Explosive Science and Engineering Facility at Pantex, and the U1a Complex Enhancements Project at the Nevada National Security Site. The increase also supports design efforts of the Tritium Finishing Facility at SRS, the Lithium Processing Facility at Y-12, the 138-kilovolt Power Transmission System Replacement at the Nevada National Security Site, and the Emergency Operations Centers at both LLNL and SNL.

8.5.4 Key Milestones

Per the *National Defense Authorization Act for Fiscal Year 2018*, DOE/NNSA established the Infrastructure Modernization Initiative program with the goal of reducing deferred maintenance and repair needs by no less than 30 percent by 2025. Major programmatic line-item project milestones and schedules are reflected in Chapter 4, "Physical Infrastructure," Section 4.2.2, Figure 4–6.

8.5.5 Infrastructure Maintenance and Recapitalization Investments

In response to Government Accountability Office (GAO) recommendations, the following 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 Replacement Plant Value) derived from the DOE Real Property Asset Management Plan and associated guidance. To address these benchmark shortfalls, NNSA has increased recapitalization investments by $24 million from FY 2019 to FY 2020. Recapitalization continues to include deactivation and demolition of excess and underutilized facilities to reduce the NNSA footprint. Maintenance investments reflect a decrease of $59 million from FY 2019 to FY 2020 to allow the sites to absorb the significant increases in FY 2018 and FY 2019 funding by increasing staffing levels to address the long-standing deficiency of a robust maintenance program. Overall funding for maintenance has grown significantly, but appropriately, over the last several years. This decrease will address carryover balances and support growing maintenance staffing levels to maintain and preserve facilities in a condition that is suitable to meet an increasing mission demand. NNSA also continues to use the 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 fiscal year 2020 NNSA infrastructure maintenance and recapitalization investments

		FY 2018	***FY 2019***	***FY 2020***
Replacement Plant Value (RPV) ($B)		50.4	51.4	52.5
Maintenance Benchmark 2 – 4% RPV	Infrastructure & Safety Maintenance Investments ($K)	515,138	515,000	456,000
	Other NNSA Maintenance Investments (direct and indirect funded) ($K)	299,851	284,922	298,008
	Total NNSA Maintenance Investments (SK)	814,989	799,922	754,008
	Maintenance as % RPV	1.62%	1.55%	1.44%
Recapitalization Benchmark 1%	Infrastructure & Safety Recapitalization Investments ($K)	482,661	450,000	447,657
	Other NNSA Recapitalization Investments ($K)	130,000	109,057	135,341
	Total NNSA Recapitalization Investments ($K)	612,661	559,057	582,998
	Recapitalization as % RPV	1.22%	1.09%	1.11%

$B = billion dollars
$K = thousand dollars

8.6 Other Weapons Activities

8.6.1 Budget

The funding schedule for Other Weapons Activities is illustrated in **Figure 8–18**.

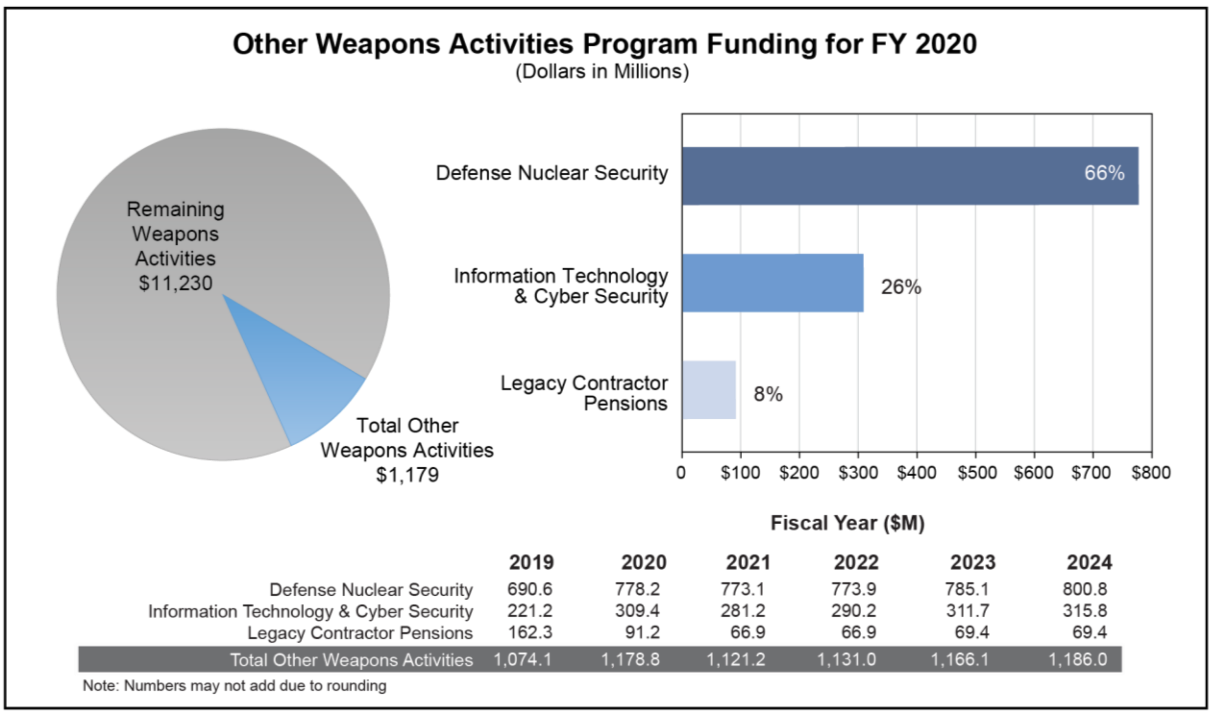


Figure 8–18. Funding schedule for Other Weapons Activities, fiscal years 2019 through 2024

8.6.2 Defense Nuclear Security

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

8.6.2.1 Accomplishments

Major accomplishments and significant contributions from the Defense Nuclear Security (DNS) Program and its subprograms since the FY 2019 SSMP are detailed in Chapter 6, "Security."

8.6.2.2 FY 2020 Budget Request Compared to FY 2019 Enacted

The budget request for DNS increased 13 percent from the FY 2019 enacted budget to support critical Security Infrastructure Revitalization Program projects to implement the 10-Year Physical Security Systems Refresh Plan at all DOE/NNSA sites. This includes Argus modernization; sustaining implementation of a technical security program across the enterprise; sustaining implementation and operation of counter unmanned aircraft systems at sites possessing SNM; efforts to begin implementation of the Design Basis Threat policy; and planned equipment life cycle replacements.

8.6.2.3 Key Milestones

This section details key milestones for DNS. **Figure 8–19** illustrates key milestones for DNS, including:

- Sustain counter unmanned aircraft systems (CUAS) implementation and operation at sites possessing Category 0/I quantities of SNM in FY 2020.
- Complete deployment of Argus security system as the standard access control and alarm system at all Category I SNM sites in FY 2020.
- Begin CUAS implementation at remaining NNSA sites in FY 2021.
- Complete Y-12 West End Perimeter Area Reduction, Perimeter Intrusion Detection and Assessment System (PIDAS) modernization, and entry control facility upgrade in FY 2023.
- Complete Pantex PIDAS physical security system components and infrastructure refresh in FY 2024.
- Complete critical Security Infrastructure Revitalization Program (SIRP) priorities in FY 2024.
- Complete execution of SIRP in FY 2030.

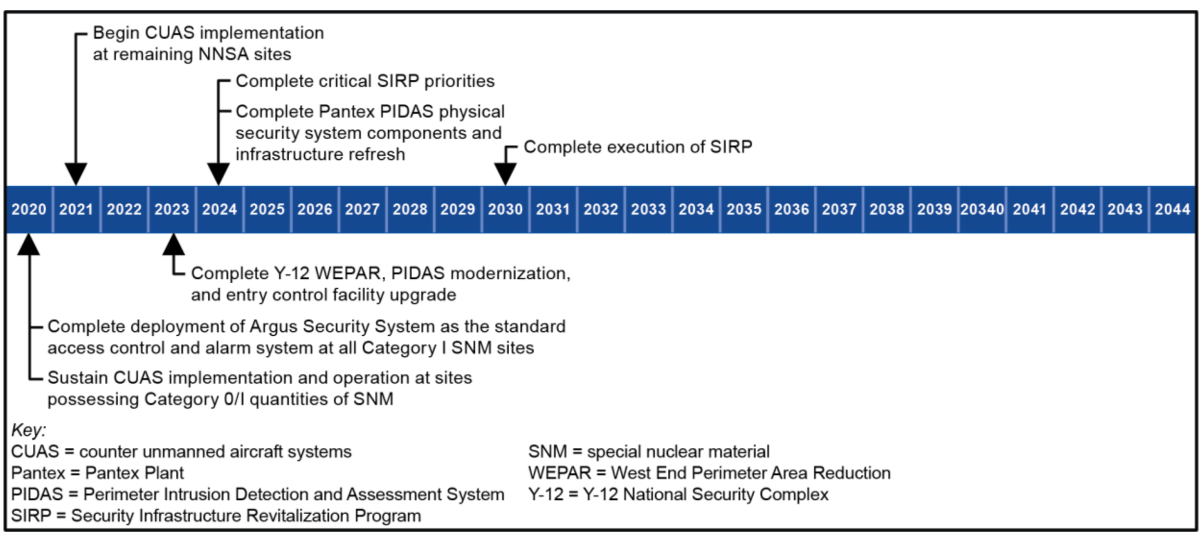


Figure 8–19. Key milestones for Defense Nuclear Security

8.6.3 Information Technology and Cybersecurity

DOE/NNSA prioritizes the delivery of Information Technology (IT) and Cybersecurity Program solutions that support and secure DOE/NNSA's nuclear security missions.

8.6.3.1 Accomplishments

Major accomplishments and significant contributions from IT and Cybersecurity and its subprograms since the FY 2019 SSMP are detailed in Chapter 6, "Security."

8.6.3.2 FY 2020 Budget Request Compared to FY 2019 Enacted

The budget request for Information Technology and Cybersecurity increased 40 percent from the FY 2019 enacted budget to continue IT and Cybersecurity modernization efforts.

8.6.3.3 Key Milestones

This section details key milestones for IT and Cybersecurity. **Figure 8–20** illustrates key IT and Cybersecurity milestones, including:

- Implement Phase I of DOE/NNSA's IT Modernization Plan in FY 2020 and Phase II in FY 2021.
- Perform cybersecurity program budget re-baseline site assessments in FY 2021.
- Complete the security architecture for the classified wireless network by FY 2023.
- Complete deployment of a new sensor platform across all DOE/NNSA sites in FY 2020.
- Establish centers of excellence to improve and enhance cybersecurity operations throughout the nuclear security enterprise by FY 2025.
- Begin development of the architecture of the classified wireless network for non-pit production facilities in FY 2021.
- Complete the phase I security architecture of the Wireless Pit Production Network by FY 2021.
- Develop and implement the Department of Homeland Security Continuous Diagnostics Program by FY 2025.
- Develop the secure cloud computing environment according to the timeline:
  - LLNL Phase I of hybrid cloud platform for Enterprise Secure Computing (ESC) cloud environment by FY 2020
  - SNL Phase I of small hybrid cloud platform for ESC cloud environment testing by FY 2020
  - East Coast data center for secondary hybrid cloud platform for ESC cloud environment by FY 2020
  - KCNSC deployment hybrid cloud platform in support of the Joint Test Demonstrator by FY 2021

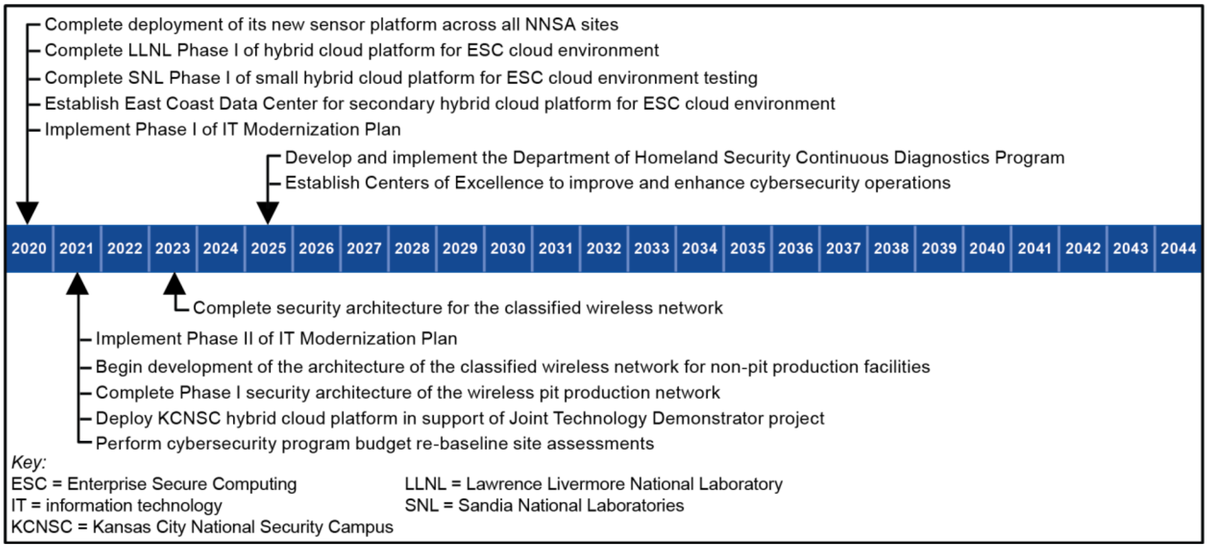


Figure 8–20. Key milestones for Information Technology and Cybersecurity

8.7 Budget Projections Beyond FY 2024

This section explains the cost estimation methodology that DOE/NNSA uses to create long-term budget projections. Cost estimates and projections for stockpile sustainment, LEPs and major Alts, and construction are provided thereafter. Other programmatic estimates are escalated to account for future inflationary increases. Section 8.8 incorporates these projections and provides the 25-year program for Weapons Activities.

8.7.1 Basis for Budget Projections

The FY 2020 – FY 2024 budget request was generated as part of the DOE/NNSA planning and programming process and reflect the roll-up of individual estimates developed interactively by DOE/NNSA's management and operating (M&O) partners and Federal program managers using historical cost data, current plans for programs and projects, and expert judgment. The budget estimates for FY 2025 and beyond reflect the costs of continuing the program of record described in this SSMP.

The budget projections beyond the FYNSP will vary depending on the individual program or subprogram. Some portions of the Weapons Activities portfolio are assumed to continue beyond the FYNSP at the same level of effort as during the FYNSP.[8] For these cost projections, escalation factors representing basic levels of inflation were used.

Some portions of the program will not proceed at the same level of effort for FY 2025 through FY 2044. This applies to major construction projects, LEPs, and, because of the future evolution in the current stockpile configuration, stockpile sustainment, as represented by the funding lines for stockpile systems. The estimates and the basis for each of these elements of the Weapons Activities portfolio are described in more detail in the following sections.

Cost estimates are different than DOE/NNSA budget requests and should not necessarily be compared to determine program health. Cost estimates, described in more detail in the following sections, are developed early in the project concept stage with a significant amount of uncertainty. Budget requests,

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

on the other hand, are a result of DOE/NNSA's programming process, resource-loaded project schedules, and other program and site-specific assumptions. Budget requests must also align with DOE/NNSA's funding limits to ensure funding is available when needed in the program life cycle.

8.7.2 Stockpile Sustainment

Costs associated with stockpile sustainment include warhead-specific assessment activities, LLC exchanges, required and routine maintenance, safety studies, periodic repairs, resolution and timely closure of significant finding investigations, military liaison work, and surveillance to ensure the continued safety, security, and effectiveness of the stockpile. These costs are incurred every year that a weapon is in the stockpile. Chapter 2, "Stockpile Management," Figure 2–1 provides a roadmap of currently planned activities for current weapons.

Figure 8–21 enumerates, in then-year dollars, the annual sustainment costs for FY 2020 through FY 2024 that are attributable to a warhead type based on updated FY 2020 numbers and estimates of the total sustainment costs by year for warheads of all types for FY 2025 through FY 2044. Between FY 2021 and FY 2044, the dominant factor is a near-constant escalation rate of 2.1 percent.

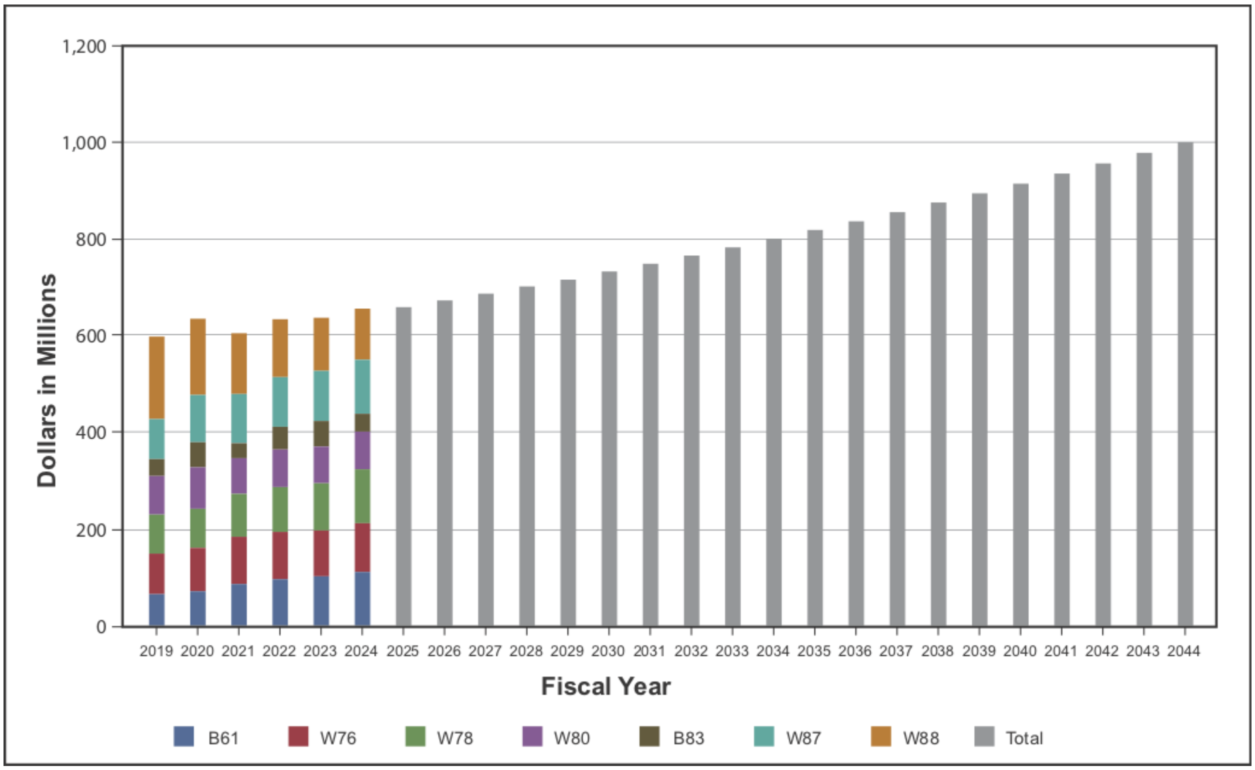


Figure 8–21. Estimate of warhead-specific sustainment costs[9]

[9] Stockpile sustainment costs estimates in previous SSMPs were obtained using methodologies largely based on a 3+2 strategy. As long-range surveillance estimates are updated, the FY 2020 SSMP uses an escalation model to estimate long-term stockpile sustainment costs.

8.7.3 Life Extension Programs and Major Alterations

Undertaken separately from stockpile maintenance, LEPs have the goal of extending the lives of warheads for several more decades. Although major Alts also make component changes, those changes do not address all the aging issues in a warhead that would require an LEP. Chapter 2, “Stockpile Management,” Figure 2–4, provides a roadmap of currently planned activities for current weapons.

The following sections summarize cost estimates for LEPs and major Alts within the current 25-year program of record. The cost estimates vary 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 bottoms-up models (deterministic, unit cost, and activity-based), depending on where the warhead program is in the *Phase 6.x Process*.

8.7.3.1 Cost Estimates throughout the *Phase 6.x Process*

LEP and major Alt cost estimates are planned and conducted using the *Phase 6.x Process*. **Figure 8–22** shows the governing cost estimate type for each phase of the process. DOE/NNSA works in conjunction with DoD and its M&O partners to develop, refine, and update the estimates throughout the *Phase 6.x Process*.

Phase 6.1	Phase 6.2	Phase 6.2A[1]	Phase 6.3[2]	Phase 6.4[2]	Phase 6.5[2]	Phase 6.6
Concept Assessment	Feasibility Study & Design Options	Design Definition & Cost Study	Development Engineering	Production Engineering	First Production	Full-Scale Production
Defense Programs Independent Cost Estimates		Weapons Design and Cost Report	Baseline Cost Report reported as part of the Selected Acquisition Report			

[1]A DOE/NNSA independent cost review is conducted by the Office of Cost Estimating and Program Evaluation prior to Phase 6.2A.
[2]A DOE/NNSA independent cost estimate is conducted prior to entry into Phases 6.3, 6.4, and 6.5.

Figure 8–22. Cost estimates across the *Phase 6.x Process*

Defense Programs independent cost estimates (ICEs) serve as the initial cost estimate generated by a Defense Programs office that is independent of the program office.[10] These estimates initiate at very early design maturity (typically more than a decade before Phase 6.1 [Concept Assessment]) and are planning estimates for alternatives analysis, early programming, and budget deliberations. Notably, Defense Programs ICEs are:

- Performed by an independent organization separate from the Federal program office[11]
- Based on a known scope and cost uncertainty at the time and updated annually for the SSMP[12]

[10] Defense Programs ICEs are performed annually by the Office of Cost Policy and Analysis for LEPs and major Alts for the SSMP.
[11] GAO extolls the value of ICEs using a different methodology and the potential benefit to decision-makers in its *GAO Cost Estimating and Assessment Guide*.
[12] 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 LEP or major Alt 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.

- Inclusive of both LEP (development and production) and non-LEP line-item costs that are critical to program success (namely Other Program Money and DoD costs)[13]
- Unconstrained from future budget availability, which may differ from future budget amounts if programming is constrained

These Defense Programs ICEs are captured in the SSMP as the program of record until the WDCR is approved. The Defense Programs ICE methodology is described in more detail in Section 8.7.3.2.

The WDCR is developed by the program team and provides preliminary cost estimates for design, qualification, production, and life cycle activities. The WDCR includes detailed multi-site input and, although primarily performed using a bottoms-up approach, it may contain other methodologies (e.g., parametric, analogous, 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) that starts on entry in to Phase 6.3.

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

A DOE/NNSA independent cost review is conducted prior to Phase 6.2A, and a DOE/NNSA ICE is conducted prior to entry into Phases 6.3, 6.4 (Production Engineering), and 6.5 (First Production).[14]

8.7.3.2 Defense Programs' Cost Estimating Methodology

Defense Programs ICEs are:

- Performed using a "top-down" analogy method that is consistent with early-stage planning.[15]
- Informed by ongoing 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.[16]
- Based on time-phased development[17] costs using standard, well-known Rayleigh profiles, as well as production costs using a nonlinear cost growth profile similar to that of the W76-1.

[13] In estimating the cost of an LEP or major Alt, 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.

[14] DOE/NNSA ICEs are statutorily performed by the Office of Cost Estimating and Program Evaluation.

[15] Additional detail on the cost estimating methodology of Defense Programs ICEs 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).

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

[17] Development costs include all design agency and production development costs, which is how DoD defines RDT&E and is consistent with Rayleigh profile usage in cost estimating.

- 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, although early-stage LEPs may experience occasional scope changes, which may result in cost changes compared to previous SSMPs. These ranges will typically be greatest for earlier-stage programs and narrow over time.

8.7.3.3 Current Estimates

Figures 8–24 through 8–27 and Tables 8–5 through 8–13 provide cost estimates for each LEP and major Alt for the 25-year SSMP timeframe. **Table 8–4** shows the type of cost estimate for each of the LEPs and major Alts included in the 25-year SSMP.

Table 8–4. Cost estimates for life extension programs and major alterations within the 25-year program of record[18]

Life Extension Program, Major Alteration, or Modification Program	*Type of Cost Estimate*	*Total Estimated Cost (FY 2019 dollars in billions)*	*Total Estimated Cost (then-year dollars in billions)*
W76 LEP	BCR/SAR	4.2	3.5
W76-2 Modification Program	BCR/SAR	.075	.075
B61-12 LEP	BCR/SAR	7.6	7.6
W88 Alt 370	BCR/SAR	2.6	2.6
W80-4 LEP	WDCR	9.6	11.2
W87-1 Modification Program	Defense Programs ICE	10.9	12.4
Next Navy Warhead	Defense Programs ICE	10.9	14.4
Future Strategic Missile Warhead	Defense Programs ICE	10.9	15.4
Next B61	Defense Programs ICE	10.0	18.5

BCR/SAR = Baseline Cost Report/Selected Acquisition Report
ICE = independent cost estimate
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 2019 and then-year dollars, is shown for each program. Where appropriate, the tables also include pre-SAR values to capture pre-Phase 6.2 costs.[19, 20, 21]

[18] SAR and WDCR values are provided when available. For programs that only have a Defense Programs ICE, the proposed budget is provided. Tables 8–7 through 8–13 provide values for high and low estimates, in addition to the SAR, WDCR, or Defense Programs ICE totals. Due to the differing types of cost estimates, the accuracy of these total program cost estimates varies.
[19] DoD amounts reflect the costs for weapon components for which they are 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 because they better reflect anticipated all-in costs.
[20] The total estimated cost is provided because LEP profiles have later portions that extend beyond the published 25-year SSMP timeframe.
[21] The low estimates presented in the following tables and graphs as the green line represent the mid-point (p50) of the cost estimate rather than the 15 percent probability (p15) that has been used in previous SSMPs. The high estimates continue to represent the 85 percent (p85). This change was made to align the high and low ranges for the LEPs with the ranges used for Capital Construction estimates.

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

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 LEP timeframes. Consideration should also be given to the varying quantities of warheads being refurbished for each system. The FY 2020 SSMP's classified Annex provides additional information on production quantities.
- The then-year Defense Programs ICEs in the tables and figures are derived from constant-year estimates using the escalation rates in the OMB Table 10.1.[22] For years beyond the 6 years projected in Table 10.1, the escalation rate for the final year is used.[23] The escalation rate used by the sites to produce the WDCRs and BCRs can differ from the OMB number used in the Defense Program ICEs. One possible difference is that the official program office estimates use escalation rates specific to each site and function, rather than a national average.
- Published estimate ranges are meant to reflect the underlying technical and cost uncertainty of the assumed scope. Early-stage programs, particularly those before Phase 6.3, may experience significant scope changes, as the Nuclear Weapons Council may update and/or down-select design options and significantly impact the work scope and cost estimate.
- Only the Defense Programs ICEs include pre-Phase 6.2 costs. The WDCR and BCR/SAR estimates do not include these costs.

When comparing a top-down Defense Programs ICE to the official bottom-up program counterpart (such as for the B61-12), DOE/NNSA primarily compares the total estimate amounts and the general shape of the time-phased profiles. If these two are in relative agreement, DOE/NNSA has increased confidence in the program estimate. DOE/NNSA does not perform or encourage additional year-by-year comparisons between the two published estimates.[24]

Figure 8–23 is a one-chart summary of the projected total nuclear weapons LEP and major Alt cost estimates from FY 2019 through FY 2044, based on the schedule reflected in Chapter 2, "Stockpile Management," Figure 2–2 of this SSMP, and the nominal LEP costs shown in Figures 8–24 through 8–27.[25] Cost estimates for programs outside of the FYNSP are long-range planning estimates and will be revised as the programs continue through the *Phase 6.x Process*. The dotted line shows the total projected LEP cost reflected in the FY 2019 SSMP. The total cumulative LEP costs over the 25-year program have increased by approximately $4.0 billion from the FY 2019 SSMP estimate. The difference in the estimates is largely driven by 2018 *Nuclear Posture Review* implementation, refined requirements that increase scope complexity, accelerated production schedule milestones, updated assumptions for future warheads, and the escalation costs of a future year replacing a lower-cost early year.

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

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

[24] The Defense Programs ICE profile reflects an idealized schedule and unconstrained budget, whereas the program profile is based on an integrated baseline schedule and programming results. This makes reconciling minor year-by-year profile discrepancies between the estimates generally infeasible; when differences arise, DOE/NNSA has much greater confidence in the year-by-year phasing of its baselined program estimate.

[25] Nominal costs are used to allow a comparison of the total LEP costs from SSMP to SSMP. Unless baselined, the cost of any particular LEP should be regarded as a cost range, as shown in the tables accompanying each LEP figure.

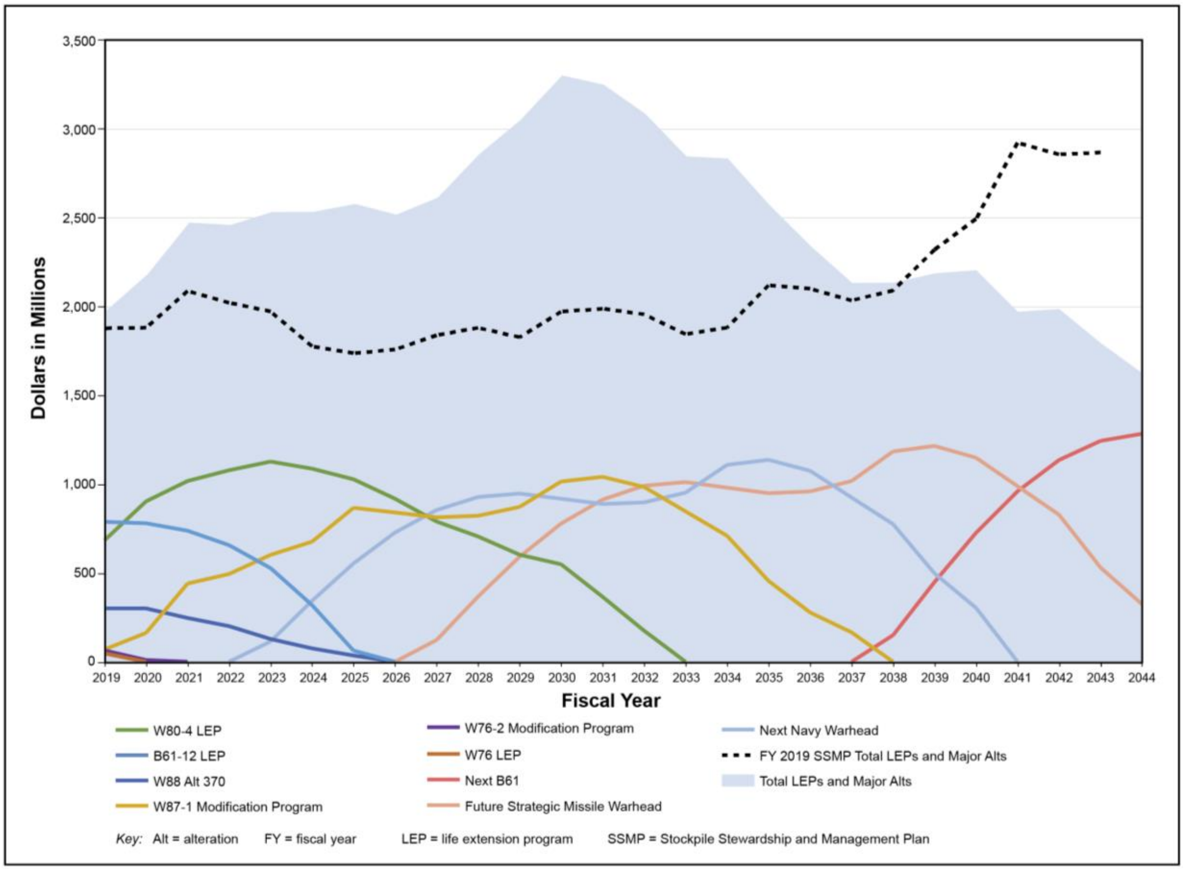


Figure 8–23. Total U.S. projected nuclear weapons life extension costs for fiscal year 2019 through fiscal year 2044 (then-year dollars, nominal costs only)

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

The W76-1 last production unit was produced in December 2018 and is scheduled for delivery to the Navy during FY 2019. The program is making all warhead deliveries to the Navy on schedule and under budget. **Table 8–5** represents the cost estimate.

Table 8–5. Total estimated cost for W76-1 Life Extension Program

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

SAR = Selected Acquisition Report

8.7.3.5 W76-2 Modification Program Cost Estimate

The DOE/NNSA laboratories and production facilities are currently executing a compressed Phase 6.3 through 6.5 process. The FY 2020 request was reduced from $33 million to $10 million based on refined program estimates. **Table 8–6** represents the total estimated costs.

Table 8–6. Total estimated cost for W76-2 Modification Program

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

8.7.3.6 B61-12 Life Extension Program Cost Estimate

The B61-12 LEP is executing within the cost documented in the October 2016 BCR, which estimated program costs at $7.6 billion (then-year dollars). The B61-12 LEP is continuing to leverage other DOE/NNSA programs for multi-system production process improvements. The costs of these related programs are estimated to be $648 million. The overall program cost is estimated at $8.3 billion, which is within 1.1 percent of the initial baseline SAR that was provided to Congress in FY 2013. The nominal values for development and production in **Figure 8–24** and **Table 8–7** reflect DOE/NNSA's FY 2016 BCR as the B61-12 LEP entered Phase 6.4. The B61-12 LEP schedule is under revision, see Section 2.5.4 (B61-12 LEP) for details. A decision on first production unit and Initial Operational Capability dates is being jointly coordinated with the Air Force. Potential impacts to total project cost are not know at this time.

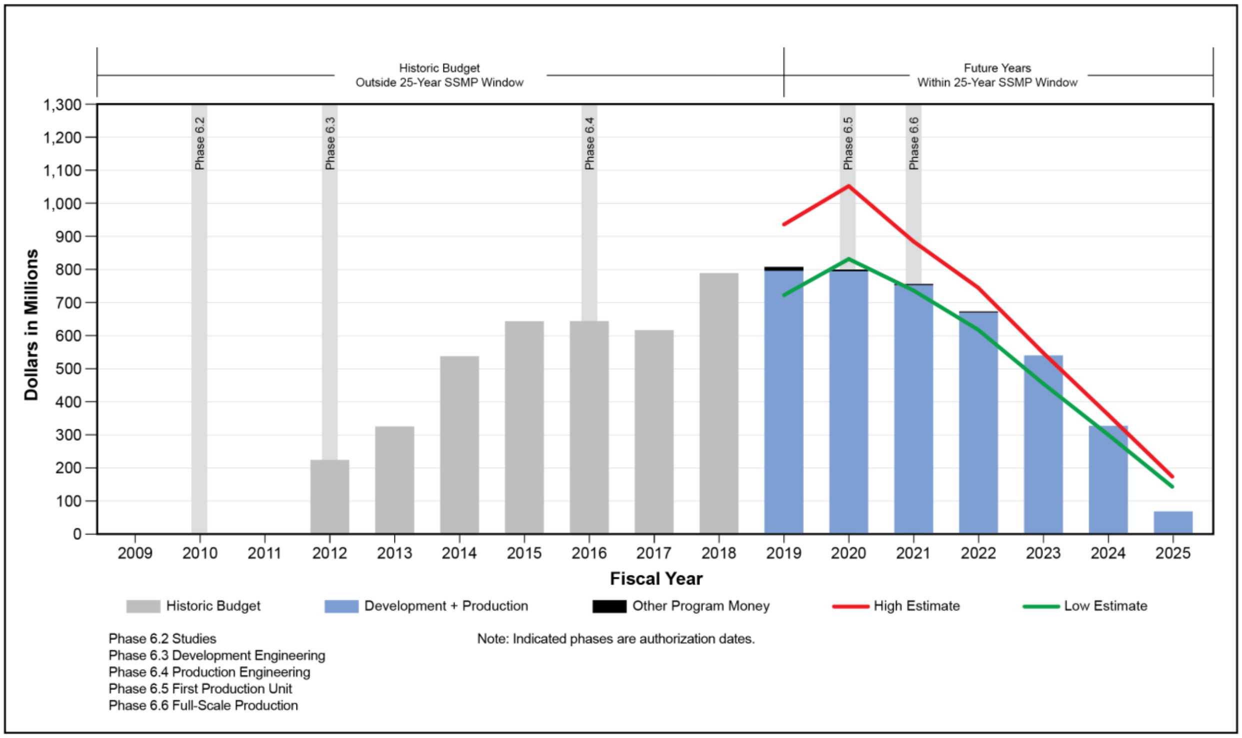


Figure 8–24. B61-12 Life Extension Program cost fiscal year 2019 to completion[26]

Table 8–7. Total estimated cost for B61-12 Life Extension Program

	DOE/NNSA		*DoD*	
Dollars in Billions	***FY 2019 Dollars***	***Then-Year Dollars***	***FY 2019 Dollars***	***Then-Year Dollars***
Pre-SAR Cost	0.4	0.4	N/A	N/A
FY 2012 – FY 2025				
High Total	8.9	8.8	0.2	0.2
Low Total	8.1	7.9	0.2	0.2
SAR Total	7.6	7.6	N/A	N/A

SAR = Selected Acquisition Report

[26] Costs represented from FY 2019 – FY 2025 are consistent with the latest BCR/SAR values. High and low estimates were determined using Defense Programs ICEs and are included for comparison to the original estimate.

8.7.3.7 W88 Alt 370 Cost Estimate

DOE/NNSA completed a high-fidelity cost estimate (the BCR) in FY 2017. The report estimate is $2.6 billion, which is approximately $255 million (or 11 percent) higher than the estimate in the 2015 SAR. The increased costs were primarily caused by increased testing and qualification, as well as planning margins for treating technical risks accompanied by some offsetting reduction in the scope associated with the nuclear components. The W88 Alt 370 also leverages other DOE/NNSA programs for multi-system production process improvements. The costs of these related programs are estimated to be $171 million. The overall program cost is estimated at $2.78 billion. These estimates represent the program baseline and are reflected in the FY 2018 SAR. DOE/NNSA has completed a BCR that included the CHE refresh and other changes. The numbers in **Figure 8–25** and **Table 8–8** reflect this baseline. The W88 Alt 370 schedule is under revision, see Section 2.5.3 (W88 Alt 370) for details. DOE/NNSA is working to minimize any delays and is closely coordinating with the Navy. Potential impacts to total project cost are not know at this time.

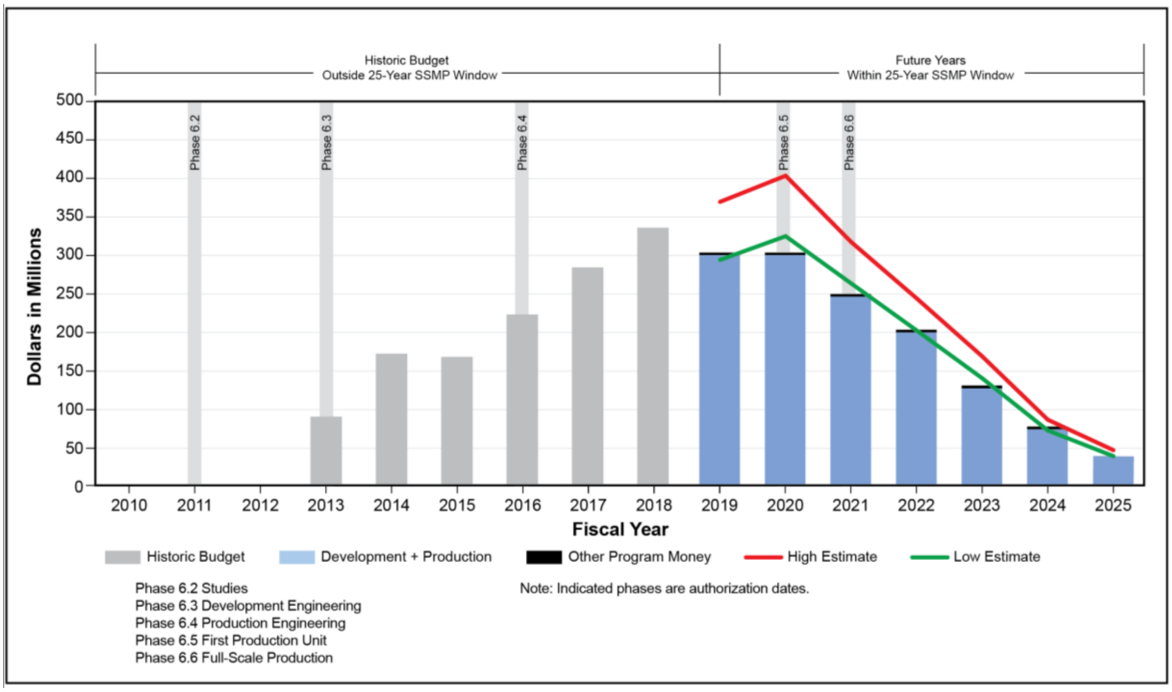


Figure 8–25. W88 Alteration 370 (with conventional high explosive refresh) cost fiscal year 2019 to completion[27]

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

	DOE/NNSA		DoD	
Dollars in Billions	***FY 2019 Dollars***	***Then-Year Dollars***	***FY 2019 Dollars***	***Then-Year Dollars***
Pre-SAR Cost	0.1	0.1	N/A	N/A
FY 2013 – FY 2025				
High Total	3.0	3.0	1.0	1.0
Low Total	2.7	2.7	1.0	1.0
SAR Total	2.6	2.6	N/A	N/A

SAR = Selected Acquisition Report

[27] Costs represented from FY 2019 – FY 2025 are consistent with the latest BCR/SAR values. High and low estimates were determined using Defense Programs ICEs and are included for comparison to the original estimate.

8.7.3.8 W80-4 Life Extension Program Cost Estimate

The W80-4 LEP completed its WDCR in February 2019, and those values are displayed in **Figure 8–26** and **Table 8–9**. The differences observed in the WDCR estimate (blue bars) and the Defense Program ICE (red and green lines) arise from two factors. The first is a difference in escalation rates used for the estimates. The WDCR used site-derived escalations rates that averaged to 3.385 percent per year. These rates are more inclusive of site specific dependencies. The Defense Programs ICE used the OMB value of 2.22 percent per year, which is the standard used for Defense Programs ICEs providing consistent site-agnostic estimates. Using the higher escalation rates increases the original high and low Defense Programs ICEs by approximately $1 billion over the life of the program. The second significant difference is time-phasing. The adjusted time-phasing reflected in the WDCR represents the current execution plan for FY 2019 and an updated profile to meet the FY 2025 first production unit. The program entered Phase 6.3 in FY 2019.

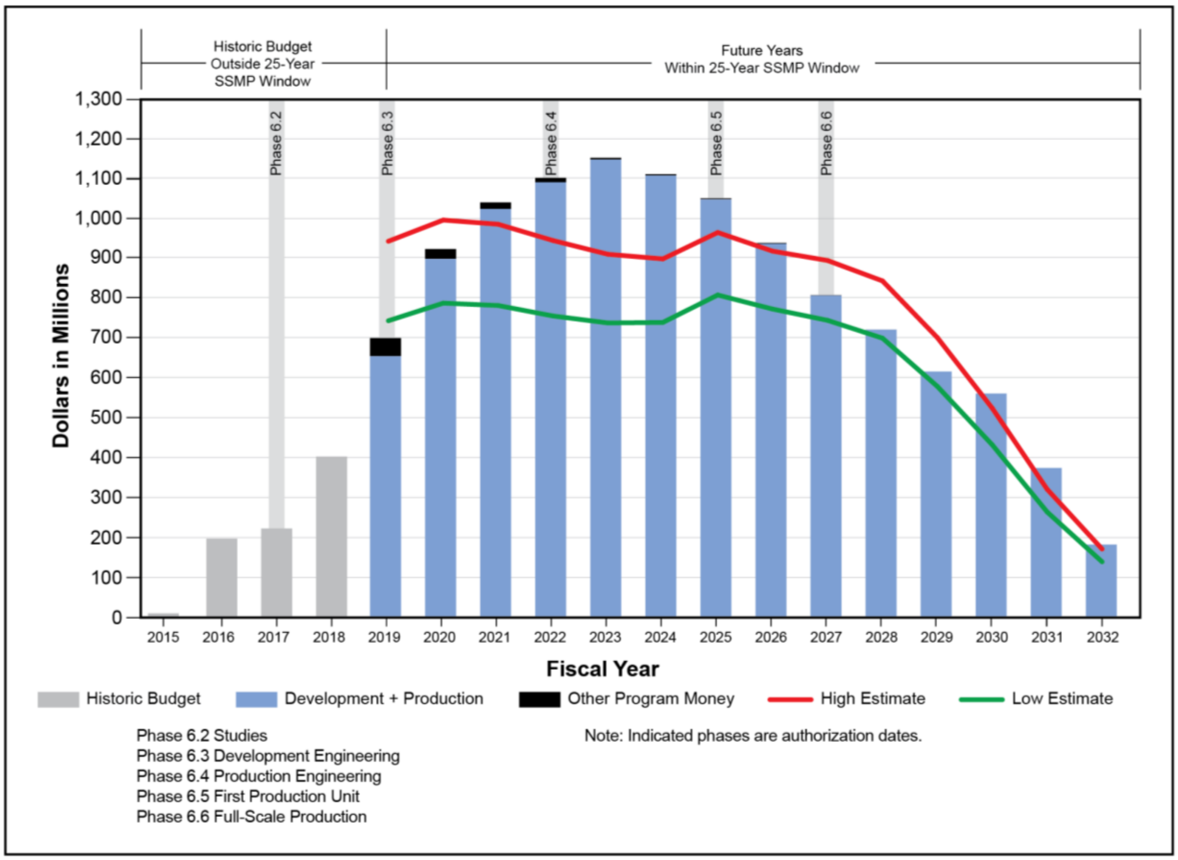


Figure 8–26. W80-4 Life Extension Program cost fiscal year 2019 to completion

Table 8–9. Total estimated cost for W80-4 Life Extension Program

Dollars in Billions	DOE/NNSA		DoD	
	FY 2019 Dollars	Then-Year Dollars	FY 2019 Dollars	Then-Year Dollars
Pre-WDCR Cost	0.9	0.9	N/A	N/A
FY 2019 – FY 2032				
High Total	9.6	10.8	0.2	0.2
Low Total	7.9	8.9	0.2	0.2
WDCR Total	9.6	11.2	N/A	N/A

WDCR = Weapon Design and Cost Report

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

The Nuclear Weapons Council authorized restart of Phase 6.2 activities, and the program is on track to support fielding of the Ground-Based Strategic Deterrent by 2030. DOE/NNSA is developing W87-1 design options for feasibility analyses. The program is also supporting a feasibility study of fielding the W87-1 nuclear explosive package in a Navy flight vehicle as directed in the 2018 *Nuclear Posture Review*.

The cost estimate in **Figure 8–27** represents a high-complexity scope case. The scope complexity includes multiple nuclear and non-nuclear components needed to reach the desired objectives for safety and surety, a significant portion of remanufacture components, and updated architectures. Additionally, there is a high level of system engineering and integration complexity due to revised design interfacing with the Ground-Based Strategic Deterrent. The W87-1 Modification Program will use the Phase 6.2 process to continue cost/benefit and trade space analysis for additional cost reductions. The estimates shown in Figure 8–27 and **Table 8–10** do not include the incremental cost to get to a 30-pit-per-year plutonium capability by FY 2026 necessary support this LEP. Those costs are captured in Plutonium Sustainment in DSW. DOE/NNSA acknowledges that this program appears to be underfunded in the FY 2020 FYNSP; however, the program is exploring cost reduction opportunities in the design option space as the program moves through Phase 6.2.

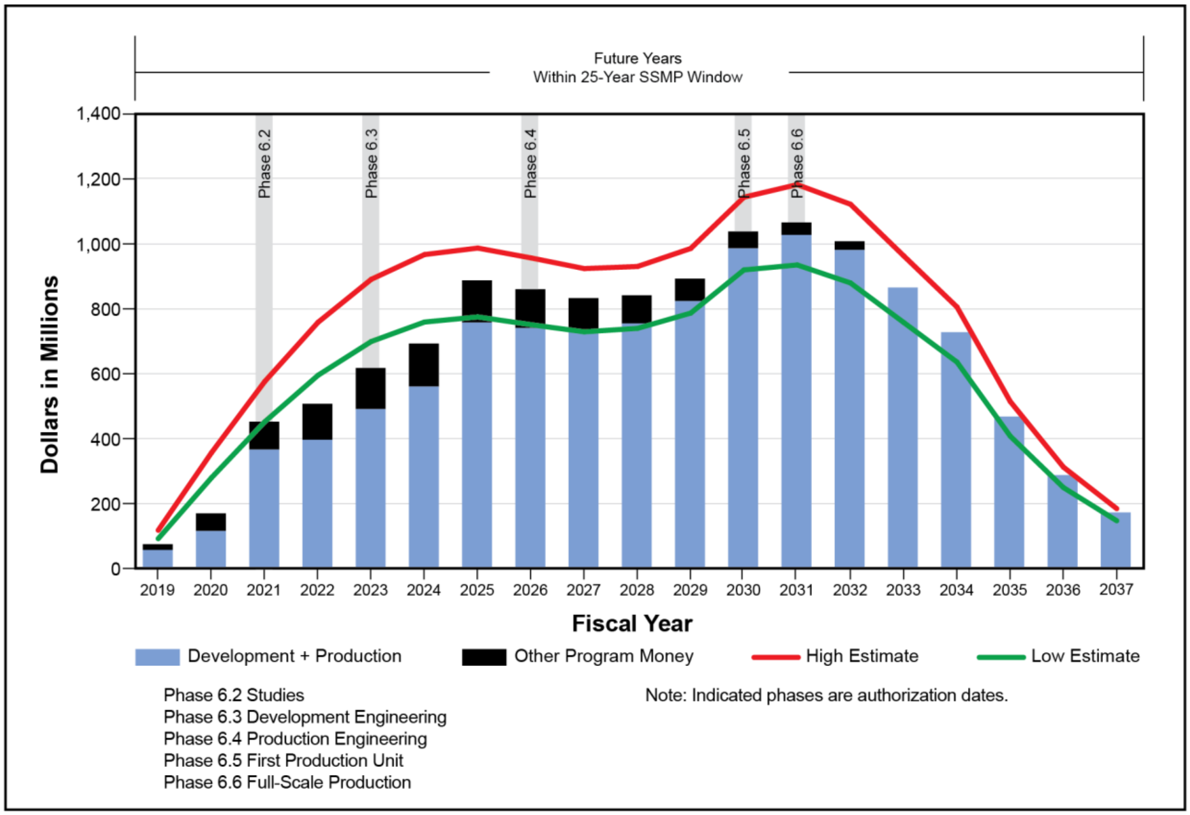


Figure 8–27. W87-1 Modification Program cost fiscal year 2019 to completion[28]

[28] Costs represented from FY 2019 – FY 2037 are consistent with the latest Defense Programs ICEs. High and low estimates were determined using Defense Programs ICEs and are included for comparison to the original estimate.

Table 8–10. Total estimated cost for W87-1 Modification Program

FY 2019 – FY 2037 (dollars in billions)	DOE/NNSA		DoD	
	FY 2019 Dollars	Then-Year Dollars	FY 2019 Dollars	Then-Year Dollars
High Total	12.2	14.8	1.0	1.2
Low Total	9.7	11.7	0.9	1.1
Proposed Budget	N/A	12.4	N/A	1.1

8.7.3.10 Next Navy Warhead Life Extension Program Cost Estimate

The Next Navy Warhead LEP cost estimate (see **Table 8–11**) provides a planning estimate for a notional system based on an existing stockpile weapon scope with increased uncertainty. This estimate shows a reduction from the previous FY 2019 SSMP estimate largely driven by the transition away from an interoperable warhead model. DOE/NNSA acknowledges the potential Navy requirement for a new AF&F set and any adjustments to this estimate will be reflected as part of the FY 2021 President's Budget Request and FY 2021 SSMP. 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 Next Navy Warhead Life Extension Program

FY 2023 – FY 2042 (dollars in billions)	DOE/NNSA		DoD	
	FY 2019 Dollars	Then-Year Dollars	FY 2019 Dollars	Then-Year Dollars
High Total	12.2	16.1	1.0	1.3
Low Total	9.7	12.8	0.9	1.2
Proposed Budget	N/A	14.4	N/A	1.2

8.7.3.11 Future Strategic Missile Warhead Life Extension Program Cost Estimate

The Future Strategic Missile Warhead LEP cost estimate (see **Table 8–12**) provides a planning estimate for a notional system based on an existing stockpile weapon scope with increased uncertainty. These estimates will change as requirements and schedules are refined and will be updated in future versions of the SSMP.

Table 8–12. Total estimated cost for Future Strategic Missile Warhead Life Extension Program

FY 2027 – FY 2046 (dollars in billions)	DOE/NNSA		DoD	
	FY 2019 Dollars	Then-Year Dollars	FY 2019 Dollars	Then-Year Dollars
High Total	12.2	17.2	1.0	1.4
Low Total	9.7	13.6	0.9	1.3
Proposed Budget	N/A	15.4	N/A	1.3

8.7.3.12 Next B61 Life Extension Program Cost Estimate

The Next B61 LEP cost estimate (see **Table 8–13**) provides a planning estimate for a notional system based on the current B61-12 scope with increased uncertainty. These estimates 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 Next B61 Life Extension Program

FY 2038 – FY 2056 (dollars in billions)	DOE/NNSA		DoD	
	FY 2019 Dollars	Then-Year Dollars	FY 2019 Dollars	Then-Year Dollars
High Total	11.8	21.9	0.2	0.4
Low Total	8.2	15.1	0.1	0.1
Proposed Budget	N/A	18.5	N/A	0.3

8.7.3.13 Summary of Cost Estimates

Figure 8–28 represents a summary of cost estimate ranges for all LEPs from FY 2019 through FY 2044.

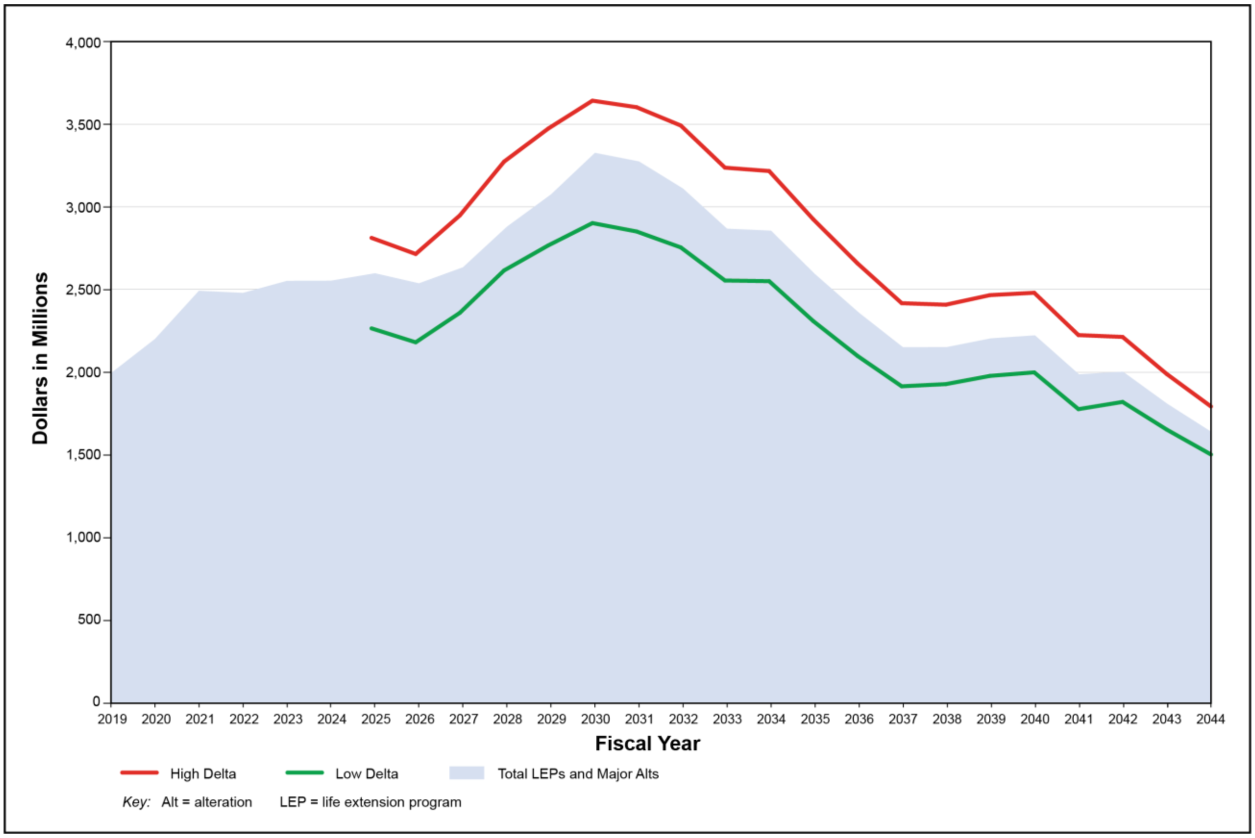


Figure 8–28. Total U.S. projected nuclear weapons life extension costs for fiscal year 2019 through fiscal year 2044 with high and low estimates (then-year dollars)

8.7.4 Construction

8.7.4.1 Cost Estimation for Capital Acquisitions

In FY 2019, programmatic capital acquisitions accounted for over 95 percent of the Infrastructure and Operations Construction Budget; the remaining costs are for general construction. In FY 2017, Defense Programs prioritized the development of improved programmatic capital acquisition cost and schedule estimates to inform long-term planning.

In FY 2019, DOE/NNSA began publishing Defense Programs ICEs in the SSMP for early-stage capital acquisitions.[29] Since these ICEs are performed at an early pre-acquisition stage (often a decade or more before a project's initial CD-0 milestone), these planning estimates primarily inform the portfolio's long-term cost projections and are supplemental to DOE acquisition requirements in DOE Order 413.3B.

[29] ICEs 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.

Notably, these Defense Programs ICEs are:

- Performed by an independent organization separate from the Federal program office.[30]
- Performed using a top-down parametric method that is consistent with early-stage planning.[31]
- 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 CD-0 (Approve Alternative Selection and Cost Range) 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.).

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

8.7.4.2 Fiscal Year 2020 through 2044 Estimates

The budget estimate for capital acquisition in FY 2020 through FY 2024, which is part of the I&O total included in Figure 8–30, reflects the DOE/NNSA current program. DOE/NNSA is executing the schedules of multiple ongoing major capital acquisition projects, such as the Uranium Processing Facility and U1a Complex Enhancements projects. A list of major capital acquisition project proposals has been developed through the efforts of a series of working groups and deep dives with representatives from DOE/NNSA sites and responsible Federal offices. DOE/NNSA reviewed hundreds of project proposals in 2018. The schedule for the highest-priority project proposals is depicted by major capital acquisition projects and project proposals listed in Chapter 4, "Physical Infrastructure," Figure 4–6. This planning schedule will be updated annually. Changes will be made based on available funding and programmatic priorities.

The current program and the program-vetted project proposals are the basis for the cost estimates. **Table 8–14** lists low and high estimate projections in then-year dollars for Weapons Activities capital acquisition projects from FY 2020 through FY 2044. As mentioned in the previous section, several of these projects contain a high degree of scope and cost uncertainties, resulting in a significant cost range. This year's SSMP high estimate benefits from several improvements to prior SSMP projection methodology, including:

- Collecting and validating capital acquisition requirements over the full 25-year SSMP timeframe.
- Performing a cost estimate for every validated project proposal (either a Defense Programs ICE, as described in the previous section for new construction projects, or site estimates for refurbishment projects).[32, 33]

[30] Defense Programs ICEs are performed by the Office of Cost Policy and Analysis.

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

[32] The provisional $15 billion high estimate for the Domestic Uranium Enrichment capability in last year's SSMP was adjusted based on further analysis to an $11 billion high estimate.

[33] For purposes of establishing this budget, it was assumed that KCNSC will not require a line-item project to maintain forecast capabilities during the planning period.

- Updating the high total to represent the 85th percentile of the confidence range for each project and anticipated future scope.[34]
- Expanding the table's time horizon to match the full 25-year SSMP timeframe.[35]

Table 8–14. Weapon Activities capital acquisition estimated costs, fiscal years 2020 through 2044

Then-Year Dollars, in Billions	*Low* [a]	*High* [b]
Weapon Activities capital acquisition estimated costs	52.9	79.2

[a] "Low" reflects the I&O Construction portfolio's estimate in Figure 8–31. The low value is programmatically informed and affected by delays in construction within the FYNSP.
[b] "High" reflects the program provided I&O Construction portfolio with the 85th percentile of the Defense Programs independent cost estimates confidence level range, which is based on the underlying scope and cost uncertainties.

The difference in the high and low estimates as compared to the FY 2019 SSMP are a result of delaying new construction projects within the FYNSP, revised cost estimates, the addition of new project proposals, and changing acquisition strategies.

8.8 Weapons Activities 25-Year Program

The projected future costs for the Weapons Activities portfolio for FY 2025 – FY 2044 should be interpreted as the range between the red high-range total lines and the green low-range total lines for Weapons Activities in the figure, which represent a quantification of uncertainty. This total cost range is necessary because of uncertainties related to the individual components of the estimates, the LEPs, and the construction costs described later in this chapter.[36]

Figure 8–29 depicts updated Weapons Activities budget projections beyond the FYSNP, based on the FY 2020 President's Budget Request. As noted at the beginning of this chapter, the FY 2020 budget request is crucial for implementing the policy directives laid down by the 2018 *Nuclear Posture Review*. The 25-year budget estimates are based on the program of record described in Chapters 2 through 6. **Figure 8–30** displays the relative makeup of the Weapons Activities Program in terms of major portfolios for the period FY 2019 through FY 2044 based on estimated program costs. This information illustrates the potential evolution of the program's direction; it does not represent the precise costs for any of the portfolios other than within the FYNSP.

[34] Use of the 85th percentile is consistent with DOE Order 413.3B guidance to select an acceptable point estimate from a confidence level range. The new high estimate includes additions to the scope from the FY 2018 SSMP (such as non-nuclear production facility modernization) consistent with the 2018 *Nuclear Posture Review*. Last year's low estimate reflected an even lower amount of new infrastructure scope, including no funds for Plutonium Pit Production or Domestic Uranium Enrichment projects.
[35] The table reflects only the 20-year post-FYNSP planning horizon in last year's SSMP.
[36] As shown in the previous sections, cost estimates for stockpile sustainment, LEPs, and construction projects were determined using various projection methodologies. Plutonium Pit Production project estimates at LANL and SRS after FY 2024 were included to create a more informed projection. Beginning in FY 2028, an additional $110 million per year was added to Plutonium Sustainment costs to adjust for increased production activities. All other programs were escalated normally.

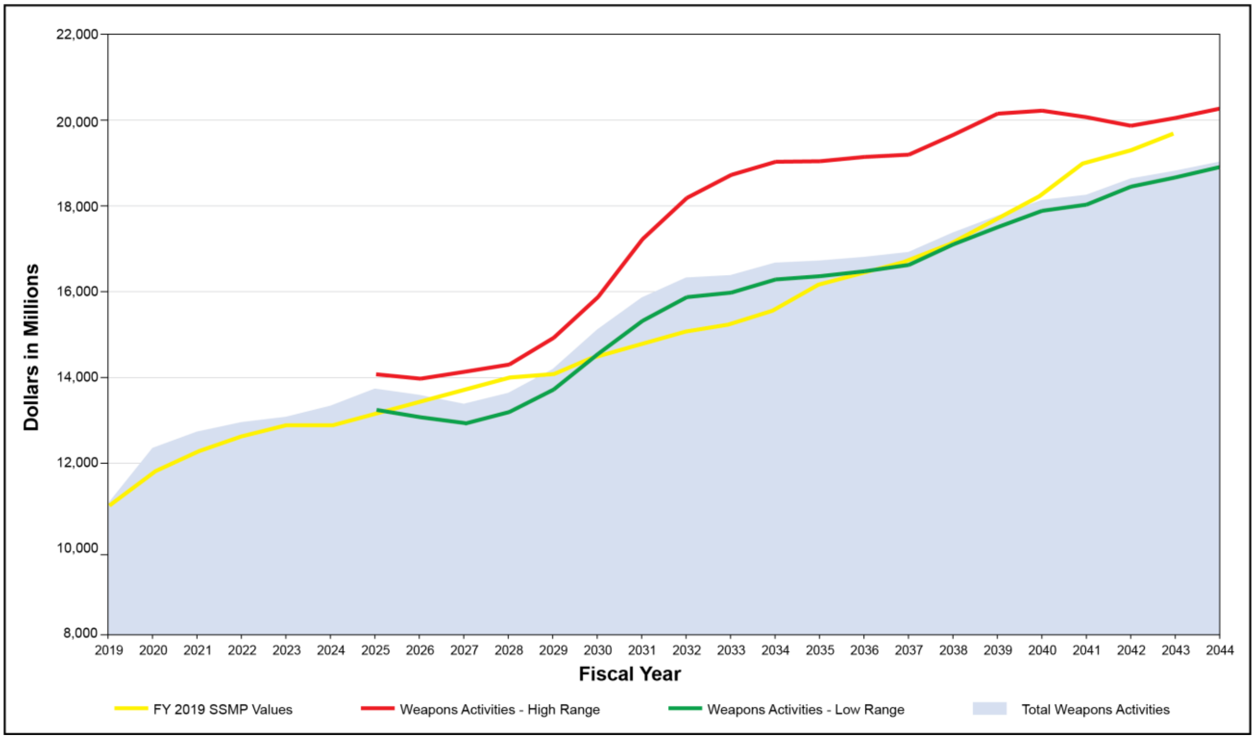


Figure 8–29. Projected out-year budget estimates for DOE/NNSA Weapons Activities in then-year dollars with high- and low-cost estimates

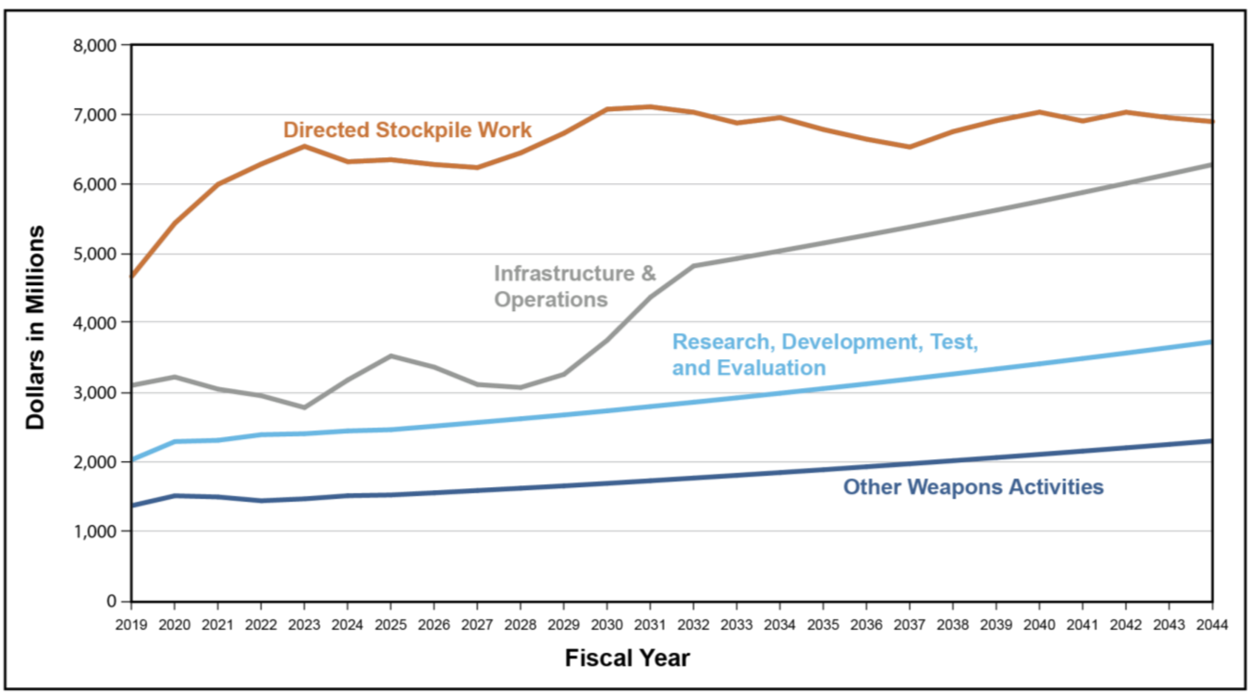


Figure 8–30. Projected out-year budget estimates for DOE/NNSA Weapons Activities in then-year dollars by portfolio

The nominal cost of the Weapons Activities portfolio from FY 2019 – FY 2020 increases by approximately 11.8 percent. This increase to the program reflects the expanded work scope including LEPs, construction projects, and strategic materials increases to meet changing requirements. Over the FY 2020 – FY 2024 period, the program cost increases at an annual average rate of approximately 2.0 percent.

The scope of the Weapons Activities portfolio has significantly increased with the need to support an increased number of LEPs, new strategic material initiatives, and the qualification of new technologies. Concurrently, significant and sustained investments across the entire enterprise are needed over the coming decade to ensure that DOE/NNSA will be able to deliver the capacity and capabilities needed to support the nuclear deterrent into the 2030s and beyond.

While Figure 8–29 shows the total Weapons Activities budget estimates, Figure 8–30 separates the major portfolio element estimates over the 25-year program. This figure does not capture the out-year uncertainty, but it does offer greater transparency into the Weapons Activities 25-year program estimate.

The DSW estimate highlights some variability over the next 10 years, with stability over the remainder of the 25-year program. The significant increase within the FYNSP is driven by:

- Ten percent growth in total LEP funding supporting the W80-4 LEP and W87-1 Modification Program
- Forty-five percent growth in total strategic materials funding predominately driven by increased pit production investments at both LANL and SRS

The DSW increase between FY 2027 and FY 2030 represents a ramp up of LEP funding supporting the simultaneous execution of the W80-4, W87-1, Next Navy Warhead, and the Future Strategic Missile Warhead.

Decreases in DSW outside of the FYNSP are largely due to pit production infrastructure investments transitioning to the I&O funding line. This change also shows up as an increase to the I&O funding line during that same timeframe.

The I&O estimate highlights variability over the next 10 years with a focused growth profile across the 25-year program. A decrease within the FYNSP is driven by:

- The ramp-down of Uranium Processing Facility and CMRR projects
- Limited investments in new programmatic construction projects and conceptual design activities between FY 2021 – FY 2024 to address LEP requirements

The programmatic construction delay during the FYNSP creates a second dip in the I&O estimates between FY 2026 and FY 2029, while conceptual design activities mature enough for new construction estimates beginning in FY 2029. After FY 2031, the I&O estimates stabilize with focused growth outpacing the remainder of the Weapons Activities portfolio. Outside of the FYNSP, DOE/NNSA is projecting nearly 60 unique programmatic construction and modernization projects that will need dedicated funding, fueling long-term focused growth in modernizing the DOE/NNSA nuclear security enterprise.

Overall spending in the remainder of the Weapons Activities portfolio remains relatively constant from the FY 2019 SSMP.

8.9 Affordability Analysis

In April 2017, GAO recommended that DOE/NNSA include an assessment of the affordability of the modernization programs portfolio in future versions of the SSMP.[37] DOE/NNSA's method for evaluating potential affordability is part of a portfolio management approach in line with the level of uncertainty affecting the out-years. DOE/NNSA has a rigorous process for developing the 5-year FYNSP budget request, while the SSMP provides the projected cost of continuing the program beyond the FYNSP, incorporating some amount of uncertainty in the out-year projects based on the uncertainties in LEP and construction 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 through the programming and budget processes.

Estimate of Weapons Activities Program Costs and Its Affordability

The projected future costs for the Weapons Activities portfolio for FY 2020 – FY 2044 should be interpreted as a range outside of the FYNSP and represents a quantification of uncertainty. This total cost range is necessary because of the uncertainties (risks) related to the individual components of the estimates, the LEPs, and the construction costs described earlier in this chapter.

The blue line in **Figure 8–31** represents the nominal total from the FY 2019 SSMP. Such costs are principally from LEPs, pit production, and other 2018 *Nuclear Posture Review* implementation cost growth discussed previously in the chapter.

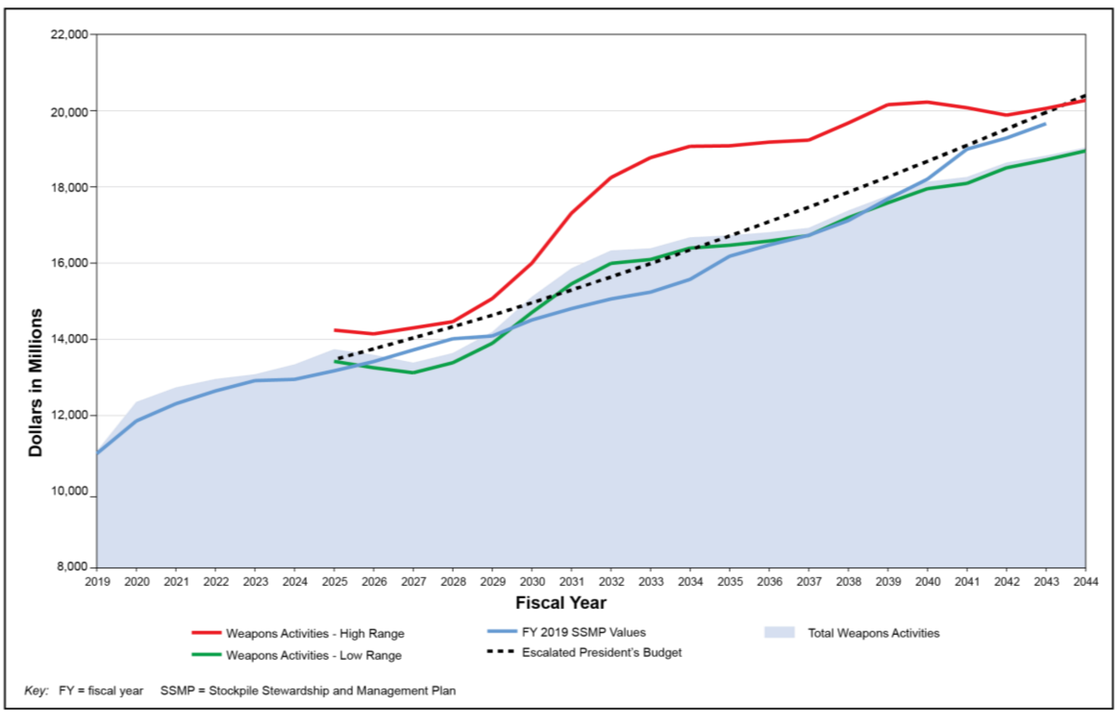


Figure 8–31. Projected out-year budget estimates for DOE/NNSA Weapons Activities in then-year dollars with high- and low-cost estimates, including the escalated President's Budget Request[38]

[37] *Action Needed to Address Affordability of Nuclear Modernization Programs*, Government Accountability Office, GAO-17-341.

[38] For the President's Budget, OMB MAX values were used for FY 2025 – FY 2029 and then escalated for FY 2030 – FY 2044.

The dashed line represents the escalated President's Budget Request after the FYNSP. This line represents a likely estimate of future years' budget authority. The nominal cost of the Weapons Activities program does not significantly exceed the escalation line and generally falls between the low and high cost ranges. Based on the FY 2020 – FY 2024 programming process, congressionally mandated funding level adjustments, and the formal process of multi-agency budget development, DOE/NNSA created an affordable and executable program. Schedules and scopes can be adjusted for outyear activities, as part of annual programming, to address shortfalls and DOE/NNSA will use updated estimates for these activities.

Chapter 9
Conclusion

This DOE/NNSA *Fiscal Year 2020 Stockpile Stewardship and Management Plan* (SSMP), together with the classified Annex, is a key planning document for the nuclear security enterprise. The SSMP documents the 25-year strategic program of record and plans developed across numerous DOE/NNSA programs and organizations to sustain the nuclear deterrent near-to-long-term through maintaining and modernizing the stockpile, scientific tools, capabilities, and infrastructure needed to ensure mission success. The DOE/NNSA Federal workforce prepares each SSMP in collaboration with management and operating partners. The plan in the FY 2020 SSMP is also coordinated with DoD through the Nuclear Weapons Council and is consistent with the Nuclear Weapons Council's Strategic Plan for 2019–2044. This SSMP is NNSA's foundation for meeting the nuclear weapons mission laid out in the December 2017 *National Security Strategy of the United States of America* (White House 2017) and the 2018 *Nuclear Posture Review* (DoD 2018). In response to new demands and challenges related to stewardship and management of the stockpile, DOE/NNSA publishes a new version of the SSMP each year with updates to its strategic plans. The FY 2020 SSMP builds on previous SSMPs and updates the costs and resources required for execution of the program based on current mission needs, the strategic environment, and new guidance.

While executing the current plan, DOE/NNSA had an outstanding FY 2018. DOE/NNSA maintained the existing nuclear weapons stockpile, made impressive progress on a number of life extension programs (LEPs), and continued to advance the science and engineering capabilities that underpin the Nation's Stockpile Stewardship Program.

Extending the life of existing U.S. nuclear warheads was accomplished by replacing nuclear and non-nuclear parts or inserting new parts that use updated technologies. DOE/NNSA's state-of-the-art capabilities for research, development, testing, evaluation, and production enabled this critical effort. The scopes, budgets, and schedules of the LEPs; infrastructure modernization; and DoD nuclear delivery systems reflect integrated and coordinated efforts.

Although many warheads in America's nuclear weapons stockpile have exceeded their original design lives, the Stockpile Stewardship Program also continues to survey, assess, and maintain the safety, security, and effectiveness of the aging nuclear weapons stockpile. This effort harnesses leading-edge science, engineering, high performance computing, and advanced manufacturing to enable the Secretaries of Energy and Defense to annually inform the President about the state of the stockpile without explosive nuclear testing.

To facilitate future scientific and engineering excellence at the national security laboratories and nuclear weapons production sites, DOE/NNSA has continued university collaborations and science, technology, engineering, and mathematics educational outreach in applied and technical research supporting technology development to maintain a pipeline for the future workforce.

Finally, DOE/NNSA continues to strengthen weapons activities strategic planning. DOE/NNSA has integrated and improved the Planning, Programming, Budgeting, and Evaluation process with improved portfolio analyses, high-quality cost-estimation techniques, and production of aggregate out-year funding wedges for portfolios such as capital assets. Annual updates to cost-estimating models enable DOE/NNSA to posture the organization to efficiently execute upcoming projects with adequate resources. DOE/NNSA continues to develop strategies to ensure our capabilities will meet the mission requirements laid out in the 2018 *Nuclear Posture Review*. 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 and, should the need arise, to design the systems of tomorrow.

Appendix A
Requirements Mapping

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

The *Fiscal Year 2020 Stockpile Stewardship and Management Plan* (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 2020 SSMP.

A.2 Ongoing Requirements

50 U.S. Code § 2521	*FY 2019 Response*	*FY 2020 Response*
§ 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.	*Unclassified* All Chapters	*Unclassified* All Chapters
(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.	*Unclassified* Chapter 3, Sections 3.1, 3.2; Appendix B	*Unclassified* Chapter 3, Sections 3.2.4; Chapter 8, Section 8.3.4; Appendix C
(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.	*Unclassified* Chapter 3, Sections 3.4, 3.5, 3.6, 3.8, 3.10, 3.11	*Unclassified* Chapter 3, Sections 3.2.1, 3.2.2, 3.2.3; Chapter 8, Sections 8.3.1, 8.3.2, 8.3.3
(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.	*Unclassified* Chapter 4, Section 4.7.5	*Unclassified* Chapter 3, Section 3.3.2; Chapter 4, Sections 4.2.1, 4.2.2, 4.3.1; Chapter 8, Sections 8.3.1–8.3.3, 8.5.3

50 U.S. Code § 2521	*FY 2019 Response*	*FY 2020 Response*
(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.	*Unclassified* Chapter 3, Sections 3.3–3.8, 3.12, 3.14	*Unclassified* Chapter 3, Sections 3.2.1, 3.2.3; Chapter 8, Sections 8.3.1, 8.3.3
(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.	*Unclassified* Chapter 2, Sections 2.2.4, 2.4.1–2.4.7; Chapter 3, Sections 3.16–3.26	*Unclassified* Chapter 2, Sections 2.1.1, 2.3.1, 2.3.2, 2.3.4, 2.3.5, 2.3.6, 2.4.1, 2.4.3, 2.4.6–2.4.8; Chapter 3, Section 3.3.2; Chapter 4, Sections 4.2–4.4, 4.6; Chapter 8, Sections 8.2.3, 8.3.5, 8.5.1
(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]	*Unclassified* Appendix B	*Unclassified* Appendix C
(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.	*Unclassified* Chapter 4, Section 4.19; Appendix B	*Unclassified* Chapter 8, Section 8.3.4; Appendix C
(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.	*Unclassified* Chapter 4, Section 4.3.4	*Unclassified* Chapter 8, Section 8.3.4; Appendix C, Section C.2

50 U.S. Code § 2521	*FY 2019 Response*	*FY 2020 Response*
(e) SUBMISSION TO CONGRESS.—The Administrator shall submit the plan required by subsection (a) to the congressional defense committees [Committees on Armed Services and Appropriations of Senate and the House of Representative] with each summary of the plan required by subsection (a) of section 4203 of the Atomic Energy Defense Act (50 U.S.C. 2523) submitted under subsection (b)(1) of that section during the 10-year period beginning on the date of the enactment of this Act.		
(f) EXASCALE COMPUTING DEFINED.—In this section, the term ''exascale computing'' means computing through the use of a computing machine that performs near or above 10 to the 18th power floating point operations per second.		

50 U.S. Code § 2522	*FY 2019 Response*	*FY 2020 Response*
§ 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.	*Unclassified* Chapter 2, Sections 2.2, 2.2.1–2.2.4	*Unclassified* Chapter 2, Sections 2.2.7–2.2.9; Chapter 3, Sections 3.1.2, 3.2.1–3.2.4; Chapter 8, Sections 8.3.1–8.3.4
(b) Coordination with Secretary of Defense The Secretary of Energy, in developing the criteria required by subsection (a), shall coordinate with the Secretary of Defense.		

50 U.S. Code § 2523	*FY 2019 Response*	*FY 2020 Response*
§ 2523. Nuclear weapons stockpile stewardship, management, and responsiveness plan		
(a) Plan requirement The Administrator, in consultation with the Secretary of Defense and other appropriate officials of the departments and agencies of the Federal Government, shall develop and annually update a plan for sustaining the nuclear weapons stockpile. The plan shall cover, at a minimum, stockpile stewardship, stockpile management, stockpile responsiveness, stockpile surveillance, program direction, infrastructure modernization, human capital, and nuclear test readiness. The plan shall be consistent with the programmatic and technical requirements of the most recent annual Nuclear Weapons Stockpile Memorandum.	*Unclassified* All Chapters ——— *Classified Annex*	*Unclassified* All Chapters ——— *Classified Annex*
(b) Submissions to Congress		
(1) In accordance with subsection (c), not later than March 15 of each even-numbered year, the Administrator shall submit to the congressional defense committees a summary of the plan developed under subsection (a).	*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 ——— *Classified Annex*
(3) The summaries and reports required by this subsection shall be submitted in unclassified form, but may include a classified annex.		

50 U.S. Code § 2523	FY 2019 Response	FY 2020 Response
(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 1.4; Chapter 2, Sections 2.2.2, 2.2.3, 2.2.4, 2.3.1 ——— *Classified Annex*	*N/A*
(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 2, Section 2.3.1; Chapter 4, Sections 4.1, 4.2, 4.2.1, 4.2.2	*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 2.2.1, 2.2.2, 2.2.3; Chapter 3, Sections 3.1–3.27	*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, Sections 1.5, 1.8; Chapter 2, Section 2.4; Chapter 3, Sections 3.28–3.31; Chapter 4, Sections 4.2.2, 4.5, 4.5.1–4.5.4, 4.7.5 ——— *Classified Annex*	*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 4	*N/A*
(6) A summary of the plan regarding the research and development, deployment, and lifecycle sustainment of technologies described in subsection (d) (7).	*Unclassified* Chapter 3	*N/A*
(7) A summary of the assessment under subsection (d)(8) regarding the execution of programs with current and projected budgets and any associated risks.	*Unclassified* Chapter 4, Section 4.7.1	*N/A*
(8) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*Unclassified* Executive Summary; Chapter 4, Sections 4.2.3, 4.3.1–4.3.5, 4.4.9, 4.5.3, 4.6.2, 4.6.3, 4.7, 4.7.3, 4.7.4, 4.7.5 ——— *Classified Annex*	*N/A*

50 U.S. Code § 2523	*FY 2019 Response*	*FY 2020 Response*
(9) Such other information as the Administrator considers appropriate.	*Unclassified* ——— *Classified Annex*	*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 1.2; Chapter 2, Sections 2.1.12, 2.5, 2.5.1–2.5.9 ——— *Classified Annex* Chapter 2, Sections 2.1, 2.2; Tables 2-1, 2-2
(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, Sections 8.7.1–8.7.3 ——— *Classified Annex* Chapter 2, Sections 2.2, 2.5; Tables 2-1, 2-3
(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 2.1.1, 2.5, 2.5.1–2.5.8; Chapter 8, Sections 8.2, 8.7.3 ——— *Classified Annex* Chapter 2, Sections 2.2, 2.5; Tables 2-3, 2-4
(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, Sections 2.2, 2.2.1–2.2.9; Chapter 3, Sections 3.1.1, 3.2.2
(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, Sections 2.2, 2.2.1–2.2.9; Chapter 3, Sections 3.1.1, 3.1.2

50 U.S. Code § 2523	*FY 2019 Response*	*FY 2020 Response*
(F) any concerns of the Administrator that would affect the ability of the Administrator to recertify the safety, security, or reliability of warheads in the nuclear weapons stockpile (including active and inactive warheads);	*N/A*	*Unclassified* Chapter 2, Sections 2.1, 2.1.1, 2.2.7, 2.3.6, 2.4.1, 2.4.3, 2.4.6; Chapter 3, Sections 3.2.1.3, 3.2.2.3, 3.2.3.3, 3.2.4.3, 3.3 ——— *Classified Annex* Chapter 2, Sections 2.5, Table 2-4
(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, 2.1.1, 2.2, 2.2.1–2.2.7, 2.3, 2.3.1–2.3.6, 2.4, 2.4.1–2.4.8, 2.5, 2.5.1–2.5.8; Chapter 3, Section 3.2
(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 2.2, 2.2.1–2.2.7, 2.3, 2.3.1–2.3.6; Chapter 3, Section 3.2
(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, Sections 1.4, 1.4.1–1.4.3, 1.4.5; Chapter 3, Sections 3.1.5; Chapter 7; Appendix D
(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 3, Section 3.1.1
(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 8.1, 8.2, 8.3.1–8.3.3, 8.7.2, 8.7.3
(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 8.1

50 U.S. Code § 2523	***FY 2019 Response***	***FY 2020 Response***
(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 3, Section 3.2; Chapter 8, Sections 8.2, 8.3.2
(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 8.2, 8.3.2
(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, Sections 2.2.1–2.2.7, 2.2.9; Chapter 3, Sections 3.1, 3.1.1, 3.1.2, 3.2.1–3.2.4
(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 3, Sections 3.2.1–3.2.4
(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 3, Sections 3.2.1.3, 3.2.2.3, 3.2.3.3, 3.2.4.3, 3.3.1 ——— *Classified Annex* Chapter 2, Section 2.5, Table 2-4
(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 3, Sections 3.1.1, 3.2.1–3.2.4; Appendix D
(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 3, Sections 3.1.1, 3.3.2; Appendix D

50 U.S. Code § 2523	*FY 2019 Response*	*FY 2020 Response*
(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, Section 7.3.4; Appendix B
(i) the number of scientists, engineers, and technicians, by discipline, required to maintain such competencies; and	*N/A*	*Unclassified* Chapter 7, Sections 7.3.1, 7.3.2; Appendix D
(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, Sections 7.4.1, 7.4.2; Appendix D
(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 4, Sections 4.2, 4.3
(i) the national security strategy of the United States as set forth in the most recent national security strategy report of the President under section 3043 of this title if such strategy has been submitted as of the date of the plan;		*Unclassified* Chapter 4, Sections 4.2, 4.3
(ii) the most recent quadrennial defense review if such strategy has not been submitted as of the date of the plan; and		*Unclassified* Chapter 4, Sections 4.2, 4.3
(iii) the most recent Nuclear Posture Review as of the date of the plan;		*Unclassified* Chapter 4, Sections 4.2, 4.3
(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 4, Sections 4.21, 4.2.2
(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 8.5.1, 8.7.4
(D) a description of— (I) the metrics (based on industry best practices) used by the Administrator to determine the infrastructure deferred maintenance and repair needs of the nuclear security enterprise; and (II) the percentage of replacement plant value being spent on maintenance and repair needs of the nuclear security enterprise; and (III) an explanation of whether the annual spending on such needs complies with the recommendation of the National Research Council of the National Academies of Sciences, Engineering, and Medicine that such spending be in an amount equal to four percent of the replacement plant value, and, if not, the reasons for such noncompliance and a plan for how the Administrator will ensure facilities of the nuclear security enterprise are being properly sustained.		*Unclassified* Chapter 8, Section 8.5.5
(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 3, Section 3.4

50 U.S. Code § 2523	***FY 2019 Response***	***FY 2020 Response***
(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 3, Section 3.4
(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 3, Section 3.4
(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 3, Section 3.4
(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 3, Section 3.4
(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 3, Sections 3.2.2.3, 3.3.3
(B) An assessment of scientific and testing instrumentation for plutonium at elemental and bulk conditions.	*N/A*	*Unclassified* Chapter 3, Sections 3.2.1, 3.2.3
(C) An assessment of manufacturing and handling technology for plutonium and plutonium components.	*N/A*	*Unclassified* Chapter 2, Section 2.4.1; Appendix D, Section D.2.2
(D) An assessment of computational models of plutonium performance under static and dynamic loading, including manufactured and nonmanufactured conditions.	*N/A*	*Unclassified* Chapter 3, Sections 3.2.1–3.2.4
(E) An identification of any capability gaps with respect to the assessments described in subparagraphs (A) through (D).	*N/A*	*Unclassified* Chapter 3, Sections 3.2.1.2, 3.2.1.3
(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, Sections 8.2.1, 8.2.3.5, 8.3.1, 8.3.3, 8.8
(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, Sections 8.2.1, 8.2.3.5, 8.3.1, 8.3.3, 8.8
(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 2, Section 2.4.1
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 6 ——— *Classified Annex* Chapter 3

50 U.S. Code § 2523	*FY 2019 Response*	*FY 2020 Response*
(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 6 ——— *Classified Annex* Chapter 3, Sections 3.2, 3.5; Tables 3-1, 3-2; Figure 3-2
(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 6, Sections 6.1.1–6.1.3, 6.2.3, 6.2.4 ——— *Classified Annex* Chapter 3, Sections 3.3, 3.7
(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 8.6.2, 8.6.3 ——— *Classified Annex* Chapter 3, Sections 3.4.2, 3.8; Tables 3-5, 3-6
(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 8.7–8.9
(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

50 U.S. Code § 2523	*FY 2019 Response*	*FY 2020 Response*
(e) Nuclear Weapons Council assessment (1) For each detailed report on the plan submitted under subsection (b)(2), the Nuclear Weapons Council shall conduct an assessment that includes the following: (A) An analysis of the plan, including— (i) whether the plan supports the requirements of the national security strategy of the United States or the most recent quadrennial defense review, as applicable under subsection (d)(4)(A), and the Nuclear Posture Review; (ii) whether the modernization and refurbishment measures described under subparagraph (A) of subsection (d)(4) and the schedule described under subparagraph (B) of such subsection are adequate to support such requirements; and (iii) whether the plan supports the stockpile responsiveness program under section 2538b of this title in a manner that meets the objectives of such program and an identification of any improvements that may be made to the plan to better carry out such program. (B) An analysis of whether the plan adequately addresses the requirements for infrastructure recapitalization of the facilities of the nuclear security enterprise. (C) If the Nuclear Weapons Council determines that the plan does not adequately support modernization and refurbishment requirements under subparagraph (A) or the nuclear security enterprise facilities infrastructure recapitalization requirements under subparagraph (B), a risk assessment with respect to— (i) supporting the annual certification of the nuclear weapons stockpile; and (ii) maintaining the long-term safety, security, and reliability of the nuclear weapons stockpile. (2) Not later than 180 days after the date on which the Administrator submits the plan under subsection (b)(2), the Nuclear Weapons Council shall submit to the congressional defense committees a report detailing the assessment required under paragraph (1).	*N/A*	*N/A*
(f) Definitions – In this section: (1) The term "budget", with respect to a fiscal year, means the budget for that fiscal year that is submitted to Congress by the President under section 1105(a) of title 31. (2) The term "future-years nuclear security program" means the program required by section 2453 of this title. (3) The term "nuclear security budget materials", with respect to a fiscal year, means the materials submitted to Congress by the Administrator in support of the budget for that fiscal year. (4) The term "quadrennial defense review" means the review of the defense programs and policies of the United States that is carried out every four years under section 118 of title 10. (5) The term "weapons activities" means each activity within the budget category of weapons activities in the budget of the Administration. (6) The term "weapons-related activities" means each activity under the Department of Energy that involves nuclear weapons, nuclear weapons technology, or fissile or radioactive materials, including activities related to— (A) nuclear nonproliferation; (B) nuclear forensics; (C) nuclear intelligence; (D) nuclear safety; and (E) nuclear incident response.		

50 U.S. Code § 2524	*FY 2019 Response*	*FY 2020 Response*
§ 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.	*Unclassified* Chapter 2, Sections 2.1, 2.2.1, 2.2.2, 2.2.3	*Unclassified* Chapter 2, Sections 2.1, 2.1.1, 2.1.2, 2.2, 2.2.1–2.2.9, 2.3.1–2.3.6; Chapter 3, Sections 3.1.1, 3.2.1, 3.2.2, 3.2.4
(2) To further reduce the likelihood of the resumption of underground nuclear weapons testing.	*Unclassified* Chapter 2, Section 2.2.1; Chapter 3, Sections 3.1–3.14	*Unclassified* Chapter 3, Section 3.2.1.3, 3.2.3, 3.2.4.2
(3) To achieve reductions in the future size of the nuclear weapons stockpile.	*Unclassified* Chapter 1, Section 1.7; Chapter 2, Section 2.2.5	*Unclassified* Chapter 2, Section 2.6
(4) To reduce the risk of an accidental detonation of an element of the stockpile.	*Unclassified* Chapter 2, Sections 2.2.1–2.2.5, 2.4.6	*Unclassified* Chapter 2, Sections 2.1, 2.3.3, 2.3.5; Chapter 3, Sections 3.2.2, 3.2.4
(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.	*Unclassified* Chapter 2, Section 2.1; Chapter 3, Sections 3.15, 3.16	*Unclassified* Chapter 2, Sections 2.1, 2.1.2, 2.3.3; Chapter 3, Sections 3.2.2, 3.2.4; Chapter 5
(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.		

50 U.S. Code § 2524	*FY 2019 Response*	*FY 2020 Response*
(c) Program budget In accordance with the requirements under section 2529 of this title, for each budget submitted by the President to Congress under section 1105 of title 31, the amounts requested for the program under this section shall be clearly identified in the budget justification materials submitted to Congress in support of that budget.		

50 U.S. Code § 2538a	*FY 2019 Response*	*FY 2020 Response*
§2538a. Plutonium pit production capacity (a) Requirement Consistent with the requirements of the Secretary of Defense, the Secretary of Energy shall ensure that the nuclear security enterprise- (1) during 2021, begins production of qualification plutonium pits; (2) during 2024, produces not less than 10 war reserve plutonium pits; (3) during 2025, produces not less than 20 war reserve plutonium pits; (4) during 2026, produces not less than 30 war reserve plutonium pits; and (5) during a pilot period of not less than 90 days during 2027 (subject to subsection [b]), demonstrates the capability to produce war reserve plutonium pits at a rate sufficient to produce 80 pits per year.	*Unclassified* Chapter 2, Section 2.4.1	*Unclassified* Chapter 1, Section 1.4.5; Chapter 2, Section 2.4.1; Chapter 8, Section 8.2.4; Appendix D, Section D.2.2
(b) Authorization of two-year delay of demonstration requirement The Secretary of Energy and the Secretary of Defense may jointly delay, for not more than two years, the requirement under subsection (a)(5) if- (1) the Secretary of Defense and the Secretary of Energy jointly submit to the congressional defense committees a report describing- (A) the justification for the proposed delay; (B) the effects of the proposed delay on stockpile stewardship and modernization, life extension programs, future stockpile strategy, and dismantlement efforts; and (C) whether the proposed delay is consistent with national policy regarding creation of a responsive nuclear infrastructure; and (2) the Commander of the United States Strategic Command submits to the congressional defense committees a report containing the assessment of the Commander with respect to the potential risks to national security of the proposed delay in meeting- (A) the nuclear deterrence requirements of the United States Strategic Command; and (B) national requirements related to creation of a responsive nuclear infrastructure.		
(c) Annual certification Not later than March 1, 2015, and each year thereafter through 2027 (or, if the authority under subsection (b) is exercised, 2029), the Secretary of Energy shall certify to the congressional defense committees and the Secretary of Defense that the programs and budget of the Secretary of Energy will enable the nuclear security enterprise to meet the requirements under subsection (a).	*N/A*	*Unclassified* Chapter 2, Section 2.4.1; Chapter 8, Section 8.2.4;
(d) Plan If the Secretary of Energy does not make a certification under subsection (c) by March 1 of any year in which a certification is required under that subsection, by not later than May 1 of such year, the Chairman of the Nuclear Weapons Council shall submit to the congressional defense committees a plan to enable the nuclear security enterprise to meet the requirements under subsection (a). Such plan shall include identification of the resources of the Department of Energy that the Chairman determines should be redirected to support the plan to meet such requirements.	*N/A*	*N/A*

50 U.S. Code § 2538b	*FY 2019 Response*	*FY 2020 Response*
§ 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.	*Unclassified* All Chapters	*Unclassified* All Chapters
(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.	*Unclassified* Chapter 1, Sections 1.5, 1.7	*Unclassified* Chapter 1, Sections 1.5, 1.7; Chapter 3, Sections 3.1.3, 3.2.2
(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.	*Unclassified* Chapter 3	*Unclassified* Chapter 1, Sections 1.5, 1.7; Chapter 3
(d) Joint nuclear weapons life cycle process defined In this section, the term “joint nuclear weapons life cycle process” means the process developed and maintained by the Secretary of Defense and the Secretary of Energy for the development, production, maintenance, and retirement of nuclear weapons.		

A.3 Other Requirements

H.R.244 – Consolidated Appropriations Act, 2017, P.L. 115-31	*FY 2019 Response*	*FY 2020 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* Chapter 2, Sections 2.2, 2.2.1–2.2.6, 2.3

Appendix B
Weapons Activities Capabilities

This table represents the breadth of capabilities that delineate the critical functions of Weapons Activities in the Department of Energy/National Nuclear Security Administration (DOE/NNSA) nuclear security enterprise. 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 NNSA missions. In part, this appendix supports legislative requirements listed in Appendix A.

Capability	***Definition***
Advanced Experimental Diagnostics and Sensors	Advanced diagnostics and sensors provide detailed measurements of materials, objects, and dynamic processes that are critical to weapon operation. 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. An example of an advanced diagnostic is static or multiframe 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.
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 control waste streams. Examples include additive manufacturing, use of microreactors, microwave casting, and electrorefining.
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.
Chemistry	Chemistry is the study of the fundamental (or elemental) composition, structure, bonding, and properties of matter. Chemistry is essential for purifying, synthesizing, processing, and fabricating materials. The stability of these materials and how properties and reactions change with time must be understood to ensure the quality, performance, reliability, and safety of the stockpile.
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 nuclear weapons. 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.

Capability	*Definition*
Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Material	Hazardous and energetic materials require safe and secure handling, packaging, processing, manufacturing, and inspection. Lithium, beryllium, and mercury have the potential to harm humans, animals, and the environment. Energetic materials (e.g., explosives, propellants) and hazardous materials require special conduct of operations, containment equipment, and facilities to handle, process, or manufacture products containing these materials.
Handling, Packaging, Processing, and Manufacturing of Special Nuclear Materials	Special conduct of operations, physical security protection, facilities, and equipment are required to handle, package, process, manufacture, and inspect components that contain special nuclear materials (e.g., plutonium, enriched uranium).
High Energy Density Physics	High energy density physics is the study of matter and radiation under extreme conditions such as those in a functioning nuclear weapon and in high-temperature experiments. Facilities such as the National Ignition Facility, Omega Laser Facility, and the Z pulsed power facility generate high energy density states and produce data for determining the physical processes that occur during these conditions and validating computational models.
High Explosives Science and Engineering	High explosives science and engineering is the study of detonation physics, shock wave propagation, and reaction initiation. It includes the design, synthesis, and manufacture of high explosives for specific applications. Knowledge of high-explosive behavior is necessary for understanding nuclear weapon performance.
High Performance Computing	High performance computing encompasses software, hardware, and facilities of sufficient power to achieve the dimensionality, resolution, and complexity in simulation codes to accurately model the performance of weapon systems and components and the fundamental physical processes that are critical to nuclear operation.
Hydrodynamic and Subcritical Experiments	Hydrodynamic experiments explore implosion physics and provide data on the behavior of full-scale dynamic systems. Subcritical experiments are driven by high explosives and contain special nuclear material that never achieves a critical configuration and does not create nuclear yield. Both types of experiments provide data that are essential to validating models within multi-physics design codes and predicting nuclear weapon performance.
Information Technology and Cybersecurity	Information technology and cybersecurity provides infrastructure and protection for both classified and unclassified computer networks and 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.
Laser, Pulsed Power, and Accelerator Technology	These technologies produce safe, reliable, and efficient lasers, accelerators, and pulsed power drivers for diagnostics and facilities, generating data at similar pressure, temperature, and radiation conditions to those in an operating nuclear weapon. Lasers and pulsed power devices accumulate energy over long periods and release it very quickly. Accelerators use electromagnetic fields to accelerate charged particles to very high speeds. The charged particles can produce high-energy x-rays to take radiographs or high-energy neutrons for nuclear physics investigations.

Capability	*Definition*
Materials Science and Engineering	Materials science, in the context of stockpile stewardship, is the study of how materials in a nuclear weapon behave under both moderate and extreme conditions of temperature and pressure. Materials engineering involves the evaluation and selection of materials for these environments. Strength, aging, compatibility, viability, and damage mechanisms are among the material 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).
Metal and Organic Material Fabrication, Processing, and Manufacturing	Although many weapon components are supplied by U.S. industries, specialized components and materials 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.
Non-Nuclear Weapon Component Manufacturing and Assembly	Many non-nuclear weapon components (e.g., microelectronics; gas transfer systems; arming, fuzing, and firing assemblies; environmental sensing devices; radars; neutron generators; and batteries) require special manufacturing, assembly, and inspection protocols.
Nuclear Physics and Radiochemistry	Nuclear physics is the study of atomic nuclei and their interactions, especially fission and fusion. Knowledge is needed regarding the probabilities of interactions of neutrons with fissile material and of light nuclei that can result in fusion. Radiochemistry, the chemistry of radioactive materials, is used to evaluate data from legacy underground tests and from experiments at the National Ignition Facility, Omega Laser Facility, and the Z pulsed power facility.
Physical Security	Physical security protects the Nation's nuclear materials, infrastructure assets, and the workforce at 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.
Radiation-Hardened Microelectronics Design and Manufacturing	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.
Secure Transportation	Protection and movement of nuclear weapons, weapon components, and special nuclear material between facilities includes design and fabrication or modification of vehicles, design and fabrication of special communication systems, and training of Federal agents.
Simulation Codes and Models	Advanced computer codes and the models embedded in these codes are developed and used to simulate the behavior of nuclear weapons. Codes range in application from design of systems to fundamental science processes. NNSA codes operate on computers ranging from desktop machines to the world's largest high-performance supercomputers.
Testing Equipment Design and Fabrication	Design and fabrication of special test equipment to simulate environmental and functional conditions must ensure that products meet specifications. Data from test equipment provide evidence for qualification, certification, reliability, surety, and surveillance.
Tritium Production, Handling, and Processing	Tritium has a 12-year half-life and must be periodically replenished in gas transfer systems. Production, handling, and processing of tritium includes the recovery, extraction, refinement, storage, filling, and inspection of gas transfer systems.

Capability	***Definition***
Weapon Component and Material Process Development	Process development of weapon components involves small-lot production, precise controls, and a deep understanding of the hazards of working with special nuclear materials and other exotic materials. Component process development is needed whenever process changes are made to reduce cost or production time.
Weapon Component 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.
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.
Weapons Engineering Design, Analysis, and Integration	Elements of weapons engineering capability include the following life cycle phases: concept exploration, satisfaction of requirements, conceptual design, detailed design and development, production, and certification and qualification. This capability also encompasses system integration, which includes understanding and developing the interfaces among the non-nuclear subsystems, between the non-nuclear components and the nuclear explosives package, and between the DOE/NNSA and Department of Defense systems.
Weapon System Assembly and Disassembly	Weapons system assembly involves the final assembly of the nuclear and non-nuclear components. Assembly requires special conduct of operations, equipment, and facilities. Disassembly, inspection, and storage or disposal of the components require similar special conduct of operations, quality control, equipment, and facilities.
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, satisfaction of specifications, conceptual design, detailed design and development, production process development, and certification and qualification. Weapons physics analysis includes evaluation of weapons effects.
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 and equipment.

Appendix C
Exascale Computing Initiative

The December 2017 *National Security Strategy* mandates that "to maintain our competitive advantage, the United States will prioritize emerging technologies critical to economic growth and security, such as data science, encryption, gene editing, new materials, nanotechnology, advanced computing technologies, and artificial intelligence." In addition, the 2018 *Nuclear Posture Review* states that the Department of Energy's National Nuclear Security Administration (DOE/NNSA) will "maintain and enhance the computational, experimental, and testing capabilities needed to annually assess nuclear weapons." To maintain competitive advantage and the necessary capabilities for the annual assessment, the United States must retain state-of-the-art capabilities in high performance computing (HPC). HPC will also help ensure national security, economic prosperity, technological strength, and scientific and energy research leadership. Failure to address national security, science, and growing big data needs will open the door to other Nations with a demonstrated commitment to HPC investment to take the lead in a number of areas. Risk would increase not only in high-end computing, but eventually in science, national defense, energy innovation, and the commercial computing market.

The National Strategic Computing Initiative (NSCI) was established as a Federal interagency campaign in 2015 to maximize the benefits of HPC for U.S. economic competitiveness, scientific discovery, and national security. Other agencies with major responsibilities for the NSCI include the National Science Foundation, the intelligence community, and the Departments of Commerce, Defense, Justice, and Homeland Security. Major thrusts of the NSCI are the exploration and development of quantum computing, bio computing, and exascale computing. Within that initiative DOE, represented by a partnership between the DOE Office of Science and NNSA, has the lead responsibility for focusing and executing the joint Exascale Computing Initiative. This initiative focuses on advanced simulation through an exascale computing program that continues exploiting legacy MOSFET[1] technology to emphasize sustained performance and analytic computing to advance DOE/NNSA missions. The objectives and the associated scientific challenges define a mission need for a computing capability of 2 to 10 exaFLOPS (1 exaFLOPS = 10^{18} floating-point operations per second) 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, NNSA will need to:

- Develop HPC technologies and systems, in close partnership with computer vendors that will provide at least an 8-fold increase in sustained application code performance over the currently largest Advanced Simulation and Computing (ASC) supercomputer, Sierra, which is a 125-petaFLOPS system (1 petaFLOPS = 10^{15} floating-point operations per second);

[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.

- Address code performance on the current advanced architecture and next-generation systems, which are employing heterogeneous architectures very different from the homogeneous computing environment we have experienced in the past 2 decades;
- Develop a tri-laboratory, open-sourced/community software stack that will run efficiently on new advanced architecture prototype systems to assess the viability of alternate HPC architecture paths for ASC; and
- Modernize computing facilities for readiness of siting exascale platforms with increasing and evolving structural integrity, power, and cooling requirements.

C.2 Approaches and Strategies

To achieve DOE/NNSA's exascale goals, the U.S. Government will interact 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 Government and private sector objectives. NNSA is continuing its partnership with the DOE Office of Science on the Exascale Computing Initiative, including investments in research and development (R&D) of software tools and applications with computer vendors, the national laboratories, and universities. In addition, the two organizations are collaborating on the joint April 2018 CORAL-2 procurement, which will deliver two exascale-class system to DOE's Office of Science in FY 2021–2022 and another to NNSA in FY 2023. This joint procurement will allow the program offices to share critical non-recurring engineering development costs with the selected vendor(s).

The current spend plan for Exascale Computing Initiative elements is shown in **Table C–1**. In FY 2020, the NNSA activities of the Exascale Computing Initiative includes ASC Advanced Technology Development and Mitigation (ATDM) subprogram, Construction: Exascale Computing Facility Modernization (ECFM) (at Lawrence Livermore National Laboratory [LLNL]), and a portion of Computational Systems and Software Environment – Exascale System (El Capitan). The Exascale Computing Initiative constitutes is about 25 percent of the ASC program. Independent funding also supports associated construction (see Chapter 4).

Table C–1. NNSA Exascale Computing Initiative funding schedule for FY 2020 through 2024

Exascale Computing Initiative Elements (dollars in millions)	*FY 2020 Request*	*FY 2021 Request*	*FY 2022 Request*	*FY 2023 Request*	*FY 2024 Request*
Advanced Technology Development and Mitigation	174.825	92	88	80	81
Construction: Exascale Computing Facility Modernization (at LLNL)	50	27	13	0	0
Computational Systems and Software Environment – Exascale System (El Capitan)	84.478	114	168	167	146
Total	**309.303**	**233**	**269**	**247**	**227**

Advanced Technology Development and Mitigation

A 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 three focus areas.

- *ATDM/ECP Application Development:* NNSA will be responsible for determining the scope and management of the stockpile simulation application development that is included in this focus area. Confidence in the safety and reliability of the nuclear weapons stockpile relies on high-fidelity simulations of all of the physical processes occurring within a nuclear weapon and its environments. This also includes the processes that support the design, production, maintenance, and evaluation of the nuclear arsenal, including life extension programs and weapons dismantlement. The ASC integrated design codes (IDCs) or more colloquially "bomb codes," model various aspects of nuclear weapons and each have 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, with the ATDM Application funding, to ensure continued future confidence in the Nation's stockpile. Exploiting the multi-level parallelism demanded by emerging computing architectures leading to exascale requires significant investment for new stockpile simulation code development over the next 5-7 years.

- *ATDM/ECP Software Technology*: Due to its stockpile stewardship mission and where appropriate, ASC will make strategic investments in ECP software technology to directly support its IDC development requirements. Funding will support further development of compilers and math libraries 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 highest control of precision in numerical approximations. Also, investments will be made in various performance analysis tools and visualization techniques to aid code developers and users to navigate the new advanced architecture systems.
- *ATDM/ECP Hardware and Integration*: NNSA will complete its obligation to fund the vendor R&D PathForward projects in FY 2020. Where appropriate, ASC will make strategic investments to directly support its stockpile stewardship code development requirements such as scalable and high-performance interconnect technologies, multi-level memory management, and heterogeneous-architecture programming.

The remainder of the ATDM portfolio includes stockpile application and computing activities that directly relate to the weapons program and thus falls outside of ECP. NNSA will continue funding the development of hostile environment simulation capabilities and provide support for additional physics and engineering models, and new verification and validation methodologies required for its next-generation weapons codes. In FY 2020, NNSA will evaluate and transition, as appropriate, the viable and validated next-generation code capabilities into its IDC portfolio which will be used for annual assessment activities. Funding also supports projects at the NNSA Labs that will seek to increase the capacity and capability of an enduring national HPC ecosystem via inter-agency collaborations with other U.S. Federal agencies.

For the stockpile computing effort, NNSA will deploy additional advanced-architecture testbeds and prototype systems for the initial testing and iterations of its next-generation IDCs. Funding will also be applied to the development, maintenance and user support for the tri-lab software stack that will be required for the next-generation codes to run efficiently on advanced hardware testbeds. In addition, NNSA will invest in the application of advanced machine learning techniques, which are well suited to the imminent advanced architectures to solving stockpile stewardship problems.

Construction: Exascale Computing Facility Modernization (at LLNL)

In addition to hardware and software technology development efforts, the exascale systems must meet exacting power usage, reliability, and functionality criteria. Each exascale-class platform will require between 30 and 45 megawatts per year to operate, as well as requisite cooling. Managing a service load of this magnitude, which is over and above existing capabilities in ASC facilities, will necessitate major facility modernizations. The ECFM project is intended to fill this gap by providing 85 megawatts of power and adding 18,000 tons of water cooling in calendar year 2022. A detailed engineering assessment in preparation for CD-2/3 (Approve Performance Baseline/Approve Start of Construction) proved the building already met requirements to support 315 pounds per square foot of rack load, so no additional investment is necessary in this area. The ECFM is essential for LLNL to successfully site the NNSA exascale system at the beginning of FY 2023. ECFM will issue contracts in FY 2020 and move into construction phase soon thereafter.

Computational Systems and Software Environment – Exascale System (El Capitan)

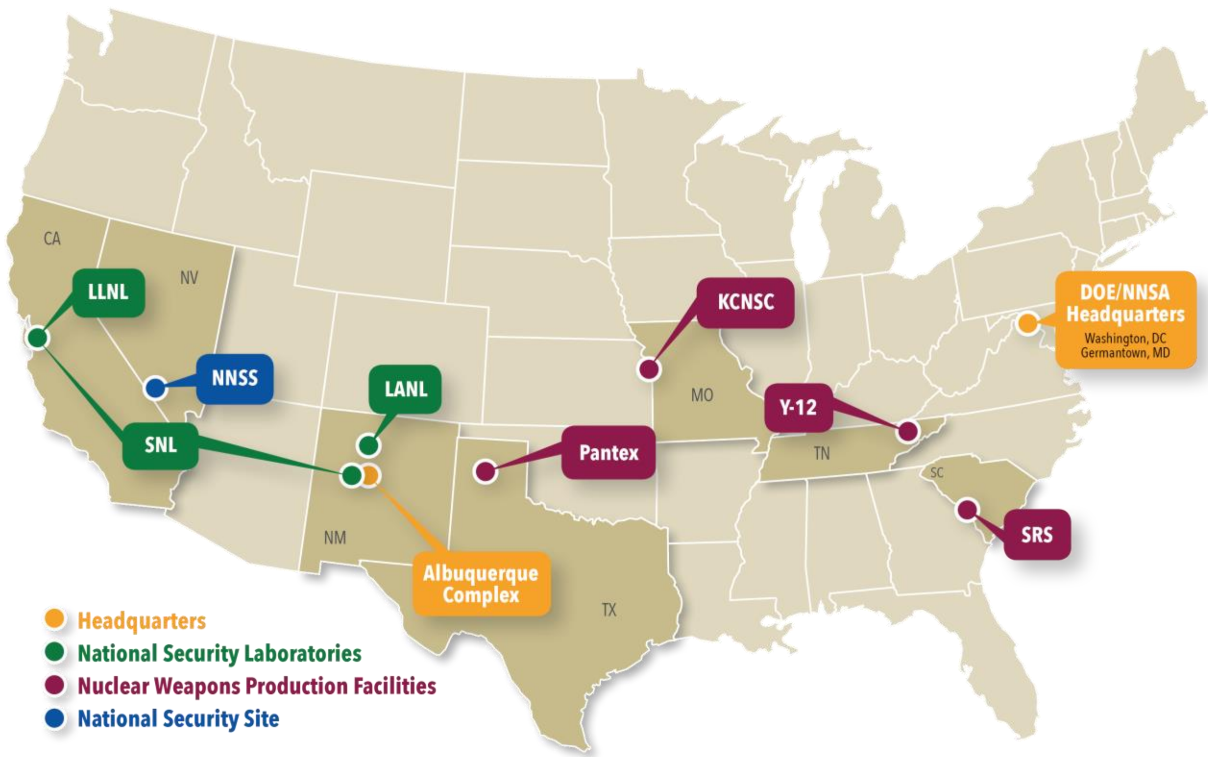
NNSA will embark on a multi-year collaboration with the selected 2023 exascale system vendor to work on, non-recurring engineering and system integration issues for El Capitan, focusing on key advanced system engineering efforts and software technologies to turn the 2023 exascale system into a capable and productive computing resource for the Stockpile Stewardship Program.

C.3 Conclusion

DOE/NNSA, through the ASC Exascale effort, is investing in products and approaches that are directly related to anticipated disruptive changes in the HPC ecosystem. Activities include R&D partnerships with multiple HPC vendors, development of next-generation weapons codes with new simulation capabilities, and procurement of an advanced architecture prototype system with a potential alternative HPC software stack. Cooperation with computer vendors has also led to significant advances in HPC software and hardware technologies. These activities have provided experience and lessons learned and have already delivered a variety of software development tools and libraries which many ASC applications now rely on. To complete this effort, more intensive research, development, and engineering effort is needed for DOE/NNSA to achieve the goal of deploying an exascale capability in 2023.

Appendix D
Workforce and Site-Specific Information

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. Specific information is included in this appendix to elaborate on each site's mission, weapon activities capabilities, fiscal year (FY) 2020 budget request, recent accomplishments, and workforce data.



KCNSC = Kansas City National Security Campus
LANL = Los Alamos National Laboratory
LLNL = Lawrence Livermore National Laboratory
NNSS = Nevada National Security Site
Pantex = Pantex Plant
SNL = Sandia National Laboratories
SRS = Savannah River Site
Y-12 = Y-12 National Security Complex

Figure D–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 ensure evolving deterrence needs can be met.
- 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, 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.

D.1 National Nuclear Security Administration

D.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 Reactors, 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 fields 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.

In 2018, the NNSA Administrator launched a special working group for the purpose of developing an enterprise-wide strategy to attract and retain the best talent to sustain current and future nuclear security missions. Headquarters will partner with the field offices' and M&O partners' Human Resources personnel in developing and implementing this shared enterprise approach.

DOE/NNSA is currently pursuing legislation to lift the overall cap of 1,690 full-time equivalents in the Federal Salaries and Expenses account, given the increase in major projects, 2018 *Nuclear Posture Review* plans and life extension programs (LEPs), and the need for appropriate program and project oversight. NNSA has an opportunity to reshape its workforce with more people trained and positioned to address challenges with new talent and technologies. Increased staffing would be beneficial to the Federal workforce's development and eliminate some single-point failures, given that many positions within NNSA are one person deep in terms of knowledge, experience, and skills.

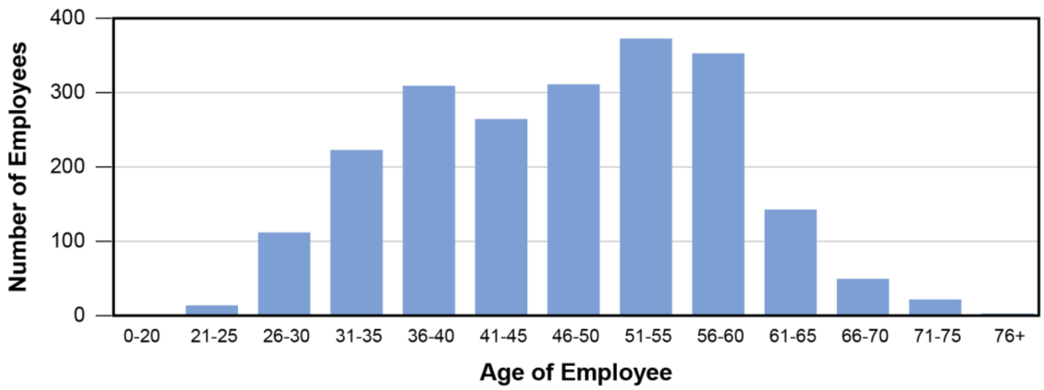
In developing the Federal workforce, DOE/NNSA recognizes the need for effective leadership; performance measures; management consistency; increased focus on training at the entry, middle, and executive levels; and increased flexibility and adaptability in the current staff, as well as the need for aggressive knowledge transfer programs. DOE/NNSA has implemented foundational competencies and has begun to develop occupational competencies and career paths. These talent management initiatives will promote NNSA as an employer of choice, build the talent needed at all levels, and foster sustained mission excellence.

DOE/NNSA has a range of initiatives to develop and broaden experience including:

- Invigorated rotational programs, development programs, and support of university research and development (R&D) in areas relevant to the NNSA mission
- Rotational assignments of M&O employees to NNSA Headquarters
- Wide variety of professional and leadership development programs
- Use details and Intergovernmental Personnel Act Mobility Program
- Support for the Integrated University Program to cultivate the next generation of leaders in nuclear nonproliferation and domestic and international nuclear security
- Encourage programs involving undergraduate research experiences, high performance computing (HPC) access, and education

A major challenge that would be solved by additional personnel is balancing time between development and workload. Mentoring, cross-training, and rotations between organizations are all efforts that supervisors and employees would like to participate in to improve their knowledge and the variety of their work functions. Currently, many NNSA supervisors are unable to engage in the aforementioned opportunities because of current workload. Experienced staff and supervisors also face challenges in finding time to mentor less experienced staff and share lessons learned. Given staffing shortages and workload, NNSA supervisors are precluded from engaging in strategic succession planning and knowledge management activities. A staffing increase would enable supervisors to apportion their workload to engage in succession planning and knowledge management activities and allow other employees the time to cross-train or develop additional skills and knowledge integral to DOE/NNSA's national security missions.

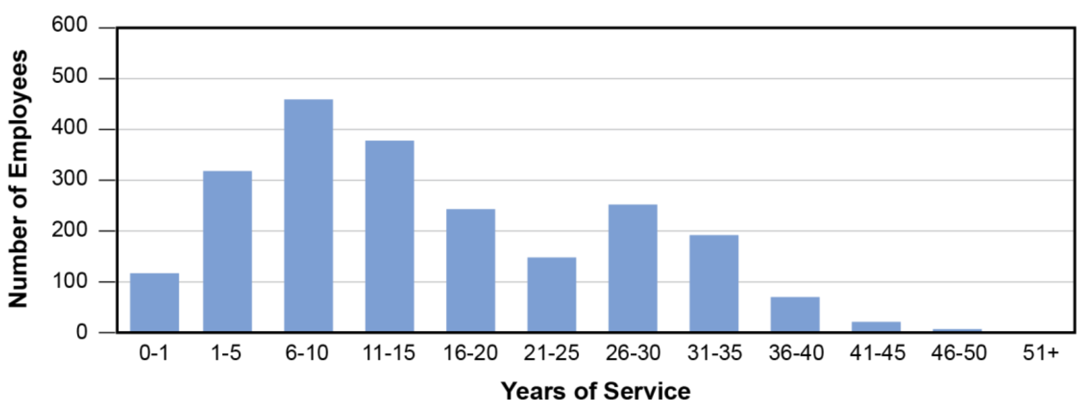
The average age of Federal employees is about 48 years; about 15 percent are retirement-eligible. NNSA has a bimodal experience distribution among its employees, with years of service averaging 16. As opposed to the age of NNSA employees being skewed to the right, the experience is slightly skewed to the left. 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 amount 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, please refer to Chapter 7, **Figures D–2** through **D–5**, and the accompanying notes.



Notes:

Like most Federal agencies, NNSA age data is skewed right, especially considering that the average retirement age is about 60 years. The data set includes approximately 266 nuclear materials couriers who are, on average, younger than the rest of the workforce. Eighty-four percent of the courier workforce is 26 to 45 years of age, so those age categories are skewed slightly by that workforce. Challenges associated with an aging workforce have been identified and are addressed in the same manner as Years of Service challenges.

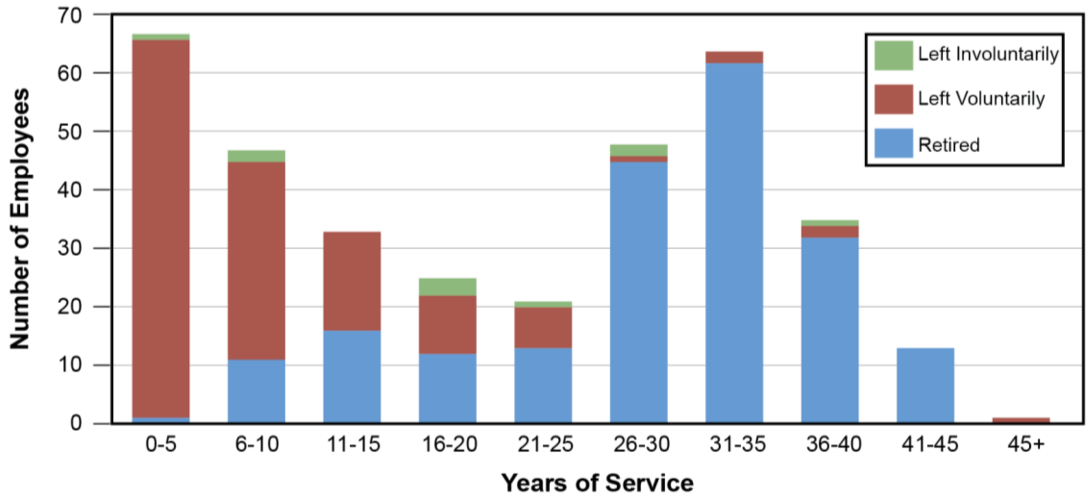
Figure D–2. Federal employees by age (as of September 30, 2018)



Notes:

NNSA has a bimodal 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 bimodal distribution (831 employees with 6-15 years of service), which represents an opportunity to manage the risk. To address these demographic challenges, NNSA has increased the NNSA Talent Management Training Budget from $3.5 million (FY 2013) to $5.8 million (FY 2018), empowering employees to refine skills and prepare for new NNSA mission growth. 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 the increased use of the NNSA Graduate Fellowship Program, Pathways Program, and Minority Servicing Institute Partnership Program.

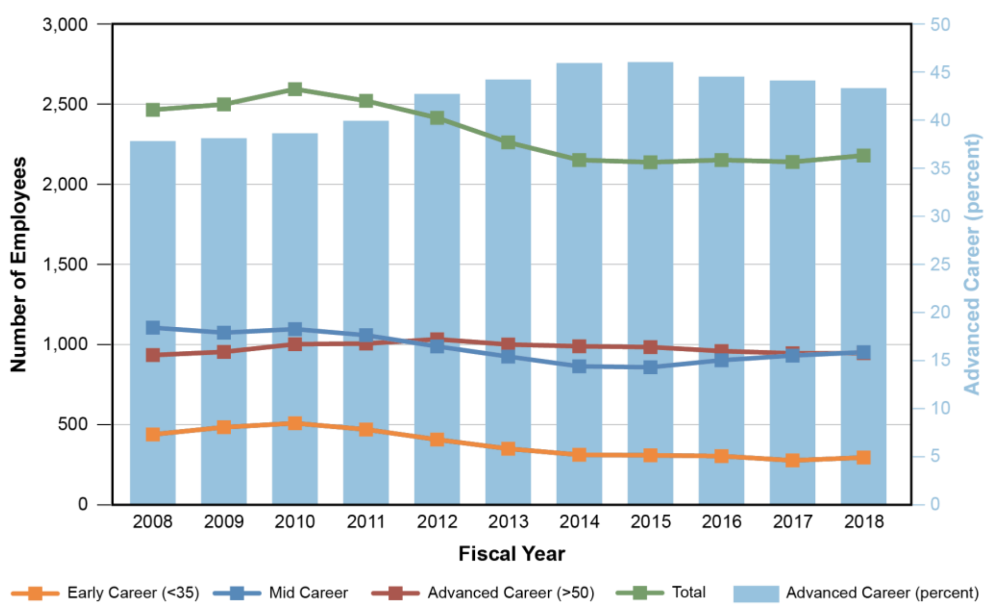
Figure D–3. Federal employees by years of service (as of September 30, 2018)



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 D–4. Years of service of Federal employees who left service (October 1, 2016 to September 30, 2018)



Notes:

In FY 2015-2018, NNSA focused on shifting retirement eligibility demographics by using the excepted service authority to hire over 20 entry-level employees each year.

Figure D–5. Federal employee trends by career stage (as of September 30, 2018)

D.2 National Security Laboratories

D.2.1 Lawrence Livermore National Laboratory

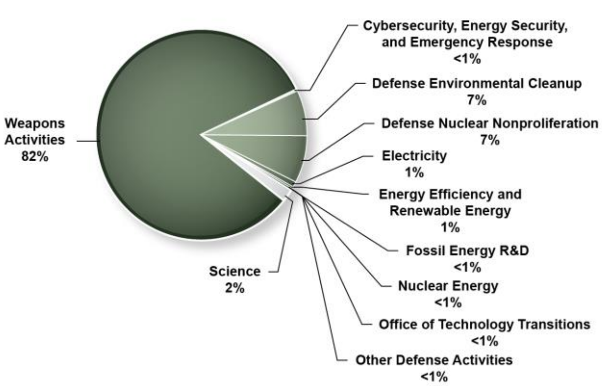
D.2.1.1 Mission Overview

DOE/NNSA sponsors the Lawrence Livermore National Laboratory (LLNL) in Livermore, California as a Federally Funded Research and Development Center (FFRDC) to provide 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.

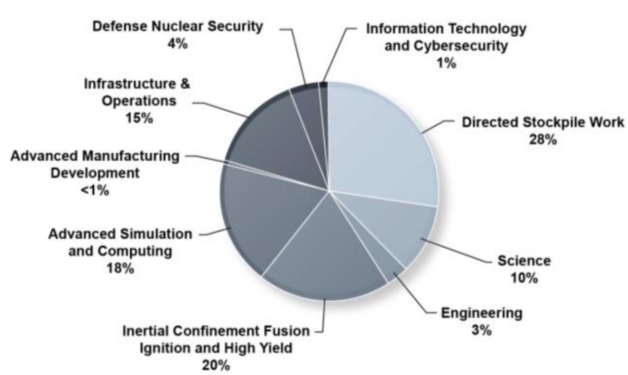
- Locations: Main site, Livermore, California (Site 200); Experimental Test Site, Tracy, California (Site 300)
- Total Employees: 6,277 (as of the end of FY 2018)
- Type: Multi-program national security laboratory
- Website: www.llnl.gov
- Contract Operator: Lawrence Livermore National Security, LLC, 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

D.2.1.2 Funding

FY 2020 request – site funding by source
(total LLNL FY 2020 request = $1,842 million)



FY 2020 Future Years Nuclear Security Program (FYNSP) request for Weapons Activities *($1,512 million)*



D.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) ST&E, high energy density (HED) physics, HPC, nuclear physics, and materials science and engineering. LLNL is the lead design physics laboratory for the W80-4 (the Air Force's cruise missile warhead) LEP and the W87-1 Modification Program. LLNL has primary certification responsibility for the W80, W87, and B83.

LLNL operates several DOE/NNSA flagship facilities such as the National Ignition Facility (NIF), Livermore Computing Center, High Explosives Applications Facility, Contained Firing Facility, Flash X-Ray, and Plutonium Superblock. LLNL also manages the physical infrastructure and capabilities supporting research, development, science, and technology missions in weapons engineering and physics, advanced materials, HPC, and HED physics.

LLNL capabilities related to design and development of stockpile systems and their associated challenges and strategies are described in **Table D–1**.

Table D–1. Lawrence Livermore National Laboratory Capabilities

Weapons Physics Design and Analysis	
LLNL is integral to the design and performance assessment of the nuclear explosive package and supports 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***
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 testing.	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.
Weapons Engineering Design, Analysis, and Integration	
LLNL is responsible for weaponizing the physics package to ensure performance through the warhead stockpile-to-target sequence at sub-scale and device scale, and to support production engineering. Engineering design and analysis provide the fundamental capability to certify the stockpile without nuclear testing by destructive and nondestructive surveillance evaluations and reliability and condition assessments. This capability is also used to fabricate complex special nuclear material target assemblies to support design physics.	
Challenges	***Strategies***
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. LLNL is continuing to invest in advanced manufacturing laboratory space and equipment development.

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 HE structures and has demonstrated their ability to detonate. LLNL holds three Records of Invention in HE-additive manufacturing technology.	
Challenges	***Strategies***
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 projects that make investments in scaled HE synthesis and large charge pressing capabilities.
High Performance Computing	
LLNL is a key contributor to 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***
LLNL must anticipate, develop, and deploy new computing architectures to support weapons 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.
High Energy Density Physics	
LLNL conducts physical process experiments to ensure that, if called on, the nuclear explosive package can produce a militarily effective yield. NIF conducts major experimental campaigns on high-Z material properties, burn physics, radiation transport, radiation hydrodynamics, mix, and code validation.	
Challenges	***Strategies***
The priorities for infrastructure are currently too low to support an aggressive stockpile stewardship experimental program. LLNL must develop an enduring infrastructure capability base in target fabrication and be prepared to manage increased facility usage in the future.	LLNL has developed a 3-year investment plan to consolidate target fabrication equipment for efficiency while supporting more than 400 shots per year. Infrastructure recapitalization and modernization are essential to realizing this plan.

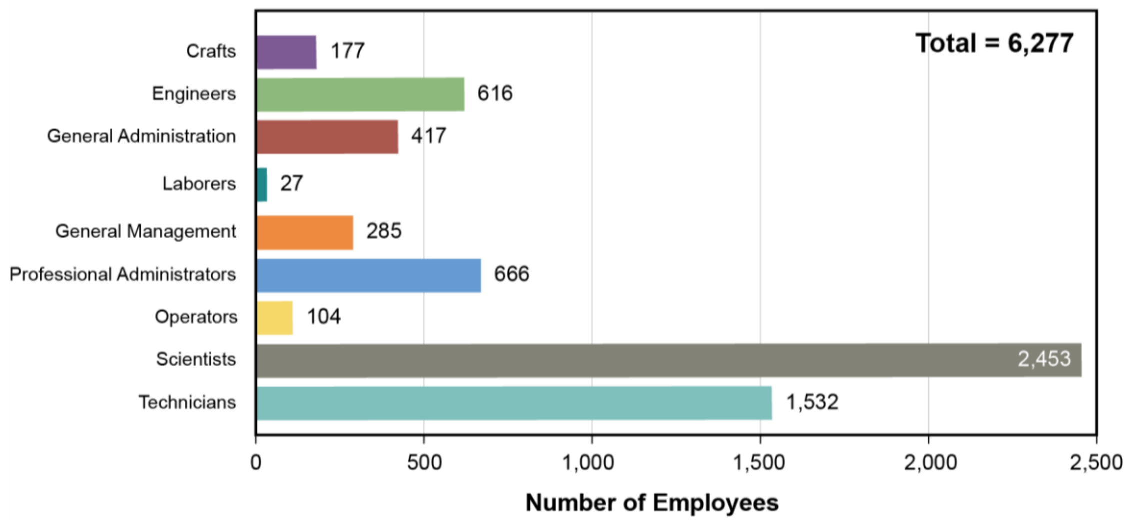
HE = high explosives
HPC = high performance computing
NIF = National Ignition Facility
RDT&E = research, development, test and evaluation

D.2.1.4 Accomplishments

- LLNL completed all deliverables for Cycle 23 of the Annual Assessment Review, including extensive peer review, as part of the Independent Nuclear Weapon Assessment Process. Laboratory scientists made significant physics improvements that added rigor to the Annual Assessment.
- In Phase 6.3, all W80-4 LEP requirements, goals, and objectives are being met through high-quality research, development, and engineering. LLNL is working closely with NNSA production agencies as they mature and transfer the design of the nuclear explosive package components through the product realization teams.
- The Sierra Initial Delivery system was sited, installed, and accepted. LLNL achieved the associated applications milestone, and the HPC system is successfully being used in support of the Advanced Computing and Simulation Program. LLNL is also providing leadership in DOE's Exascale Computing Project. A Request for Proposals was issued for development of LLNL's exascale system, "El Capitan," and LLNL is managing a line item for the required facility upgrades.
- NIF experiments in FY 2018 provided valuable data for code validation focused on informing capsule and hohlraum designs that intend to push target performance toward burning plasma and ignition. NIF achieved 2.1 megajoules (115 percent design level) in a laser test shot, and the Advanced Radiographic Capability conducted its first Compton radiography experiments on layered implosions.
- LLNL researchers at the Joint Actinide Shock Physics Experimental Research (JASPER) completed the first precision measurements of shock-compressed plutonium sound speeds; NIF facility readiness is on track for future plutonium equation-of-state shots; and LLNL conducted key hydrodynamics experiments to prepare for subcritical experimental testing.
- LLNL application of advanced manufacturing to make HE exemplified progress in a major initiative. LLNL is working with KCNSC and Y-12 to develop modernized production capabilities. A new open campus Advanced Manufacturing Laboratory at LLNL will work with industry to expand DOE/NNSA's capabilities.
- LLNL met requirements to sustain the four LLNL systems (W80, B83, W84, and W87). LLNL also executed four hydrodynamic tests to support LEPs and alterations (Alts), including two experiments for the W80-4 and one each for the B61-12 and the W88.
- LLNL provided leadership to address and expand the DOE/NNSA complex-wide facility solutions, including heating, ventilation, and air conditioning asset management (Cooling and Heating Assessment Management Program) and other tools such as the Mission Dependency Index and BUILDER. LLNL also chaired the Product Realization Integrated Digital Enterprise Program and supports all required nuclear explosive safety studies.

D.2.1.5 Lawrence Livermore National Laboratory Workforce

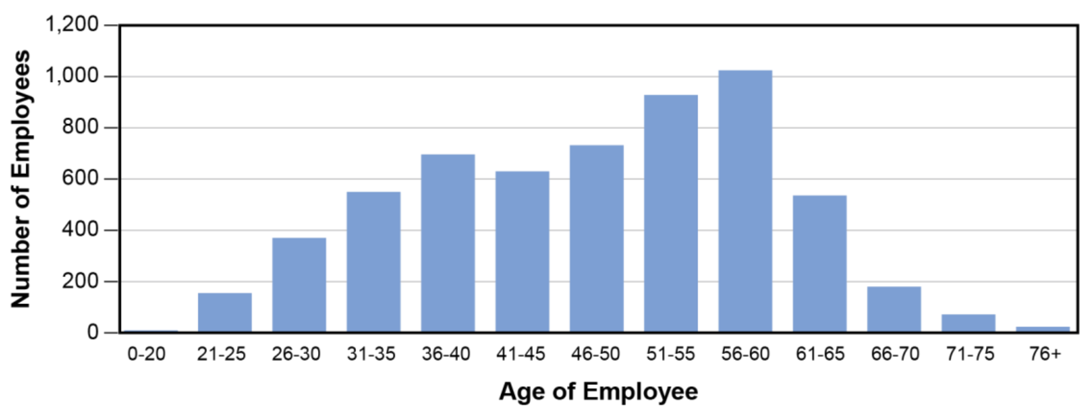
LLNL has 6,277 employees, with an average age of 48 years and an average of 14 years of service. Approximately 26 percent of LLNL's employees are eligible to retire. Since the end of FY 2016, LLNL hired 1,314 employees and experienced 820 separations, resulting in a net gain of 494. Retirement separations are dispersed throughout many different "years of service" groups. Voluntary separations were most pronounced among employees with 5 years of service or less. LLNL's population was reduced after a contract transition in FY 2008, although hiring has increased in the last 4 years. Recent hires have increased in the early-career workforce, while the mid- and advanced-career workforce has remained relatively stable over the last 4 years. LLNL anticipates growth over the FYNSP period, especially as the work scope increases for W80-4 LEP and W87-1 Program activities. Workforce demographics are illustrated and discussed in **Figures D–6** through **D–14**.



Notes:

Includes the core population.

Figure D–6. LLNL total workforce by Common Occupational Classification System (as of September 30, 2018)

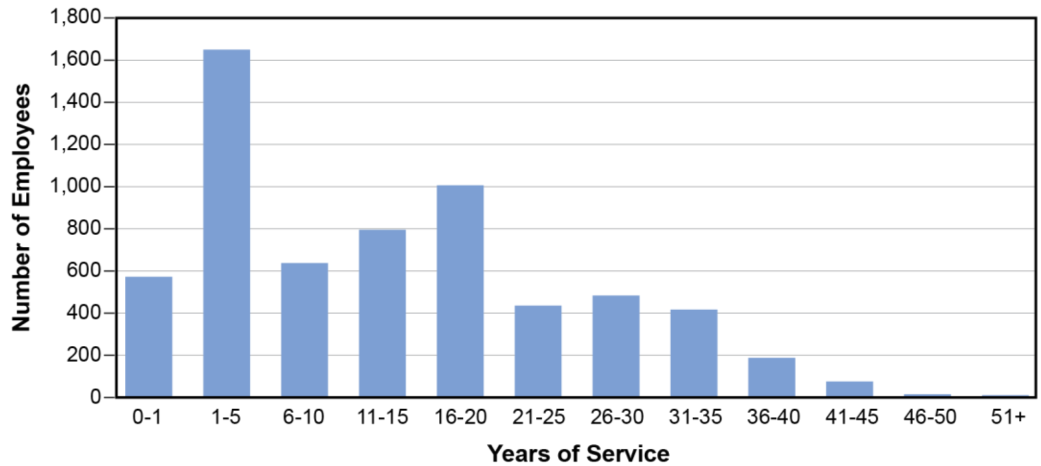


Notes:

Retirement eligible = 50+ years old and > 5 years of service.

LLNL's overall average age is 48.4; 46.8 percent of the core population is greater than 50 years old; the median age of the core population is approximately 50 years. Succession planning is critical.

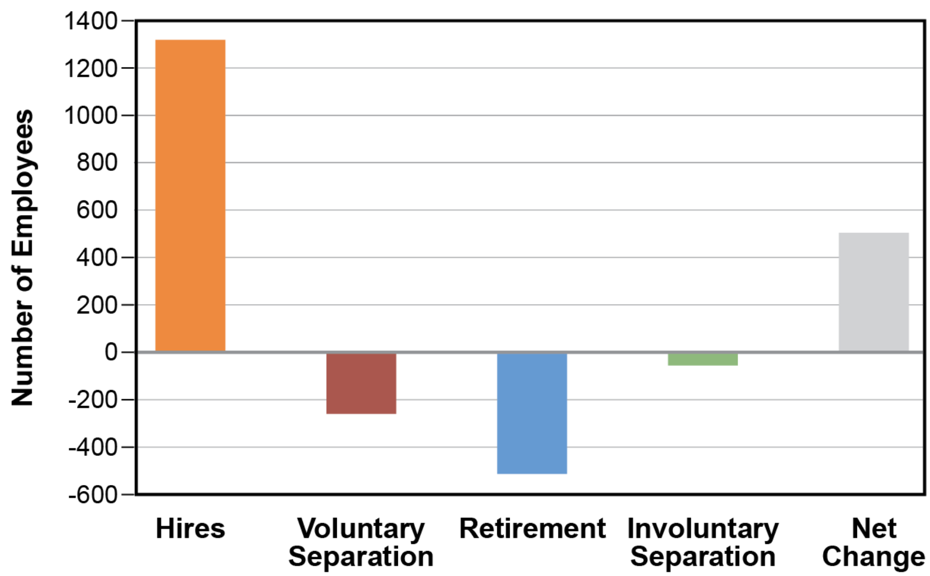
Figure D–7. LLNL employees by age (as of September 30, 2018)



Notes:

Approximately 25.5 percent of LLNL's population has 21+ years of service. While LLNL has an experienced population, increasing retirements and increasing new hires are lowering the average for years of service.

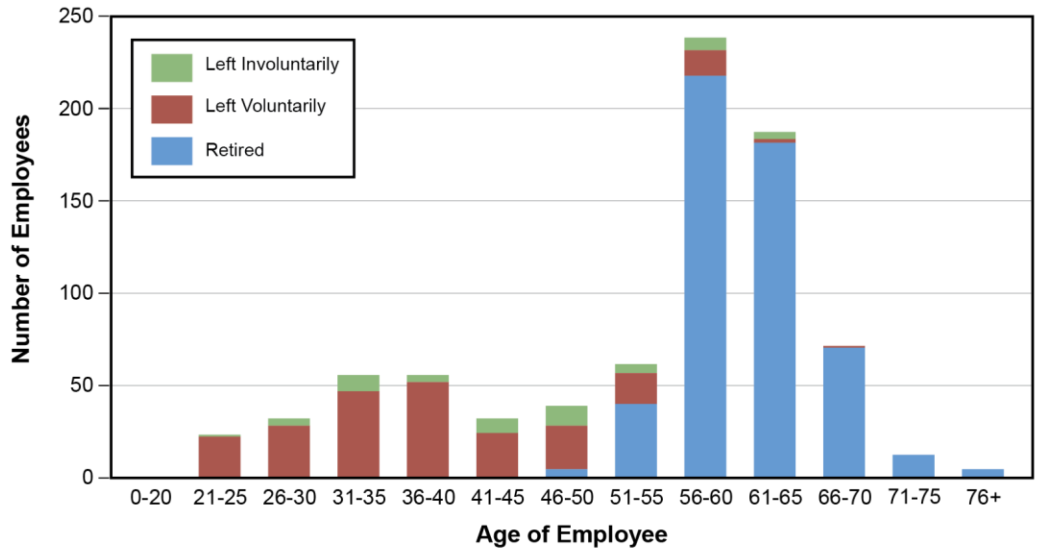
Figure D–8. LLNL employees by years of service (as of September 30, 2018)



Notes:

Hires included 243 conversions from non-career (students/post-docs) to career appointment types.

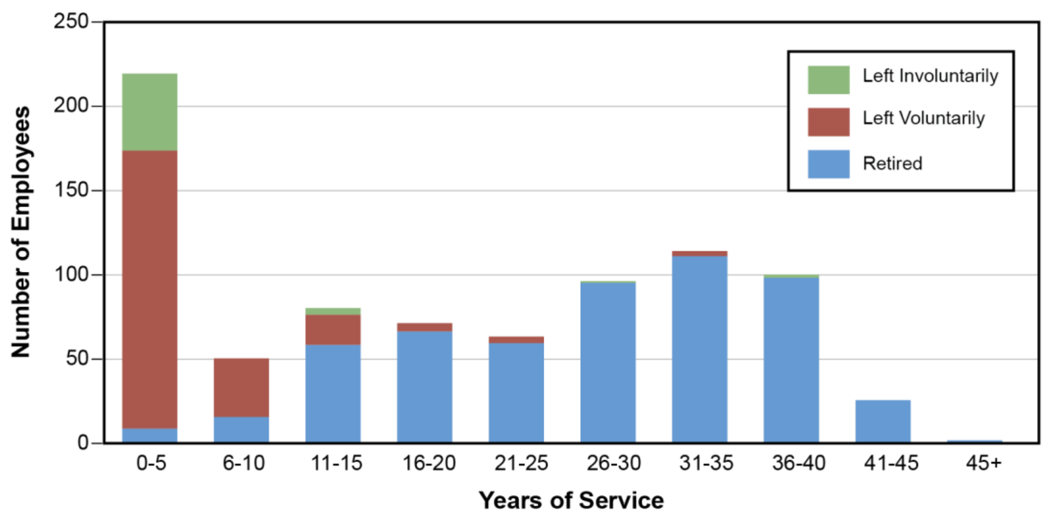
Figure D–9. Change in last 2 fiscal years at LLNL (October 1, 2016 to September 30, 2018)



Notes:

Average age for retirement separations is approximately 62 years. Average age for non-retirement separations is approximately 40 years.

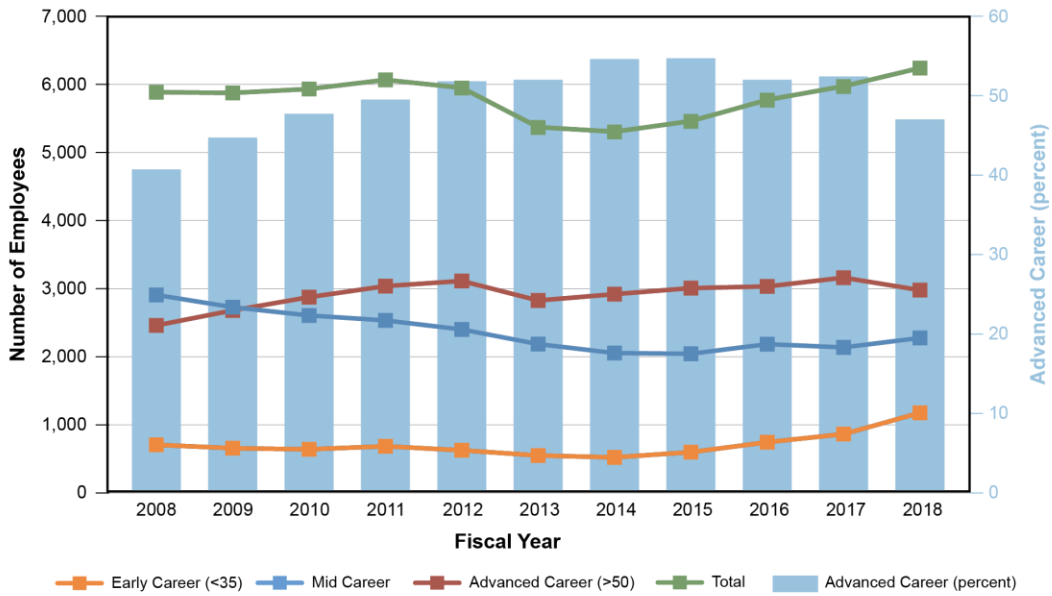
Figure D–10. Age of LLNL employees who left service (October 1, 2016 to September 30, 2018)



Notes:

Average years of service for retirement separations is 27.7 years. Average years of service for non-retirement separations is 4.8 years.

Figure D–11. Years of service of LLNL employees who left service (October 1, 2016 to September 30, 2018)



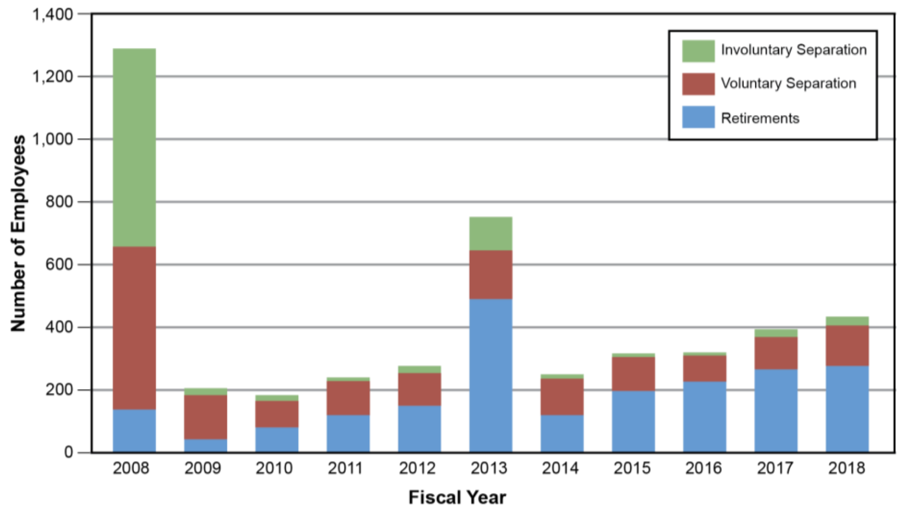
Notes:

The population generally decreased between FY 2011 and FY 2014 as budgets decreased, and as the cost of labor increased. LLNL has recently increased hiring. The biggest change in population was during FY 2008, when LLNL went through contract transition to Lawrence Livermore National Security, LLC, from the University of California. LLNL implemented an Involuntary Separation Plan and experienced a 16.4 percent population decrease. In FY 2013, LLNL experienced another significant decrease of 10.2 percent due to a restructuring in its Security Organization and the self-select voluntary separation plan.

LLNL's aging population is a concern; the overall average age is 48.4; 46.8 percent of our core population is greater than 50 years old; and the median age of our core population is approximately 50 years.

Despite increasing retirements, increasing hires are resulting in a net population growth. We have ramped up hiring in all age ranges (except for 60+ years). The FY 2018 Early Career population has increased by 40.5 percent compared to last year.

Figure D–12. LLNL trends by career stage (as of September 30, 2018)

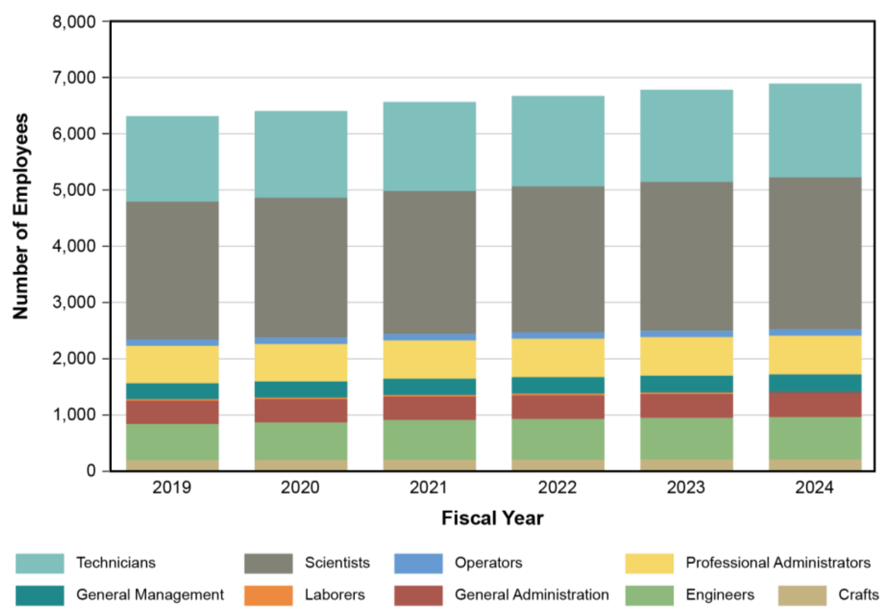


Notes:

The increase in FY 2008 was because of contract transition from the University of California to Lawrence Livermore National Security, LLC, and the Involuntary Separation Plan. The increase in FY 2013 was due to security restructuring and the self-select voluntary separation plan. Retirements were higher in FY 2012 and FY 2013 due to pending and actual changes in retiree benefits from a defined benefit plan to a defined contribution plan. The dip in 2014 occurred due to the earlier retirements in 2012 and 2013. The spike in 2008 was caused by the transition to competitive contracting.

Sixty-three percent of our separations in FY 2018 were retirements; retirements have been steadily increasing since FY 2014.

Figure D–13. LLNL employment separation trends (as of September 30, 2018)



Notes:

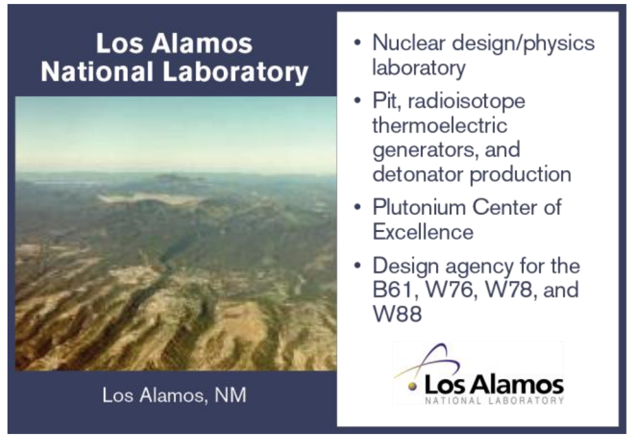
Our population is expected to continue to grow over the FYNSP period to meet the laboratory missions and anticipated scope increase associated with the W80-4 LEP and the W87-1 nuclear design and certification activities.

Figure D–14. Total projected LLNL workforce needs by Common Occupational Classification System over the FYNSP period (as of September 30, 2018)

D.2.2 Los Alamos National Laboratory

D.2.2.1 Mission Overview

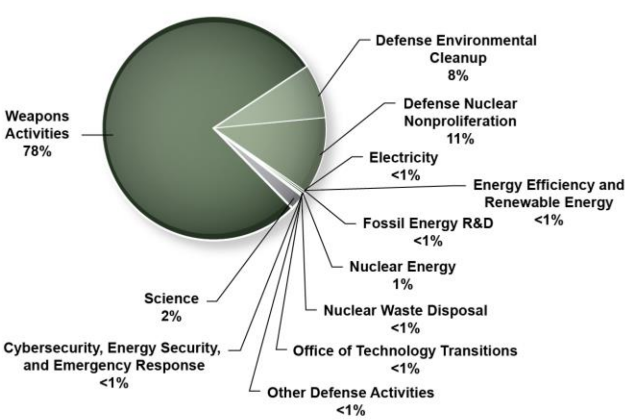
DOE/NNSA sponsors the Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico, as an FFRDC. LANL champions four "science pillars": information science and technology, materials for the future, nuclear and particle futures, and the science of signatures. These pillars capture the laboratory's diverse array of scientific capabilities and expertise to address global challenges in national and economic security, including nuclear nonproliferation and counterterrorism; medicine and health sciences; and advanced computational capabilities as an FFRDC, while also participating in DOE's Strategic Partnership Projects.



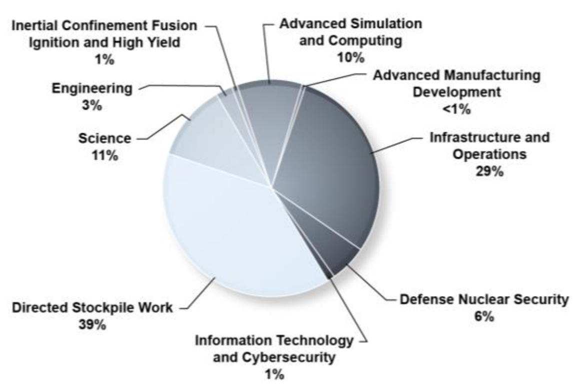
- Location: Los Alamos, New Mexico
- Total Employees: 7,876 (as of the end of FY 2018)
- Type: Multi-program national security laboratory
- Website: www.lanl.gov
- Contract Operator: Triad National Security, LLC, is made up of three members: Battelle Memorial Institute, Texas A&M University, and the University of California
- Responsible Field Office: Los Alamos Field Office

D.2.2.2 Funding

FY 2020 request – site funding by source
(total LANL FY 2020 request = $2,528 million)



FY 2020 FYNSP request for Weapons Activities
($1,967 million)



D.2.2.3 Site Capabilities

LANL is one of two nuclear design and physics laboratories in the nuclear security enterprise and the Center of Excellence for Plutonium. Core competencies at LANL include weapons physics design and analysis; weapons engineering, design, analysis, testing, and integration; stockpile component production and surveillance for pits, detonators, and radioisotope thermoelectric generators; HED physics; materials science and engineering; and HPC. LANL is the lead design physics laboratory for the B61, W76, W78, and W88.

LANL operates several DOE/NNSA flagship facilities such as the Plutonium Facility Complex (Technical Area 55 [TA-55]), Nicholas Metropolis Center for Modeling and Simulation, Dual-Axis Radiographic Hydrodynamic Test Facility, Los Alamos Neutron Science Center, the National Explosives and Engineering Weapons Campus, Uranium R&D facility (Sigma), Center for Integrated Nanotechnologies, National High Magnetic Field Laboratory, and Waste Handling Facilities. LANL's primary capabilities and their associated challenges and strategies are described in **Table D–2**.

Table D–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 testing, HPC, HE RDT&E, weapons engineering, surety, radiography, assembly, accelerator technology, and subcritical experiments.	
Challenges	***Strategies***
Key challenges are continued aging in weapons materials and components, an aging workforce with weapons knowledge and experiments, a lack of programmatic needs to transition to the next generation of designers and engineers, and degrading design and certification infrastructure.	Current LEPs and Alts provide near-term opportunity to reinvest in current capabilities and exercise the workforce. LANL is working closely with DOE/NNSA to address aging enduring physical infrastructure and modernize specialized capabilities such as DARHT, Sigma, HPC, HE, and weapons engineering facilities. Strategies to recapitalize plutonium and detonator production capabilities are also being addressed.
High Performance Computing	
This 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 to improve confidence in the predictive capability for stockpile stewardship for LEPs and significant finding investigations (SFIs). The Advanced Simulation and Computing Program leverages both the Advanced Technology System (ATS) and Commodity Technology System for this work.	
Challenges	***Strategies***
Near-term challenges, circa 2026, include accommodation of the next-generation supercomputer (ATS-5) at LANL. Additional electricity and cooling infrastructure will be needed.	Planning is ongoing for both the near-term and long-term HPC infrastructure. Trinity (ATS-1) will be replaced in fiscal year 2021 by Crossroads (ATS-3). The Exascale Class Computer Cooling Equipment Project, scheduled for completion in FY 2020, will provide warm-water cooling for Crossroads.
Plutonium	
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.	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.

Weapons Engineering and Energetics	
Weapons engineering and HE capabilities provide the materials, components, and assemblies for weapons work. This capability includes the experimental testing to assess the current state of the stockpile; surveil the current stockpile and addresses 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***
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.	Recapitalization investments will ensure the long-term viability of enduring facilities. 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.
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***
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.	Strategic investments are being planned and implemented to recapitalize DARHT, procure additional vessels, and replace DARHT Axis I. 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.

Alt = alteration
HPC = high performance computing
RDT&E = research, development, test and evaluation
DARHT = Dual-Axis Radiographic Hydrodynamic Test
Sigma = Uranium R&D Facility

D.2.2.4 Accomplishments

Complimentary to accomplishments listed in Chapters 2, 3, and 5, notable FY 2018 achievements for LANL include:

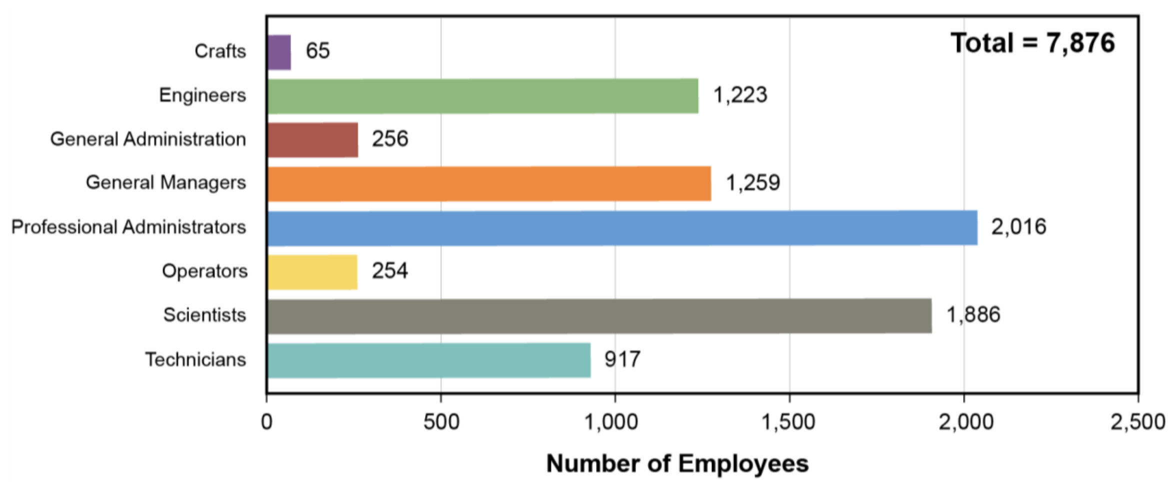
- LANL has met or will meet all statutorily required deliverables for the annual assessment reporting process. Specifically:
  - Annual assessment reports for the B61, W76, W78, and W88 were distributed on July 30, 2018.
  - The Director's Red Team briefed the Director on August 10, 2018.
  - LLNL and LANL Independent Nuclear Weapons Assessment Teams briefed the LANL and LLNL Directors, respectively, during the week of August 13, 2018.
  - The Director's annual assessment letter was signed out on September 24, 2018.
- In support of Stockpile Assessment, LANL, and LLNL contributed to Stewardship Capability Delivery Schedule (formerly known as the Predictive Capability Framework) Level-1 Milestone, culminating in a final review meeting at SNL in August 2018. This milestone demonstrated significant advances in the understanding of boost initial conditions, anomalous performance, and stockpile assessment metrics.

- LANL continues successful execution of the B61-12 LEP and expects to meet first production unit in 2019. LANL has successfully passed all of the LANL-owned Final Design Review and associated Gate Review requirements for Phase 6.4. The detonator team began Quality Evaluation lot manufacturing of the 4E10 cable in May 2018 after starting this activity late in FY 2017; manufacturing of the Quality Evaluation lot is 90 percent complete. LANL also executed 14 additional mechanical tests on aged plutonium samples (beyond the original 24-test commitment) to provide plutonium aging data for LEPs.
- The Weapons Program continues successful execution of the W88 Alt 370 Program, with first production unit expected in 2019. Detonator production delivered the first lot of War Reserve detonators in May 2018 (ahead of schedule); the third delivery is also on pace to be delivered ahead of schedule.
- The W88 Alt 940 Mechanical Assembly Final Design Review was passed with conditions addressed by a successful follow-on Delta Final Design review in August 2018.
- LANL executed the Vega subcritical experiment, which completed the Lyra subcritical experiment series. This series provided important information about future stockpile options and plutonium manufacturing. All seven subcritical experiments executed this decade for DOE/NNSA were led by the LANL Weapons Program.
- In FY 2018, LANL executed 14 hydrotests, including the Vega and LAMARCK confirmatory subcritical experiments for LLNL.
- In FY 2018, the Enhanced Capabilities for Subcritical Experiments (ECSE) team redesigned the Scorpius injector, published a Conceptual Design Report, completed 2 independent Technology Readiness Assessments, and completed 17 Corrective Actions stemming from an independent cost review. ECSE's Advanced Sources and Detectors met Critical Decision 1 in February 2019.
- LANL researchers are successfully developing and tailoring HE formulations that have insensitive high explosive (IHE)-like safety characteristics and conventional high explosive (CHE)-like performance characteristics.
- LANL scientists have completed a large-scale, three-dimensional full-system weapons simulation of a historic nuclear test on the Trinity supercomputer. This is the first simulation completed for the Advanced Computing and Simulation Large Scale Calculation Initiative. This simulation is already helping to resolve a 50-year-old question for the U.S. weapons program.
- The Plutonium Sustainment program completed four pit development builds and produced feed material from the restarted electrorefining processes. The program also completed almost 30 equipment construction and installation projects.
- In FY 2018, TA-55 produced the first batches of americium-241 in the United States since 1984 and the first purified plutonium metal produced since the 2013 pause. This successful project, which re-established a domestic supply in support of domestic energy security, can now transition to routine production operations.
- LANL produced and delivered 20 flight-quality fueled clads and eight spares as part of NNSA's commitment to the Mars 2020 mission.
- LANL presented three power supply trainer units for the DOE/NNSA Diamond Stamp. These trainer units represent the first Mark Quality products manufactured at TA-55 since the last War Reserve W88 pit sale in May 2012.

- LANL has taken on the production mission for detonator cable assemblies. Detonator production has also assisted LLNL in supporting the W80-4.
- On July 24-26, 2018, LANL hosted a Pit Production workshop on behalf of Defense Programs, with over 100 participants from DOE/NNSA, SRS, LLNL, and LANL. The workshop allowed participants to dive in to specific focus areas and collaborate on the Plutonium Pit Implementation Plan. LANL supported a second workshop at SRS in October 2018.
- LANL executed shock initiation experiments needed for the only full characterization of a lot of HE for the stockpile.
- LANL digitized over 94,000 items of historical weapons information (drawings, specifications, test data and videos).

D.2.2.5 Los Alamos National Laboratory Workforce

LANL has 7,876 employees, with an average age of 47 years and an average of 13 years of service. Approximately 44 percent of LANL's employees are eligible to retire. Since the end of FY 2016, LANL has hired 1,966 employees and experienced 1,308 separations, resulting in a net gain of 658. 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. Discounting the departure of 123 employees due to the Environmental Management contract split, the rate of voluntary separations has remained constant while retirements have slowly increased since FY 2013. 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 D–15** through **D–23**.

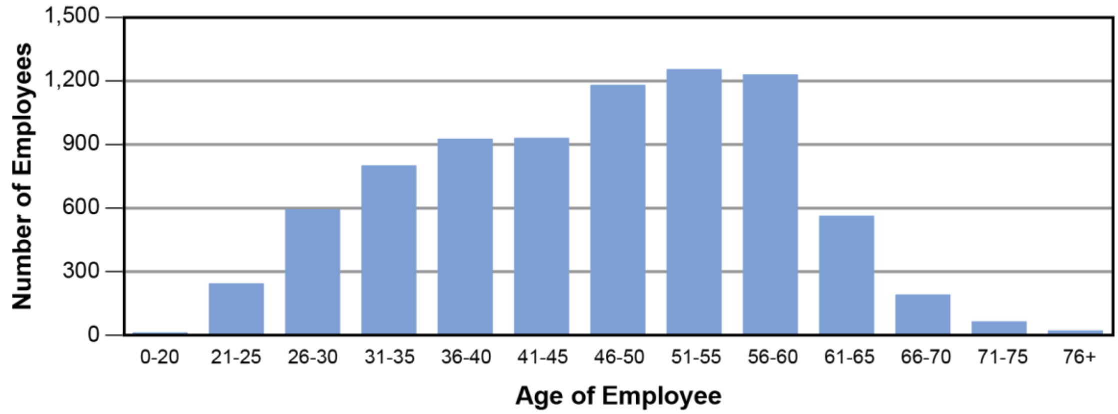


Notes:

LANL continues to see growth in the total headcount to match programmatic requirements.

Data includes only regular employees. LANL's Common Occupational Classification System-coded Laborers and most of the Craft 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 D–15. LANL total workforce by Common Occupational Classification System (as of September 30, 2018)

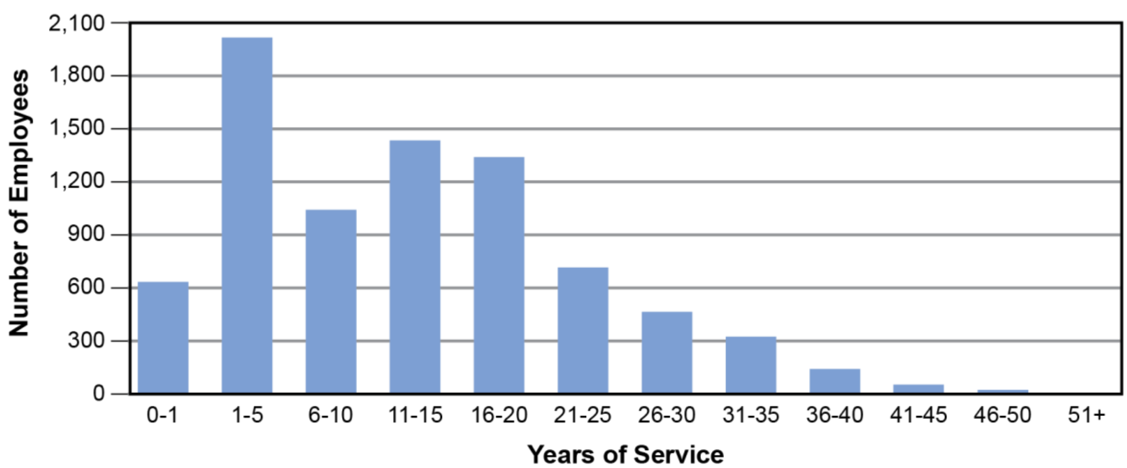


Notes:

LANL continues to experience an increasing termination rate as retirements continue to rise. In addition, LANL has continued to make a concerted effort to plan for and hire people who would take those places and fill the increasing demand for LANL services. That increase in hiring is reflected most predominantly in the 31-40 age categories. This hiring and retirement pattern is shifting the average age lower than in previous submissions.

It is important to note that all Common Occupational Classification System-coded Laborers and most Crafts employed at LANL are considered temporary and are not considered "permanent career employees." This approach matches prior LANL submissions.

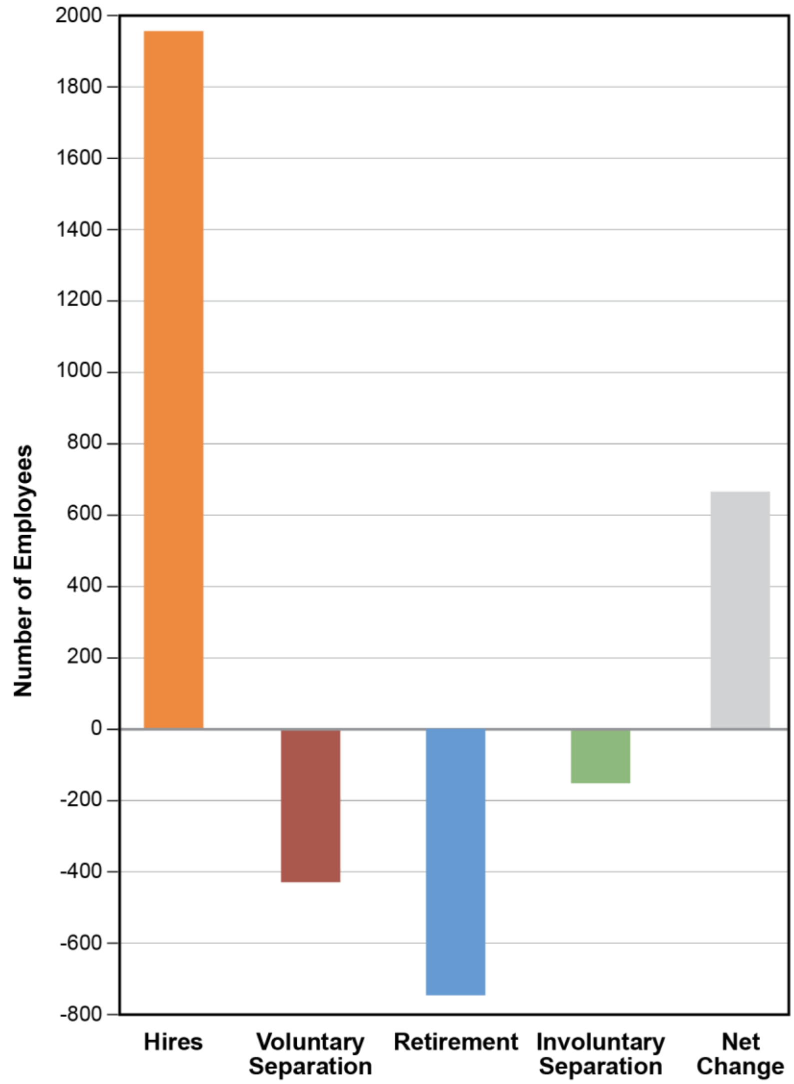
Figure D–16. LANL employees by age (as of September 30, 2018)



Notes:

LANL's effort to hire a larger number of employees again this year shows in the increased number of hires in the 0-5-year service bands. Note that LANL grants service credit for some employees in non-career status (e.g., post-docs, term employees), so when they are granted career status, they come with pre-existing service time. For example, a postdoc may already have 2 years of service credit when converted to permanent staff. As a result, many FY 2018 hires fall into the 1-5-year service band.

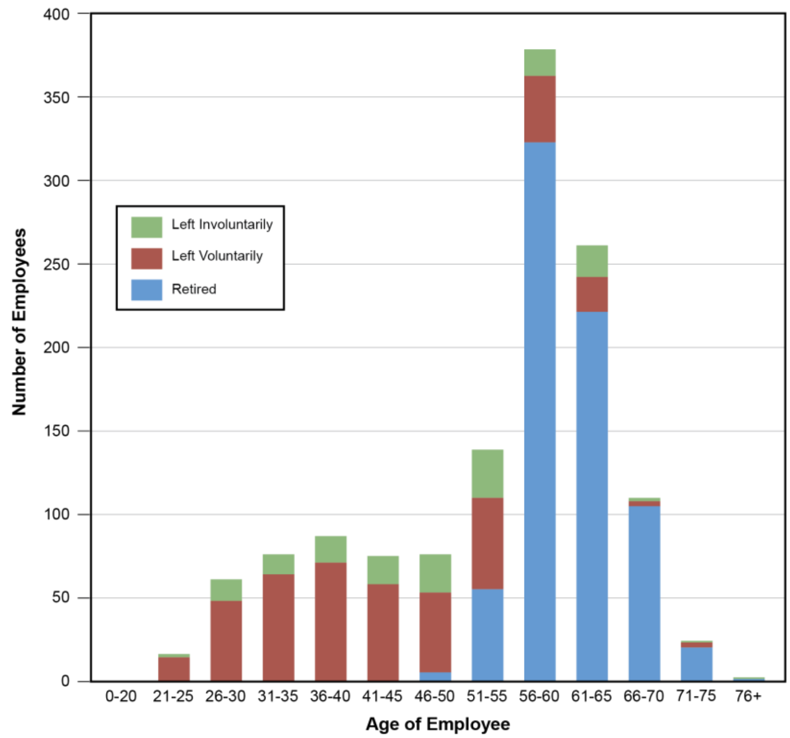
Figure D–17. LANL employees by years of service (as of September 30, 2018)



Notes:

Due to increasing budgets, LANL has conscientiously been hiring to grow. In addition, LANL is seeing an increasing number of retirements due to an aging workforce, and those employees need to be replaced. Calendar year 2018 saw an increased retirement rate because of the contract transition on November 1, 2018, as well as some increase in other voluntary terminations. 123 voluntary terminations were a result of the Environmental Management contract being transferred from Los Alamos National Security to N3B.

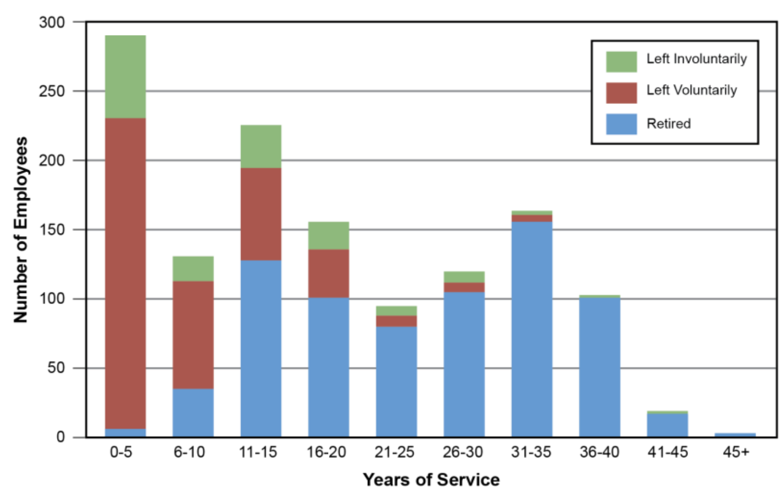
Figure D–18. Change in last 2 fiscal years at LANL (October 1, 2016 to September 30, 2018)



Notes:

Separation trends remain consistent with expectations. The spike in retirements in the 50-60 age band is largely attributed to employees retiring under LANL's pension plan. Since 2006, new employees have been enrolled in a 401K retirement plan, where retirements tend to peak in the 61-65 age band.

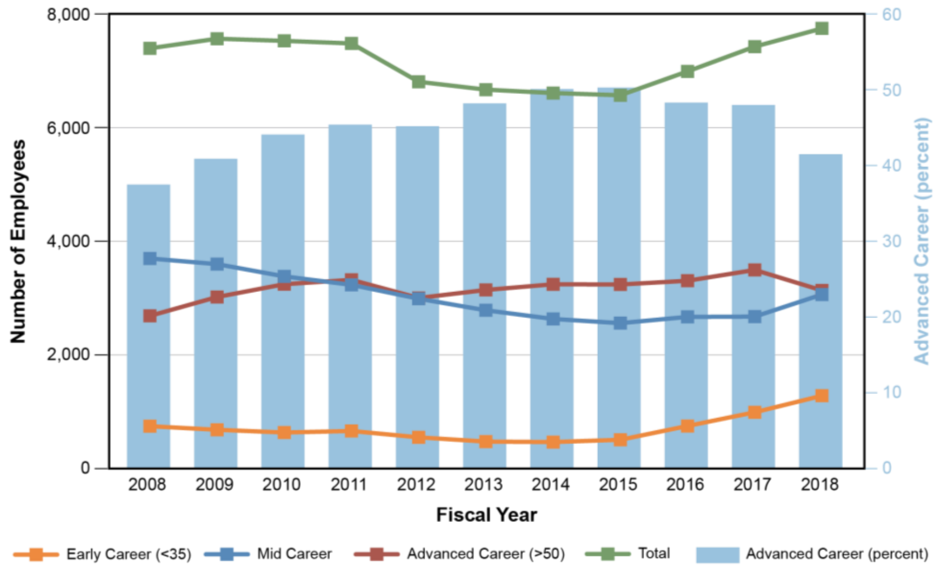
Figure D–19. Age of LANL employees who left service (October 1, 2016 to September 30, 2018)



Notes:

Separation trends remain consistent with expectations. Those with less service primarily leave voluntarily, while those with more service primarily leave for retirement. As LANL has increased hiring over the last 3 years, the number of employees in the 0-5 years of service band has grown to nearly one third of the permanent workforce. The relatively large attrition count for that service band is a result of the increase in that population.

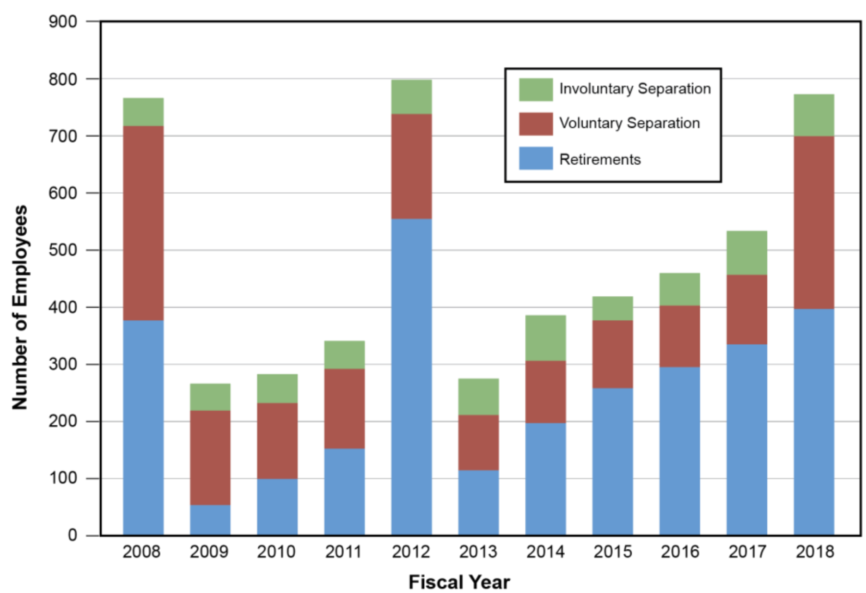
Figure D–20. Years of service of LANL employees who left service (October 1, 2016 to September 30, 2018)



Notes:

As LANL has increased hiring over the last several years, particularly in the 31-40 age band, the count of early-career employees has continued to climb. The mid-career population is also beginning to increase due to both hiring and the maturation of the growing early-career population. The advanced career group population has declined because of an increase in retirements, as expected.

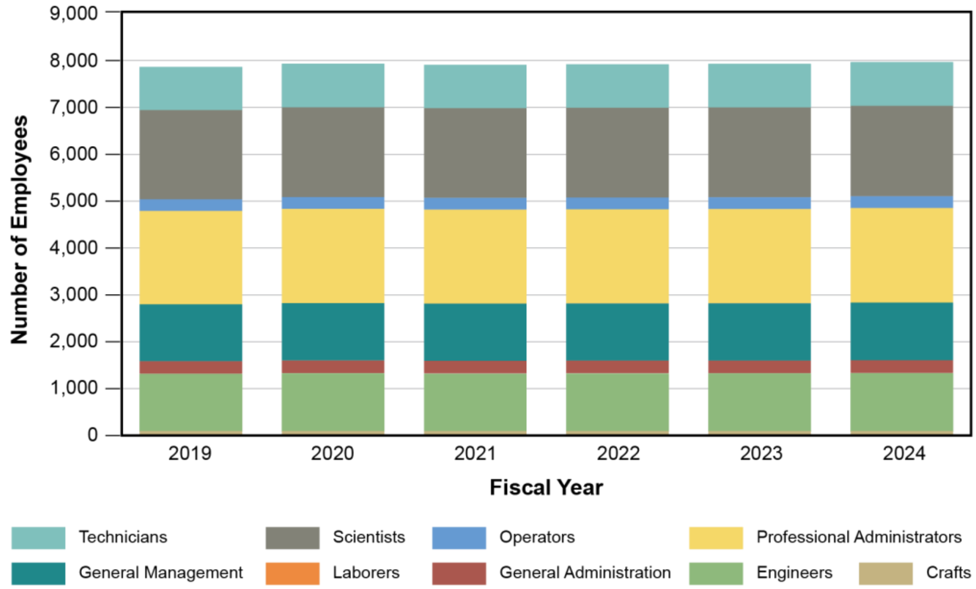
Figure D–21. LANL trends by career stage (as of September 30, 2018)



Notes:

FY 2018 saw an increase in attrition due to two key factors: (1) DOE split the Environmental Management contract into a new company, causing 123 voluntary terminations; and (2) the run-up to the M&O contract change on November 1, 2018, inspired a noticeable increase in voluntary terminations, both retirement and non-retirement. Given the timing of the contract change, it is expected that a number of transition-related terminations will fall into the FY 2019 reporting period. Separations were higher in FY 2008 and FY 2012 because of scaled workforce actions due to budgetary reductions. The dips in 2009 and 2013 occurred due to the early retirements in 2008 and 2012.

Figure D–22. LANL employment separation trends (as of September 30, 2018)



Notes:

Workforce headcount needs are projected to increase modestly over the FYNSP.

Figure D–23. Total projected LANL workforce needs by Common Occupational Classification System over the FYNSP period (as of September 30, 2018)

D.2.3 Sandia National Laboratories

D.2.3.1 Mission Overview

For more than 70 years, Sandia National Laboratories (SNL) in Albuquerque, New Mexico and Livermore, California 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. SNL has been operated by National Technology and Engineering Solutions of Sandia, LLC, since May 2017. As a multi-mission national laboratory and FFRDC, SNL serves as an objective, independent, and trusted advisor, drawing upon deep science and engineering experience 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 ensure the Nation receives 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 research, design, development, qualification, testing, certification, and systems integration of all components to arm, fuze, and fire a weapon to military specifications and ensure safety and security. The integration role is evident in three key areas:

- Internal 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

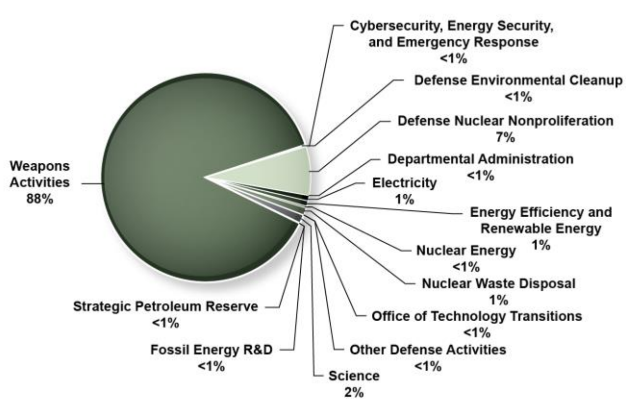
The current modernization programs to expand the life of existing stockpile systems constitute SNL's largest, most complex design, development, and qualification work scope in the last 30 years. SNL is involved in all stockpile modernization programs currently underway (the W76-1 LEP, B61-12 LEP, W88 Alt 370, W80-4 LEP, W87-1 Modification Program, and W76-2 Modification Program) and Mk21 Fuze, and is responsible for the design to extend the life of the Safeguards Transporter and its replacement design (the Mobile Guardian Transporter) for secure transport of nuclear weapon materials and components to NNSA partner sites and DoD customer sites. SNL also has production agency responsibilities for some weapon components (e.g., neutron generators and trusted, strategic radiation-hardened microsystems).

The 2018 *Nuclear Posture Review* underscores continuity in warhead modernization as a top priority and the rebalancing of priorities in response to a deteriorated global security environment and uncertain future threats. The 2018 *Nuclear Posture Review* concluded that 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.

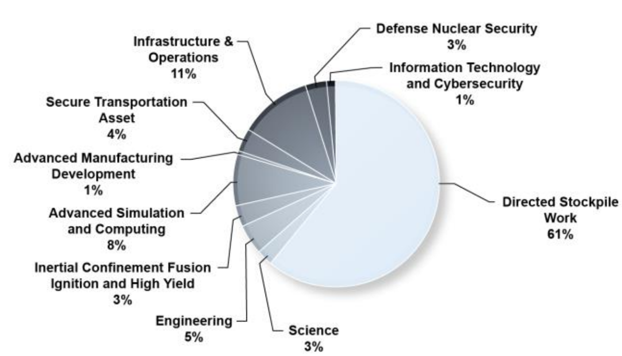
- Primary Sites: Albuquerque, New Mexico; Livermore, California; Tonopah Test Range, Nevada; Kauai, Hawaii
- Total Employees: 11,471 (as of the end of FY 2018)
- Type: Multi-mission national security laboratory
- Web site: www.sandia.gov
- Contract Operator: National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc.
- Responsible NNSA Field Office: Sandia Field Office

D.2.3.2 Funding

FY 2020 request – site funding by source
(total SNL FY 2020 request = $3,360 million)



FY 2020 FYNSP request for Weapons Activities
($2,941 million)



D.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 robust 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's broader set of capabilities supporting other national security needs include cybersecurity and intelligence science, physical and biological sciences and engineering, and synergistic global security engineering. 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, and materials science to provide expertise in disciplines 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 activity capabilities support an evolving set of mission requirements, are interdependent, and contribute across the entire weapons life cycle. SNL capabilities related to DOE/NNSA weapons activities and their associated challenges and strategies are described in **Table D–3**.

Table D–3. Sandia National Laboratories Capabilities

Agile Component and Systems Design, Engineering, Production, Surveillance and Integration	
Systems engineering, surveillance, and integration 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, modifications, 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.	
Challenges	***Strategies***
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 power source R&D and production and surveillance testing capabilities.	Proactively engage with NNSA to ensure an integrated approach that collocates related capability assets to improve efficiency and effectiveness and recapitalizes aging and inadequate facilities.
Threats by adversaries are evolving rapidly and unpredictably. Traditional weapon design development cycles are too long, impeding the ability to respond in a timely manner to emerging threats.	Seek ways to accelerate the development cycle and advance prototyping capabilities to more quickly respond to emerging threats; participate in the Stockpile Responsiveness Program.
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.
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.
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 and R&D Certification and Safety.

Microsystems R&D and Manufacturing	
Trusted, strategic, radiation-hardened advanced microelectronics (i.e., nanoscale and microscale system science, engineering, and technology).	
Challenges	***Strategies***
Trusted microelectronics fabrication facilities are aging and past their design lives.	Complete SNL Silicon Fabrication Revitalization. Work with NNSA in extended life planning to maintain the R&D capability and ensure an uninterrupted ability to produce trusted, strategic radiation-hardened microelectronics.
Materials Science and Engineering and Advanced Manufacturing	
Virtually every class 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.	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; capture the phenomenology driving this behavior; define and predict performance in current and future stockpiles; and enable applications in additive manufacturing with a science basis for qualification.
The material science and engineering facility at SNL California does not meet modern seismic and other building code standards. SNL Albuquerque facility operations exceed 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.
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 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.
Engineering Sciences and Testing, Radiation Effects and High Energy Density Physics, and Advanced Experimental Diagnostics and Sensors	
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. Research and testing to support design, qualification, and surveillance.	
Challenges	***Strategies***
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.
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.
High Performance Computing and Codes, Models, Data Analytics	
Modeling and simulation capabilities of physical phenomena.	
Challenges	***Strategies***
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.
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.

Alt = alteration
HERMES = High-Energy Radiation Megavolt Electron Source
HPC = high performance computing
IDC = integrated design codes
Z = Z pulsed power facility

D.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 the cost, schedule, and technical performance criteria critical to the NNSA mission.
- **Production collaboration success.** The SNL production community, in partnership with KCNSC, Pantex, and external suppliers, delivered over 40,000 components that support 51 products serving 6 different weapon systems. Nearly half of these components were new or modified designs. These collaborations resulted in risk avoidance/mitigation, increased productivity, reduction of backlogs, and leverage of resources to meet commitments on weapon-related deliverables while maintaining a historically high acceptance rate.
- **Demonstrated advanced hypersonic capabilities.** SNL capabilities in material science, guided flight systems, and modeling and simulation led to the technology advancements required for the successful launch of Conventional Prompt Strike Flight Experiment-1, demonstrating this capability for the Nation.
- **B61-12 LEP on track to meet 2020 first production unit.** Proactive management of B61-12 design, test, and qualification activities has resulted in successful on-time deliverables, milestones, testing, and retirement of overall program risk. The program successfully completed final design reviews and executed aggressive flight and qualification test schedules. It also completed

mechanical, thermal, electrical, and electromagnetic radiation environments qualification activities for normal and abnormal environments.

- **W88 Alt 370 on track to meet 2019 first production unit.** SNL kept life-of-program costs within the submitted Baseline Cost Report, while executing an aggressive testing schedule and standing up and upgrading a key qualification capability. The program successfully completed final design reviews, executed an aggressive flight and qualification test schedule, and simultaneously completed Production Readiness Reviews.
- **High Operational Tempo Sounding Rocket Flight Test (HOT SHOT).** The HOT SHOT experiment better prepared NNSA to provide a robust, flexible, and resilient nuclear deterrent into the future. SNL developed, coordinated, and executed the first of a series of HOT SHOT experiments aimed at accelerating development cycles and increasing responsiveness. Using reconstituted sounding rockets, with experiments added on multiple decks, allowed prediction of the structural response of non-instrumented components during flight in combined environments. The experiment demonstrated more efficient collection of data for predicting component response and supported SNL computer model validation.
- **Electronic Neutron Generators (ELNG) efficiencies.** The SNL ELNG Product Realization Team successfully completed qualification testing of the first B83, B61, and B61-12 ELNGs produced at SNL, eliminating a hydrotest for a cost reduction of $2.8 million. SNL also developed a new testing capability that replicates required environments while minimizing the risks of over-testing.
- **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

- **Delivered 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 advanced architecture prototype HPC system, an unprecedented number of shots on the Z machine, and analysis of stockpile issues through numerical simulation that will have significant impact on future annual assessment reviews.
- **Engineering sciences and computational modeling key to B61-12 qualification.** Data from B61-12 flight tests, full-scale wind tunnel tests, and computational simulation have been integrated to develop the aerodynamic performance model for the B61-12 qualification effort. The model is being used to assess weapon margins against requirements.
- **Simulation improves manufacturing yield.** Use of the Sierra/Aria simulation code enabled optimization of a weapon packaging process to improve manufacturing yield of a B61-12 component.
- **Acquisition of advanced HPC system.** SNL successfully led a tri-laboratory team to maintain the acquisition schedule for an advanced architecture prototype HPC system acquisition schedule while operating under tight fiscal constraints. This acquisition will enable NNSA to evaluate the feasibility of emerging HPC architectures as production platforms to support stockpile stewardship.
- **Silicon Fabrication facility (SiFab) pre-builds will support a flexible, responsive stockpile during fabrication conversion.** SNL's SiFab completed all planned life-of-program wafer fabrication for the modernization programs and delivered over 6,000 War Reserve parts to NNSA to support baseline first production unit dates for the B61-12, W88 Alt 370, Mk21 Fuze, and W80-4. This pre-build allows the Microsystems and Engineering Sciences Applications (MESA) facility to begin

6-inch to 8-inch wafer fabrication conversion without disrupting weapon deliverable schedules. The conversion to 8-inch tools is required to support production for the W80-4, W87-1, and future weapons programs.

Attract, Retain, and Develop Talent

- The SNL FY 2019 Truman Fellowship attracted 17 qualified applicants from among the best nationally recognized PhD scientists and engineers; SNL made 2 offers and both applicants accepted. The newly established Jill Hruby Fellowship, honoring SNL's former Director who was NNSA's first female Laboratory Director, attracted women scientists and engineers interested in pursuing technical leadership careers in national security. From the 41 qualified applicants, SNL made 2 offers; both applicants accepted.
- SNL established a cross-divisional recruiting team to address the challenges of attracting and retaining cybersecurity, computer science, and computer engineering personnel. As a result, SNL hired a total of 134 R&D employees in cybersecurity, computer science, and computer engineering, a 179 percent increase from FY 2017.
- 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.
- SNL launched a new early-career leadership development program to expose early-career employees to leadership tools, methodology, and language. It attracted 30 high-potential participants in the first year and will enable future leaders to advance early in the employee life cycle by providing clear promotion and development paths.
- 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 2 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.
- The Military Academy 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 Academy 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.

Awards and recognition in 2017-2018. SNL received five coveted R&D 100 awards in each of the last 2 years. SNL employees earned 17 national technical awards, and 23 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.

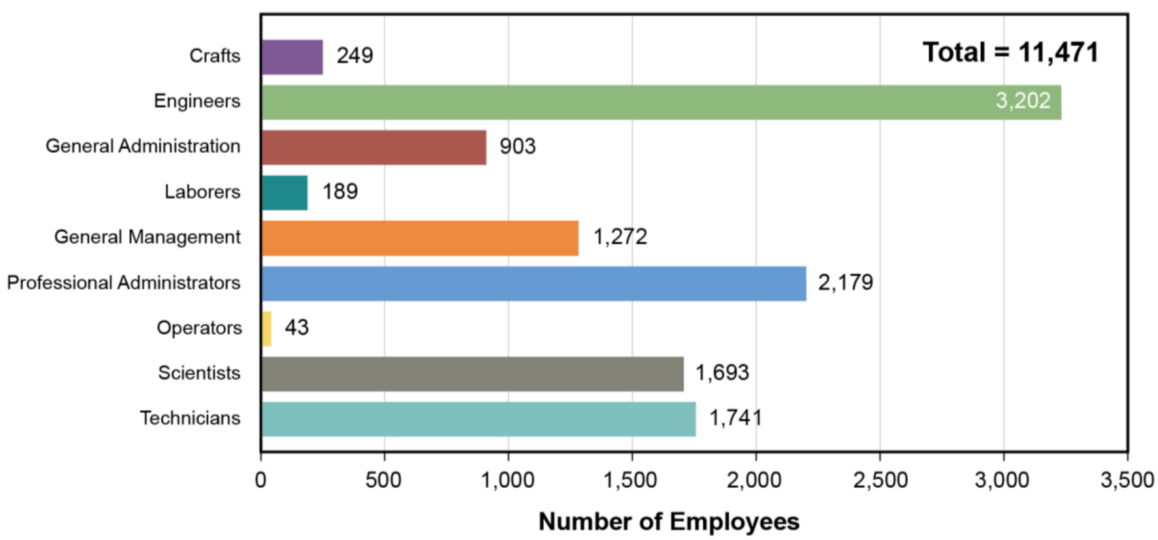
Infrastructure investments. SNL managed 6,000 direct- and indirect-funded construction projects totaling $265 million in FY 2017 and FY 2018. These investments addressed highest-risk areas affecting mission deliverables. One noteworthy accomplishment was completion of the Battery Test Facility, a 7,500-square-foot facility for the testing of performance and electrochemical analysis of energy storage devices. Moving these operations to a specially designed, dedicated laboratory reduces the safety and programmatic risks caused by having these operations in the existing Power Sources facility, which houses high-density office and laboratory space.

Other DOE/NNSA Accomplishments

- **Center of Excellence in Cyber Threat Intelligence**. SNL deployed a network sensor that leverages behavior-based heuristics, machine-learning, and statistical techniques to five DOE/NNSA sites to provide enterprise-wide visibility into anomalous network behavior for analysis and mitigation. Cybersecurity analysts, dubbed "hunters," have been actively analyzing cybersecurity events using the newly deployed network sensor in partnership with NNSA's Information Assurance Response Center and have successfully identified multiple malware campaigns at various DOE/NNSA sites.

D.2.3.5 Sandia National Laboratories Workforce

SNL has a headcount of 11,471 employees; the average age is approximately 46 years, and 15.5 percent of the population is eligible for retirement. The average for years of service is 11.5 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. Fifty-three percent of voluntary separations 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 D–24** through **D–32** illustrate these SNL workforce demographics and others.



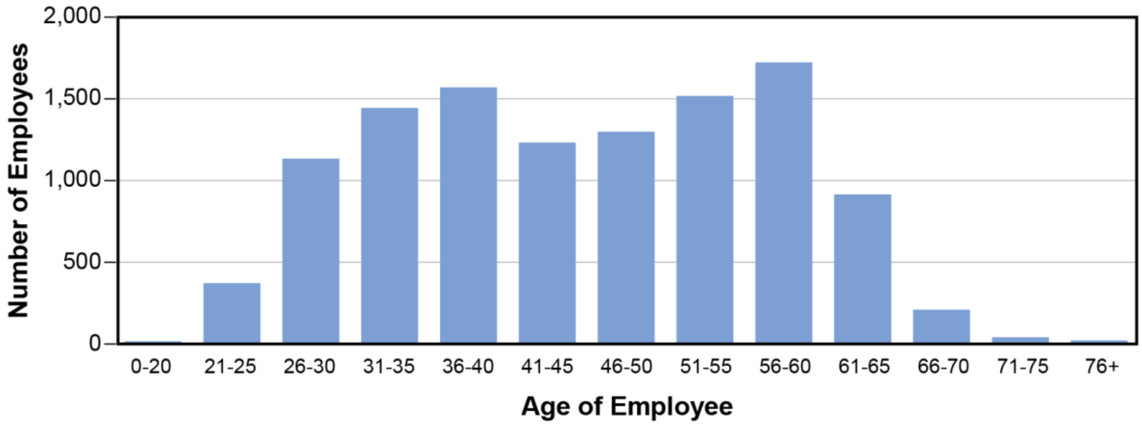
Notes:

Sixty-two percent of SNL's headcount is aligned with technical duties and responsibilities ranging from R&D to applied engineering to operations.

SNL uses a systems integration approach to workforce assignments. Team members are matrixed to support key mission areas, including the Strategic Partnership Projects. Growth of approximately 1,465 in overall regular headcount since FY 2014 is consistent with robust program growth in LEP areas tempered by attrition.

Advanced degrees are held by 54.7 percent of the workforce; 17.0 percent have PhDs, and 37.7 percent have Masters degrees.

Figure D–24. SNL total workforce by Common Occupational Classification System (as of September 30, 2018)



Notes:

The average age of the employee population is 45.7 years. A large proportion of the population is aged 56 and above (25.2 percent). Approximately 13.1 percent of the population is aged 30 or less. The remaining 61.7 percent is between the ages of 31 and 55.

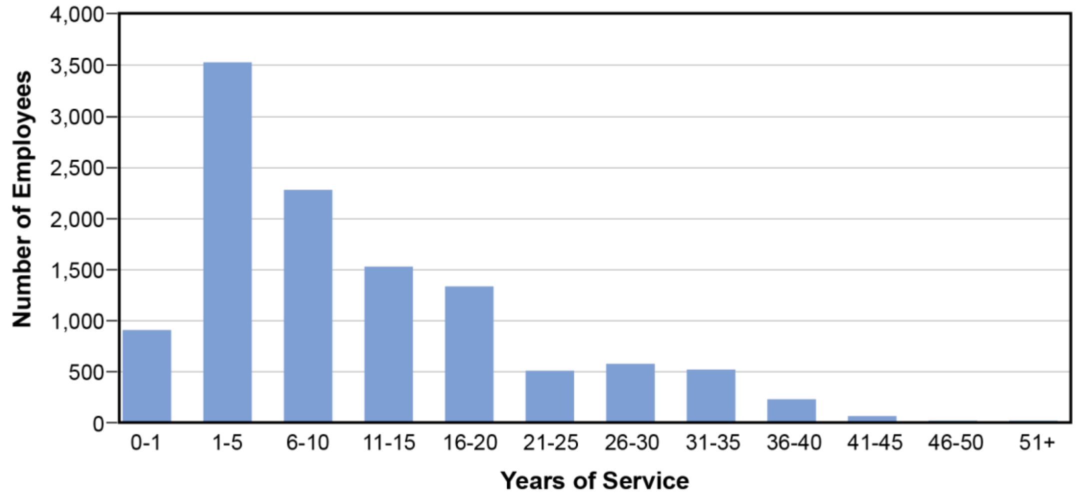
Retirement-eligible SNL employees are at 15.5 percent; this rate has remained stable in the last 3 years.

The bimodal age distribution has lessened in recent years due to increasing hiring of experienced professionals to meet skill gaps. While the bimodal distribution is not extreme, there are categories in which this is more pronounced (i.e., engineers and scientists). SNL continues to take this into account as it plans for mentoring and knowledge transfer.

The FY 2019 hiring projections reflect a continuing mix of hires between experienced and new college graduates to meet skill gaps. SNL is experiencing some challenges in attracting and hiring personnel in the science, technology, engineering, and mathematics fields because of increased competition from the private sector. This is especially acute in the cybersecurity, computer science, and computer engineering skill areas. SNL is monitoring and adjusting its recruiting strategies accordingly to meet the talent needs of the enterprise.

Based on the age distribution, retirement is anticipated to increase in coming years. These openings will place greater pressure on recruiting future talent and retaining existing SNL employees.

Figure D–25. SNL employees by age (as of September 30, 2018)

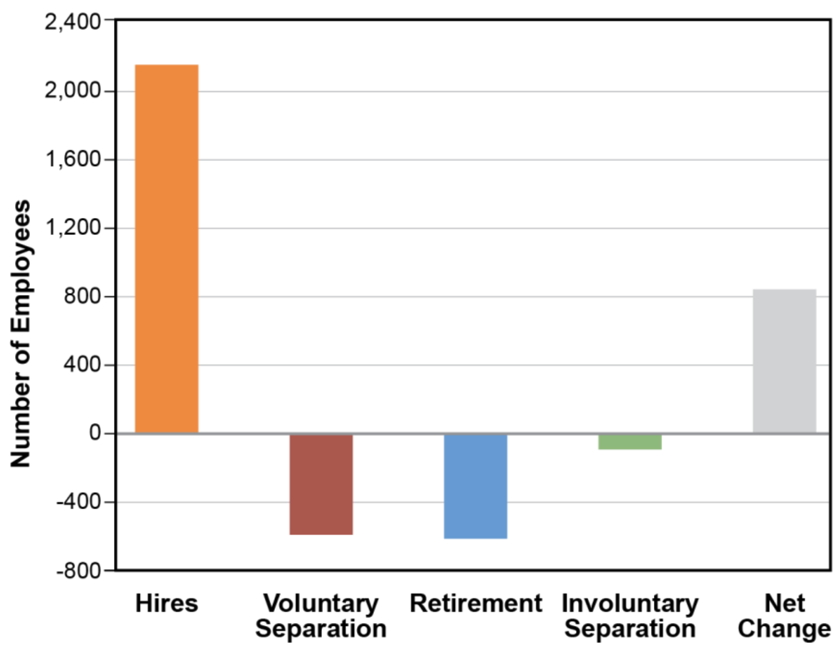


Notes:

Employees with 15 or less years of service total 72.2 percent; 38.9 percent have 5 or less years of service. These numbers reflect the hiring of 3,345 new regular employees over the past 5 years (FY 2014 through FY 2018).

The mix of both experienced and new college graduates assures that the necessary skills and capabilities are present to support SNL's mission work. Strong hiring over the past 5 years ensures that a substantial percentage of employees are in the earlier phases of their careers to replace those in later career phases. This trend will require an increased focus on knowledge transfer and training programs.

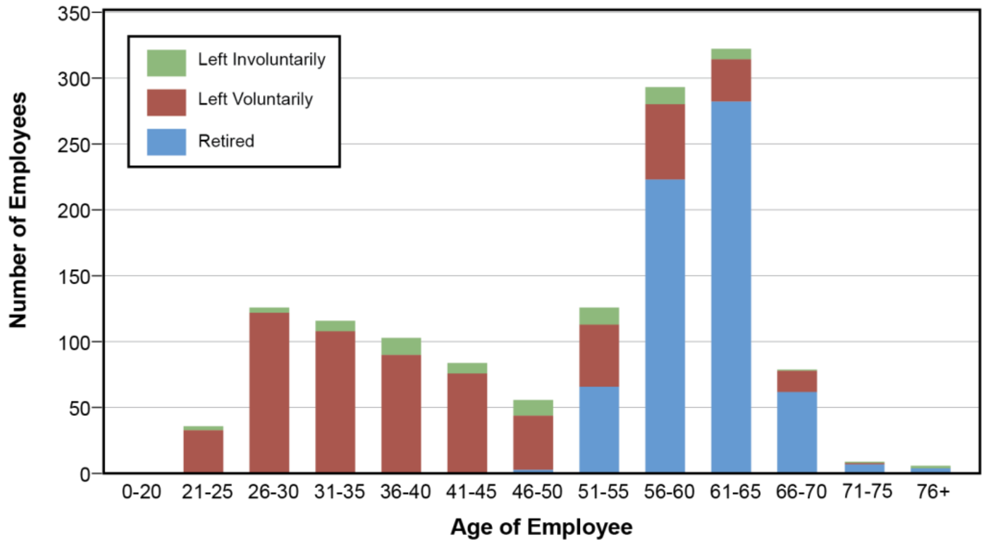
Figure D–26. SNL employees by years of service (as of September 30, 2018)



Notes:

A net change of 815 regular employees reflects strong hiring efforts to meet mission demand in FY 2017 and FY 2018. Most of this growth is attributable to the growing mission scope related to stockpile modernization through LEP activities and growth in Strategic Partnership Programs. SNL has maintained downward pressure on support organizations where applicable to further drive direct mission support within allocated budgets.

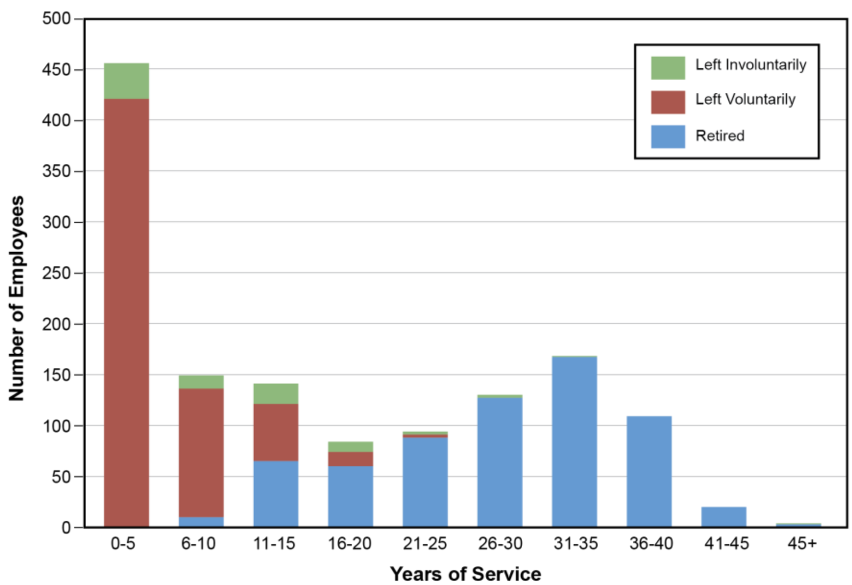
Figure D–27. Change in last 2 fiscal years at SNL (October 1, 2016 to September 30, 2018)



Notes:

About 51.3 percent of voluntary separations are clustered between the ages of 26 and 40. Higher numbers of retirements are reflected in the age group between 56 and 65 years of age, which represents 37.4 percent of separated employees during the last 2 fiscal years.

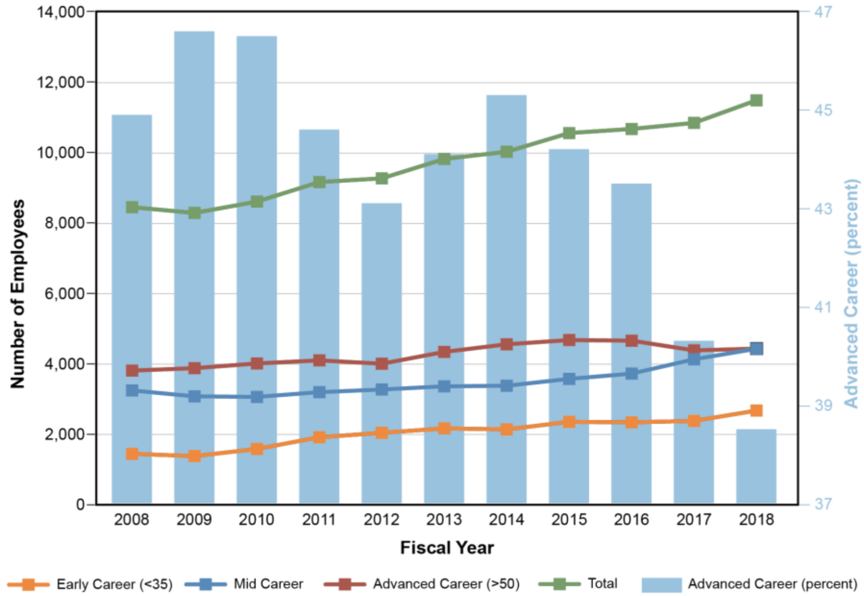
Figure D–28. Age of SNL employees who left service (October 1, 2016 to September 30, 2018)



Notes:

Of the voluntary employee separations, 67.8 percent had 5 or less years of service; 88.2 percent had 0-10 years of service; and 97.2 percent had 15 or less years of service. This turnover may reflect the external demand for technical skills in the highly competitive market where SNL competes for talent. These losses place increased importance on a speedier clearance process, training programs, and knowledge transfer to be able to train new staff entering SNL and a robust overall Employee Value Proposition that is current and relevant to the labor market.

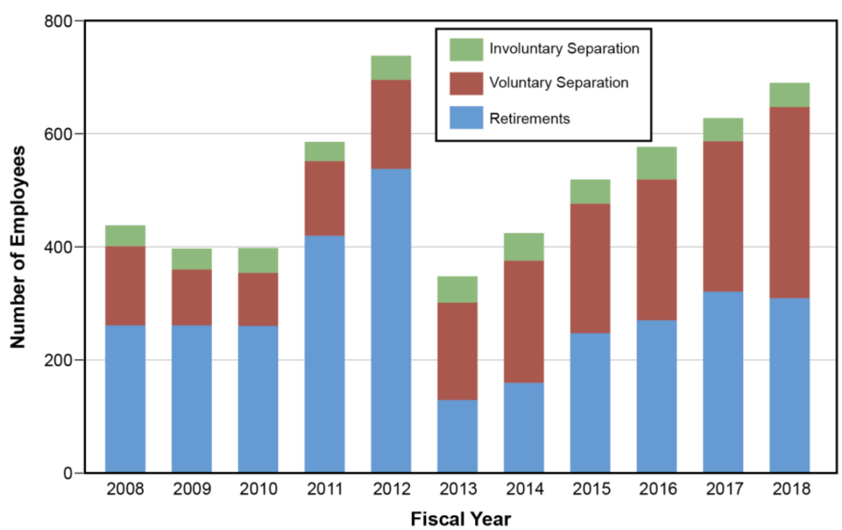
Figure D–29. Years of service of SNL employees who left service (October 1, 2016 to September 30, 2018)



Notes:

The upward trend in headcount reflects an increase in mission work and demands. The mix of staff by career stage reflects the demand for new talent in all three career areas and the skills they bring to SNL for a balanced workforce. Within the advanced career segment, the net growth over time is heavily influenced by retirements from the workforce. The net impact is a generally steady advanced career population and slightly increasing mid- and early-career segments. As retirements increase at SNL due to older employees exiting the workforce, the size of the advanced career population is expected to begin a slight decline in the coming years.

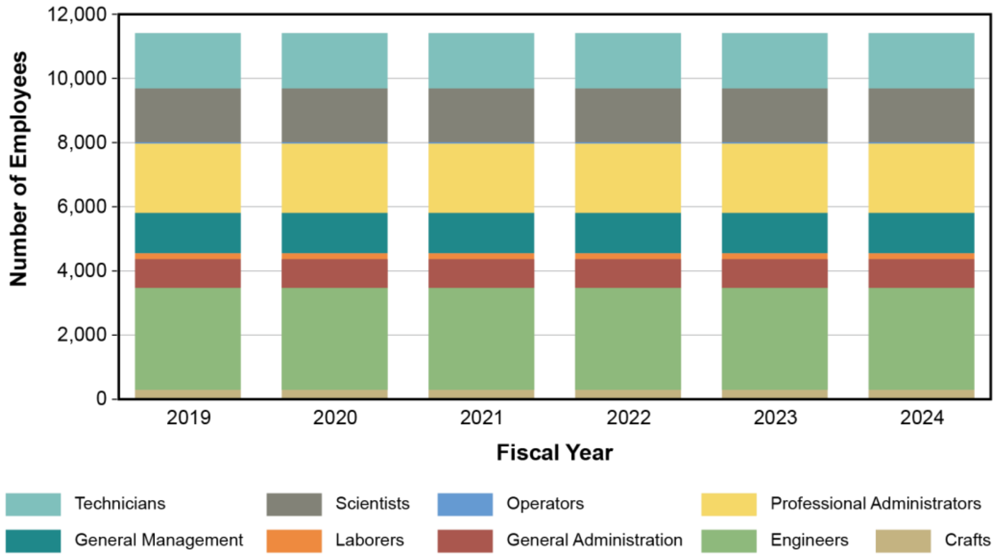
Figure D–30. SNL trends by career stage (as of September 30, 2018)



Notes:

Retirements were higher in FY 2011 and FY 2012 because of announced pending changes in retiree benefits, which encouraged 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. Retirements increased from FY 2015 to FY 2018 as expected as SNL returned to historical retirement rates and the workforce aged. SNL's hiring projections are adjusted annually to assure talent is available to meet mission requirements.

Figure D–31. SNL employment separation trends (as of September 30, 2018)



Notes:

The SNL workforce has grown by approximately 800 since the FY 2018 SSMP. Fluctuations in the workforce are a function of variations in workload among multiple programs, retirements, and separations. SNL's best estimate of workload depicts a continued flat trend overall. SNL monitors workload fluctuations and manages the stability of the workforce through Strategic Partnership Projects, temporary staffing options, cross-training within programs, and strategic hiring.

Figure D–32. Total projected SNL workforce needs by Common Occupational Classification System over the FYNSP period (as of September 30, 2018)

D.3 Nuclear Weapons Production Facilities

D.3.1 Kansas City National Security Campus

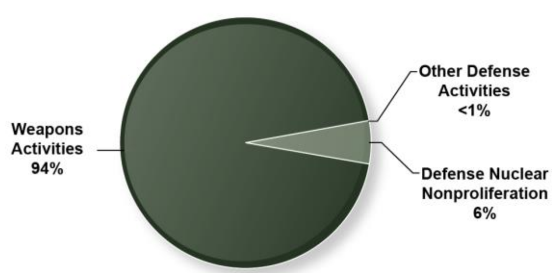
D.3.1.1 Mission Overview

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 partners with the national 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 the development and delivery of field-ready engineering solutions for other government agencies' national security missions.

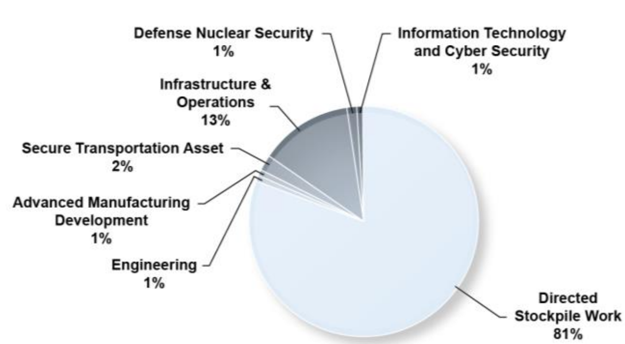
- Locations: Kansas City, Missouri; Albuquerque, New Mexico
- Total Employees: 4,156 (as of end of FY 2018)
- Type: Multi-program nuclear weapons production facility
- Website: www.kcnsc.doe.gov
- Contract Operator: Honeywell Federal Manufacturing & Technologies
- Responsible Field Office: Kansas City Field Office

D.3.1.2 Funding

FY 2020 request – site funding by source
(total KCNSC FY 2020 request = $996 million)



FY 2020 FYNSP request for Weapons Activities
($940 million)



D.3.1.3 Site Capabilities

KCNSC's capabilities support both weapon systems currently in the stockpile and those being modernized via LEPs, Alts, and modifications (Mods). For legacy systems, these activities include Directed Stockpile Work in the management, production, processing, and delivery of hardware for limited life component (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 D–4**.

Table D–4. Kansas City National Security Campus Capabilities

Non-nuclear Weapon Component Manufacturing and Assembly	
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 upon specialized equipment and facilities (cleanrooms, environmentally controlled areas, etc.) and the ability to maintain them (i.e., calibration and metrology).	
Challenges	***Strategies***
• Balancing the growing maintenance needs of aging production equipment with the needs for emerging production technology for the LEPs. • The availability of a cleared and ready labor force.	• Continue planning and budgeting through various funding sources, including 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.
Testing Equipment Design and Fabrication	
KCNSC designs and produces testing equipment to support its mission and that of the other sites within the nuclear security enterprise. Often, these testing systems are integrated with various types of environmental conditioning equipment, such as thermal chambers or centrifuges, to perform automated testing for weapon environments. These testing systems are vital to the development, qualification, and acceptance of weapon systems and components.	
Challenges	***Strategies***
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	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 Projects. • Deploy Common Tester Architecture. • Provide flexibility in assignment areas. • Better plan and execute resource-loaded program schedules. • Obtain appropriate funding to develop new capabilities.

• New capabilities required by emerging programs (e.g., shock, vibration, combined environments) • Difficulty simulating realistic (combined) flight environments	• Use RASR [Research and Sounding Rocket] and HOTSHOT [High Operational Tempo Sounding Rocket Flight Test] rocket flight tests to simulate environments.

Fabrication and Support of Secure Transportation Assets	
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 the design, fabrication, and maintenance of multiple system capabilities and facilitates safety engineering, technical documentation, and training of the Federal agents that perform STA functions.	
Challenges	***Strategies***
• 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.	• 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.

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***
• Maintaining test and measurement systems beyond design life to support surveillance testing. • Engaging workforce in older technologies. • Material availability due to sunset technologies for legacy JTA programs.	• Replace select test equipment and modernize capabilities. • Successfully execute hiring, retention, and knowledge preservation strategies. • Periodically update designs and modernize technology for JTA systems.

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, and 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***
• 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.

Site-Wide Challenges of the Workforce Associated with Multiple Capabilities	
Challenges	***Strategies***
• Recruitment and retention of a skilled, diverse, and effective workforce. • Competitive salaries for employers across the region and competition for top talent remains 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 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. • Secure additional workspace.

JTA = joint test assembly

D.3.1.4 Accomplishments

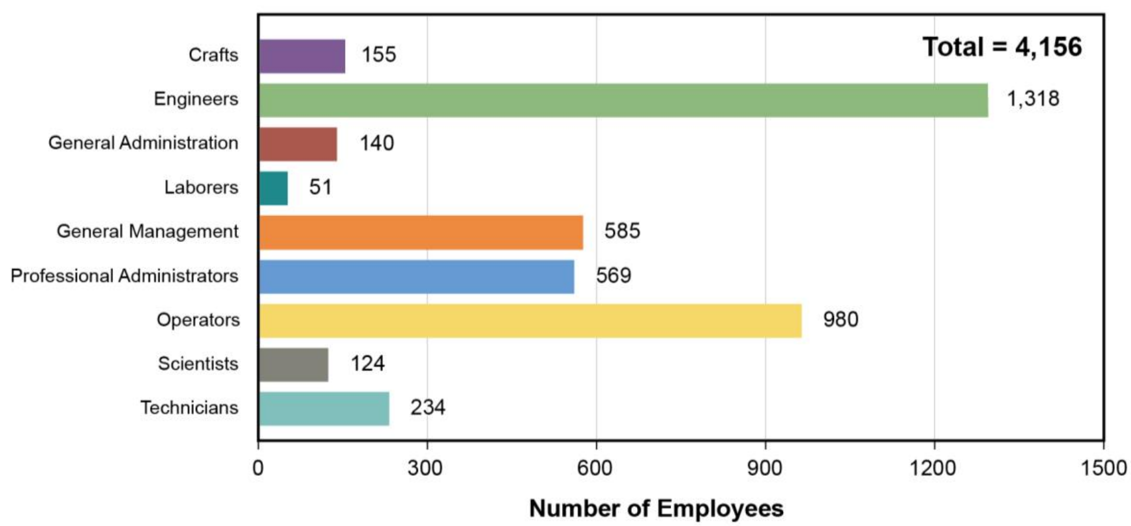
- Delivered first production units of 11 B61-12 weapon components early or on time and 56 B61-12 Type 5B/5D trainer components. Delivered first production units of nine W88 Alt 370 components early or on time.
- Delivered over 158,619 items in support of the Defense Programs mission, including over 25,000 items to support critical systems tests and trainers for the B61-12 and W88 Alt 370.
- Completed production requirements for 40 percent of the W76-1 LEP ship entities.
- Partnered with the Kansas City Field Office to complete final disposition of the Bannister Federal Complex by accelerating planned decommissioning actions, coordinating transfer of utilities, and supporting transfer of the Floodwall Operation.
- Qualified and sold the first War Reserve additively manufactured component to production stores. This milestone for the B61-12 has paved the way for additional parts in the near future and is the culmination of multiple technology development efforts across the nuclear security enterprise.
- The 13,000-square-foot KCNSC Advanced Manufacturing Facility was completed on time, consolidating advanced manufacturing operations in one area under a single management system.
- Realized Supply Chain Management Center total savings through centralizing the procurement function for the nuclear security enterprise and Environmental Management.
- The KCNSC Research and Sounding Rocket initiative flew its first test flights. The rocket flights are designed to expose new technologies to environments that cannot be replicated in ground/laboratory testing in a rapid, yet cost-effective, manner to increase knowledge and understanding of mechanical properties and performance.
- Digital Manufacturing has achieved a cost benefit of more than $124 million over the last 5 years, with $31.7 million in FY 2018 alone, through over 63,000 parts produced.

- Surpassed 1 year of safety without a Days Away From Work Case; achieved 5 years without a Days Away From Work Case for KCNSC New Mexico operations.
- KCNSC has achieved a tremendous increase in skilled labor in its business. The population of operators has increased 75 percent over the past 2 years (FY 2017 – FY 2018) in preparation for production for B61-12, W88 Alt 370, and Mk21 arming and fuzing assembly.
- Completed the new 100-workstation expansion of the Manufacturing Innovation Center, which is focused on the onboarding, efficiency, and utilization of direct hourly employees who support development, production, and other reimbursable projects for the nuclear security enterprise.
- Selected as the production agency for the Mobile Guardian Transporter, which has a first delivery in FY 2025 based on capabilities and past performance.
- Onboarded new commodity vendors in cables, tooling, materials, and machined parts and implemented supplier improvement plans for key existing partners in all commodity teams.
- Received DOE/NNSA acceptance of earned value management in KCNSC's production approach for the B61-12 and W88 Alt 370, which will be piloted and implemented in 2019.
- Initiated and led four W80-4 scheduling summits across the nuclear security enterprise and benchmarked scheduling methodologies to build resource-loaded Primavera P6 schedules for the program's Weapon Design and Cost Report.
- Implemented a process improvement for the Interim Q clearance request process, submitting requests before employee start dates instead of 2-3 months after. Days to receive an Interim Q after the start date have been reduced from 122 days to 22 days (82 percent reduction).
- Led nuclear security enterprise implementation of NAP-24A (Weapon Quality Policy) Attachment 4, for which DOE/NNSA awarded a Defense Program Award of Excellence, and was the primary nuclear security enterprise responder to DoD regarding a new supply chain-focused Executive Order.
- Successfully built a tool for the W80-4, enabling the ability to monitor and track alignment of NNSA Integrated Master Schedule milestones for the program, resulting in the Federal Program Office officially tasking KCNSC with the responsibility of managing the tool and the alignment process for all nuclear security enterprise sites.
- Early delivery of W88 Alt 370 Demonstration and Shakedown Operation-29 qualification flight test hardware.
- The Code Management System completed all development build activities and delivered first process prove-in requirements.
- W88 Alt 940 completed qualification and delivery of the first trainer units.
- Implemented a high-speed video capability with the release of a qualified tester for B61-12 and W88 Alt 370 mechanisms. These technologies have significantly surpassed the prior test capabilities for understanding and diagnosing stronglink products in development and production.
- Completed required qualification activities for 3X Acorn Quality Evaluation Review.
- Developed and implemented a CAT Milestone process and tools to track and manage key program milestones for the B61-12 and W88 Alt 370.
- Successfully collaborated with SNL to develop a plan to re-accept W80-1 Stockpile Management program Trajectory Sensing Signal Generator components at extreme temperatures.

- Deployed a new application to manage orders and achieved 72 percent reduction of expired orders.
- Completed digitization of classified aperture cards in the Legacy Data Capture program.
- Over 475 Honeywell employees have volunteered more than 3,200 hours at various community events.

D.3.1.5 Kansas City National Security Campus Workforce

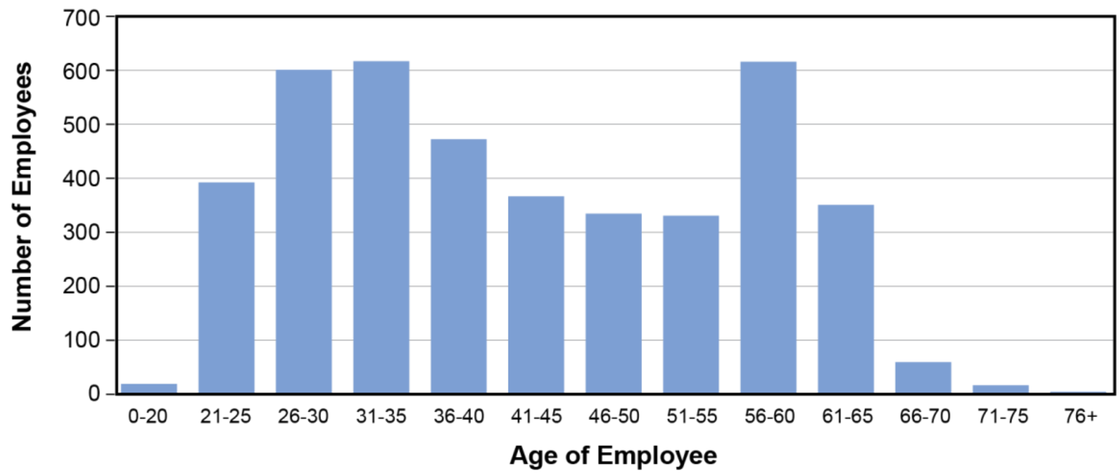
KCNSC has 4,156 employees, with an average age of 42.86 years and over half of employees with 5 or fewer years of service. Approximately 23 percent of KCNSC's employees are eligible to retire. KCNSC has a bimodal distribution for employee age; nearly 71 percent of employees have 10 years or less of service. Since the end of FY 2016, KCNSC has hired 1,684 workers and experienced 605 separations, resulting in a net gain of 1,079. Of those separations, many were voluntary separations by early-career employees, while many advanced-career employees retired. Forty-seven percent of separations were employees with less than 5 years of service. Since FY 2014, the number of early- and mid-career employees has steadily increased, while the number of advanced-career employees has remained flat. KCNSC will continue to add staff over the FYNSP period as the workload for LEPs and Alts increases. Workforce demographics are illustrated and discussed in **Figures D–33** through **D–41**.



Notes:

Headcount is up 577 from FY 2017 and 1,079 from FY 2016. KCNSC is preparing for production builds on the B61-12, W88 Alt 370, and Mk21 Fuze. Operator headcount has increased 75 percent from FY 2016 (980 from 559, respectively) and operators are now nearly one quarter (23.6 percent) of the plant population. Engineering continues to be steady, making up about one third of the plant population.

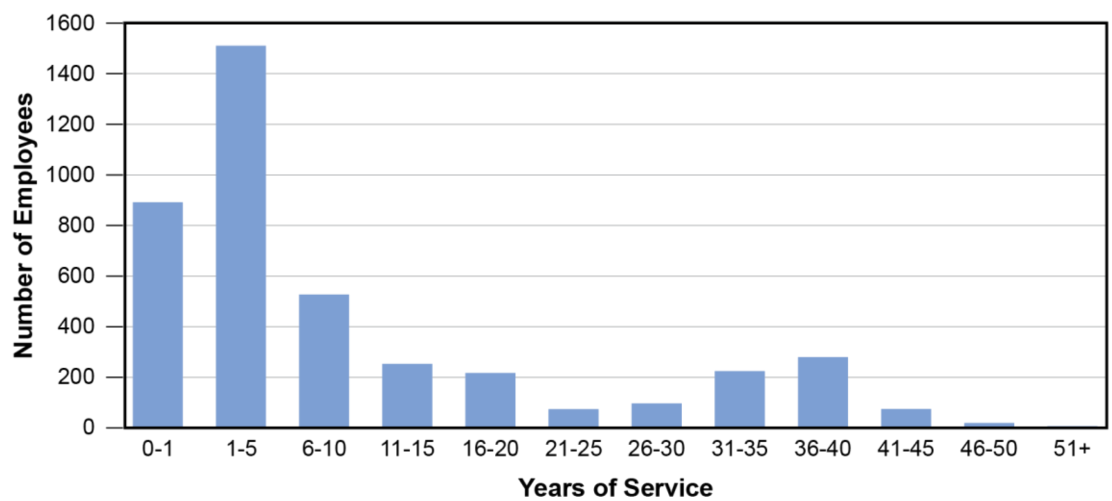
Figure D–33. KCNSC total workforce by Common Occupational Classification System (as of September 30, 2018)



Notes:

The average age of the plant workforce (42.86 years) continues to decrease, down from 45.48 in FY 2016 and 43.65 in FY 2017. One in four (24.2 percent) of plant workers is under the age of 30; one in two (50.3 percent) is under the age of 40; and only one in three (32.9 percent) is over the age of 50. Retirement-eligible employees continue to decrease, down from 32.27 percent in FY 2016 and 25.76 percent in FY 2017.

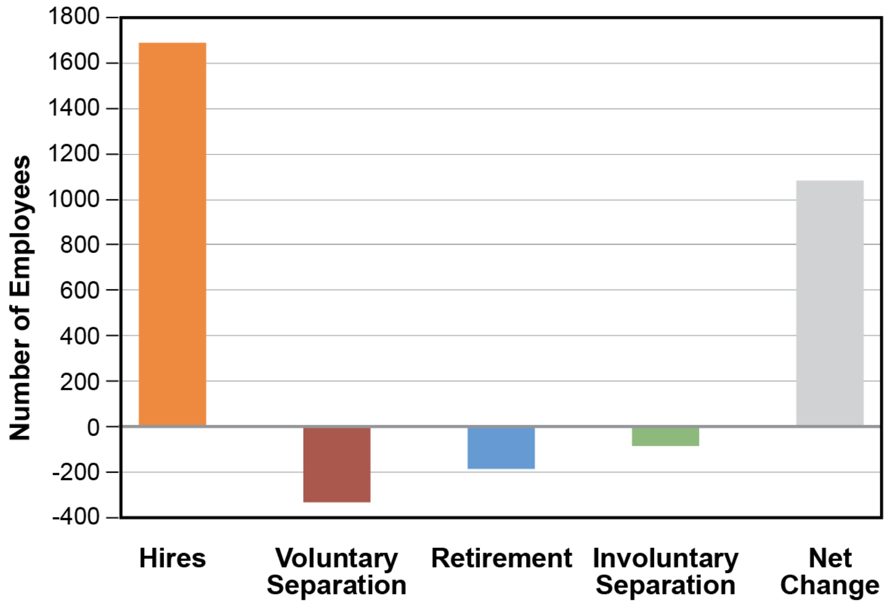
Figure D–34. KCNSC employees by age (as of September 30, 2018)



Notes:

The average for employee years of service is down to 10.07 from 13.83 in FY 2016 and 11.43 in FY 2017. One in five (21.6 percent) plant employees has 1 year or less of service; over half (58.23 percent) have 5 years or less; 70.93 percent have 10 years or less; and 17.9 percent have more than 20 years of service.

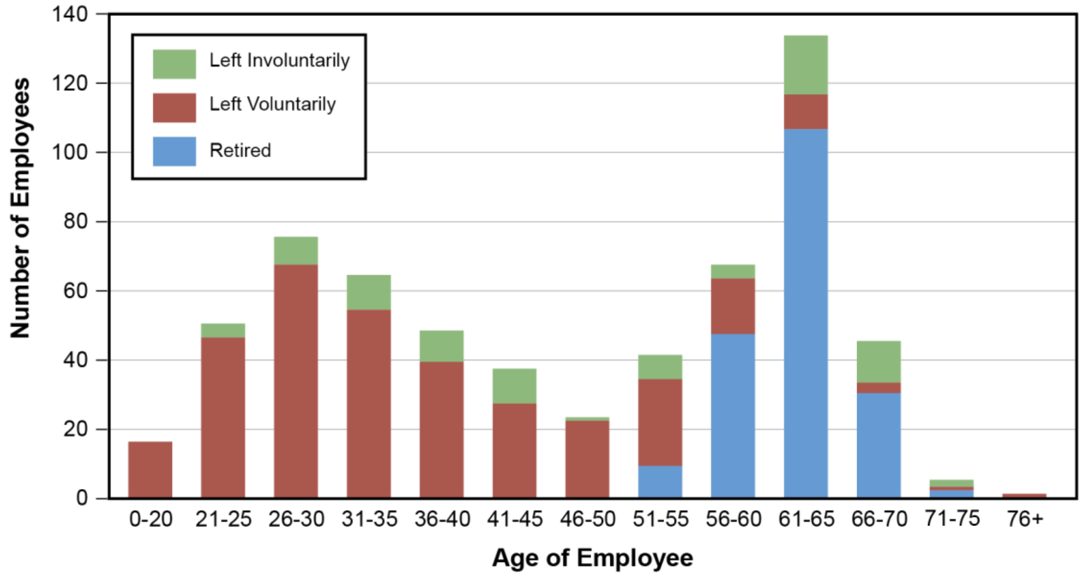
Figure D–35. KCNSC employees by years of service (as of September 30, 2018)



Notes:

KCNSC had a net increase of 1,079 employees in the period from FY 2017 and FY 2018; 577 of those were hired in FY 2018. For the reporting period, 53.6 percent of the separations were voluntary separations, and an additional 32.6 percent were due to retirements.

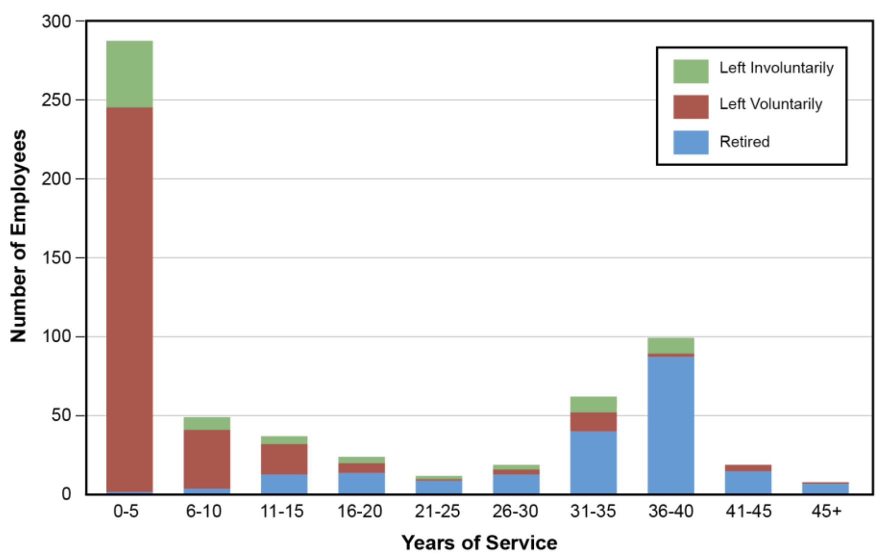
Figure D–36. Change in last 2 fiscal years at KCNSC (October 1, 2016 to September 30, 2018)



Notes:

Looking at separations by age group as a percentage of the total separations for the period (2 years), 23.3 percent were under 30 when they separated; 41.8 percent were under 40; and a similar number (41.5 percent) were 56 or older.

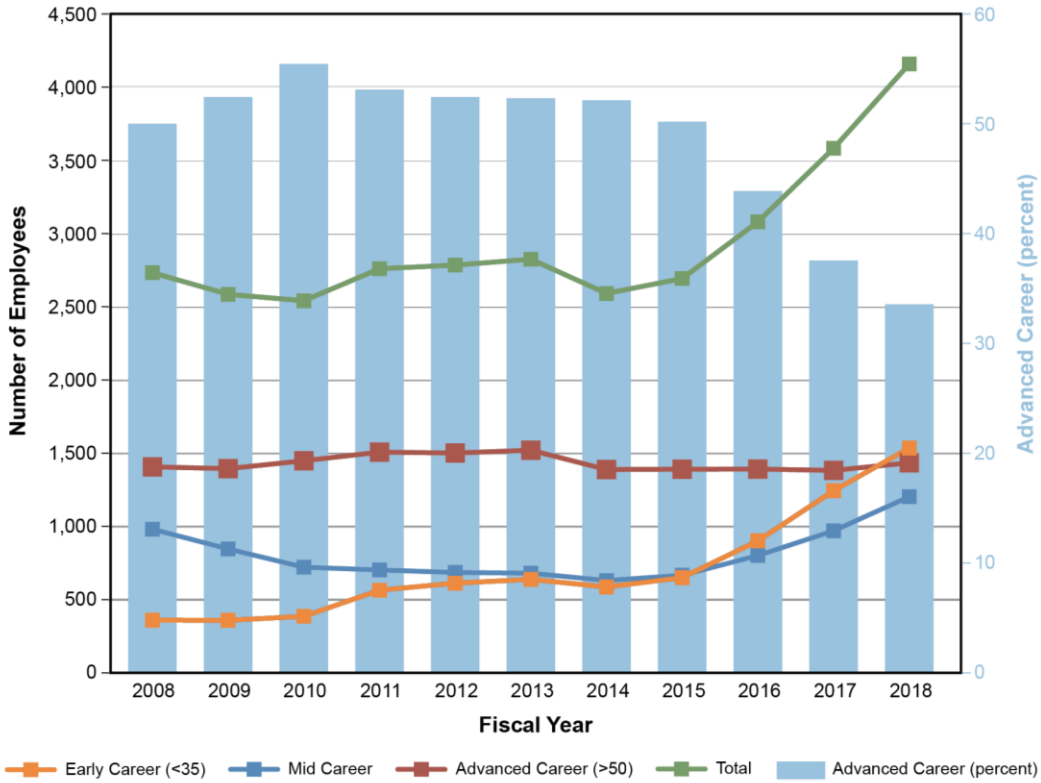
Figure D–37. Age of KCNSC employees who left service (October 1, 2016 to September 30, 2018)



Notes:

Looking at separations by years of service and grouping them as a percentage of total separations for the period (2 years), nearly half of the separations (47.1 percent) occurred with 5 years of service or less; 55 percent occurred with 10 years of service or less; and only 30.4 percent occurred with 31 or more years of service.

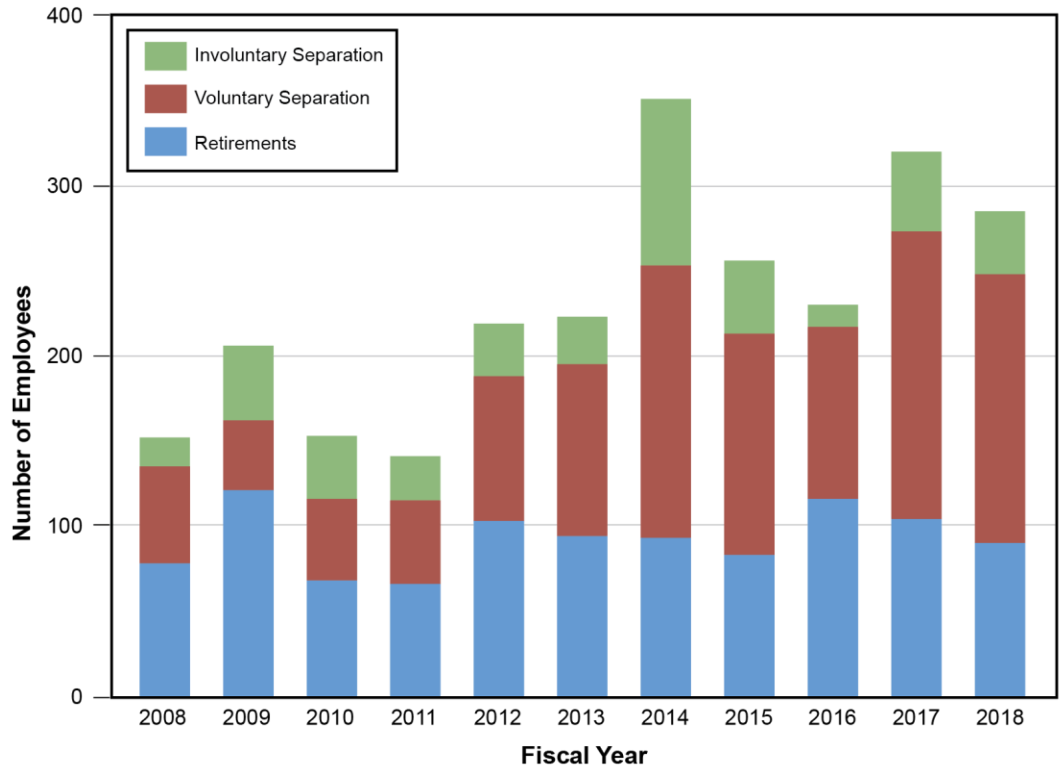
Figure D–38. Years of service of KCNSC employees who left service (October 1, 2016 to September 30, 2018)



Notes:

Early-career employees increased by 23.6 percent from FY 2017; mid-career employees increased by 24.2 percent from FY 2017; advanced-career employees increased by 3.8 percent from FY 2017; and the total increase was 16.1 percent from FY 2017. This is the first time KCNSC has had more early-career than advanced-career employees.

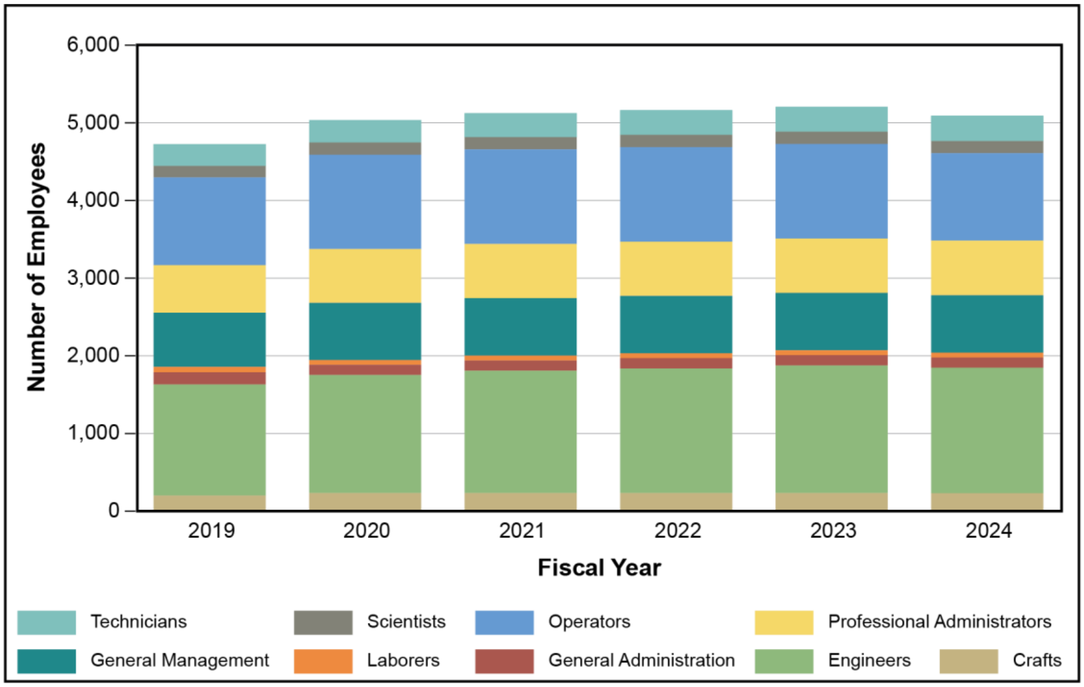
Figure D–39. KCNSC trends by career stage (as of September 30, 2018)



Notes:

Employee separations for FY 2018 were lower than the previous year, but still higher than in recent history. While overall attrition is below industry averages, attrition has increased for the employee group with less than 5 years of service. The investment in Q-cleared employees is high in the first few years of service, which drives a need for a strategy for increasing retention.

Figure D–40. KCNSC employment separation trends (as of September 30, 2018)



Notes:

The projected workforce needs over the FYNSP period shows an increase from last year's estimates in both salary and hourly labor. The W80-4 LEP released its Weapon Design and Cost Report, which provided improved estimates of the required hourly and salary labor. Hourly labor also increased because of expected workload increases on the B61 LEP and a better line of sight into the scope required for the W87-1 and W88R. The labor category was also adjusted upward to incorporate expected timing for the W87-1, and future warhead programs.

Figure D–41. Total projected KCNSC workforce needs by Common Occupational Classification System over the FYNSP period (as of September 30, 2018)

D.3.2 Pantex Plant

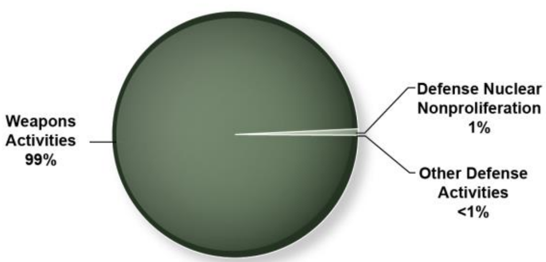
D.3.2.1 Mission Overview

The Pantex Plant (Pantex) outside of Amarillo, Texas is the only DOE/NNSA site authorized to assemble or disassemble nuclear weapons and, as NNSA's High Explosive Production Center of Excellence, has cradle-to-grave responsibilities for 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.

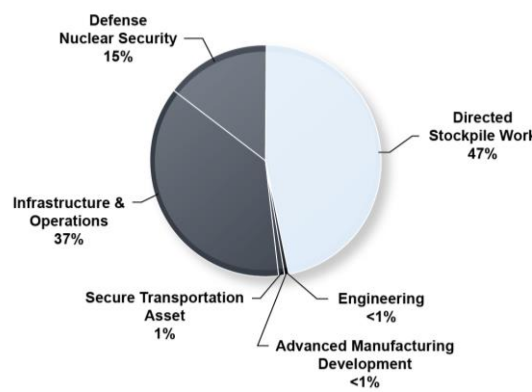
- Location: Amarillo, Texas
- Total Employees: 3,266 (as of the end of FY 2018)
- Type: Single-program nuclear weapons production facility
- Website: www.pantex.energy.gov
- Contract Operator: Consolidated Nuclear Security (CNS), LLC, a corporate subsidiary of Bechtel National, Leidos, ATK Launch Systems, and SOC, LLC
- Responsible Field Office: NNSA Production Office

D.3.2.2 Funding

FY 2020 request – site funding by source
(total Pantex FY 2020 request = $959 million)



FY 2020 FYNSP request for Weapons Activities
($950 million)



D.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 D–5**.

Table D–5. Pantex Plant Capabilities

Challenges	Strategies
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***
Development, establishment, and implementation of the Documented Safety Analysis process for new programmatic weapons activities.	Streamline the Documented Safety Analysis process methodology for efficiency and effectiveness.
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.	Develop and evaluate options for upgrading or acquiring replacement equipment.
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 of 1940s vintage.	The High Explosives Pressing Facility received CD-4, Approve Start of Operations, in FY 2017. The High Explosives Pressing Facility consolidates HE operations from numerous buildings to reduce the movement of HE within the plant, benefiting worker safety and minimizing impact to other plant operations. High Explosive Science and Engineering and HE formulation facilities are planning recapitalization of end-of-life equipment needs and establishing major modernization plans.
Special Nuclear Material Accountability, Storage, Protection, Handling, and Disposition	
These are requalification capabilities for pits for LEPs and storage of pits and weapons.	
Challenges	***Strategies***
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 and proceed with the CD process for the Material Staging Facility. Deploy new requalification equipment for upcoming LEPs. Upgrade existing requalification equipment.

CD = Critical Decision
HE = high explosives

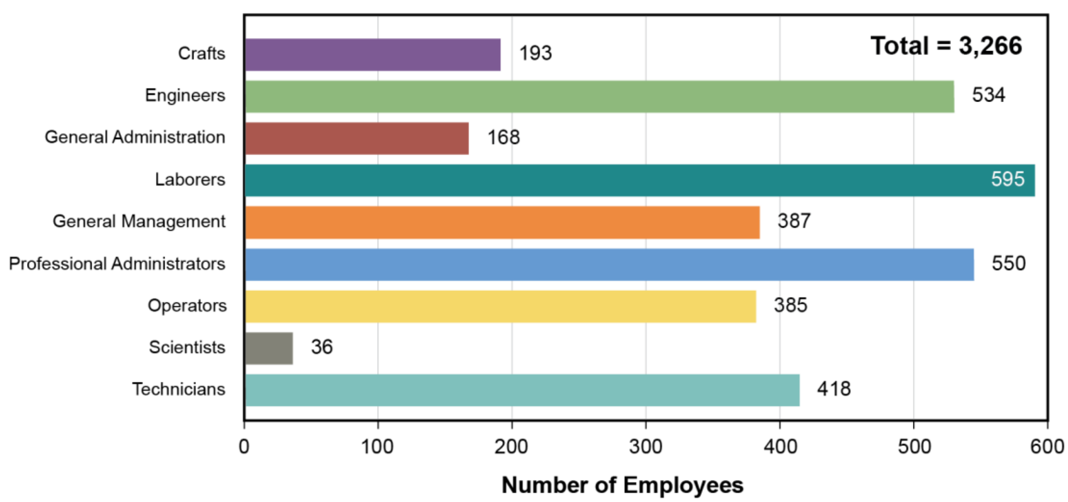
D.3.2.4 Accomplishments

- Increased the margin on DOE/NNSA delivery commitments to the Navy and completed the most first-time assemblies in the history of the W76-1 LEP at Pantex.
- Exceeded FY 2018 baselined production deliverables (102 percent) and shipped all required units to DoD on schedule.

- Exceeded the baseline for the W87 LLC exchange program and met the baseline for the W80 Alt 369 program at Pantex.
- Recovered a 6-month schedule delay on pit requalification activities, positioning Pantex to meet the B61-12 pit first production unit baseline in December 2018.

D.3.2.5 Pantex Plant Workforce

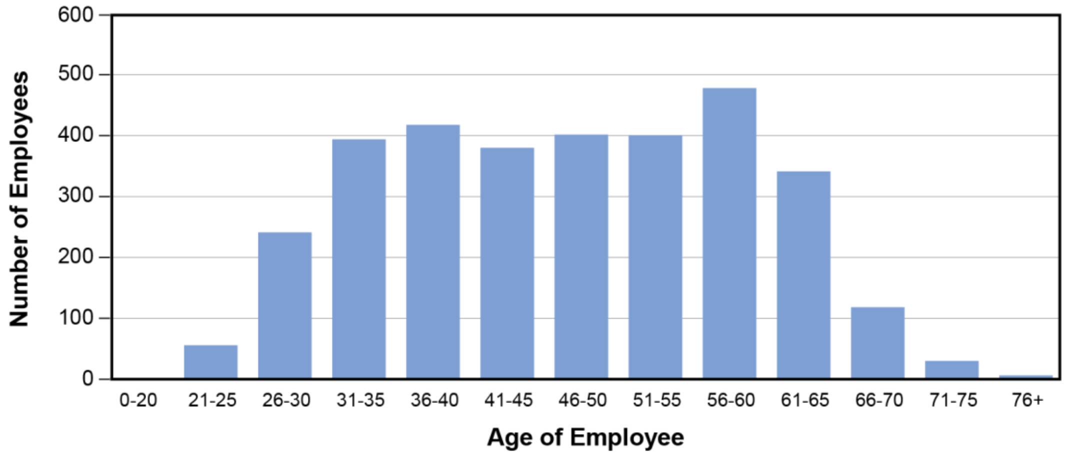
Pantex's headcount at the end of FY 2018 was 3,266. The population's average age is 47 years, and approximately 28 percent of the employees are retirement-eligible. Most employees are between 30 and 60 years of age. The average employee has 14 years of service; most employees have 1-5 years of service. Between the end of FY 2016 and FY 2018, Pantex had an overall increase of 20 employees. Retirement of older, advanced-career employees accounted for most of the separations, while younger, early-career employees accounted for more voluntary separations. A similar trend occurred in the years of service categories, with more retirements among those many years of service, and more voluntary separations among those with fewer years. Over the past few years, the number of mid-career employees has dipped, while early- and advanced-career employees have slightly increased. Pantex anticipates a headcount between 3,000 and 3,500 over the FYNSP period. Workforce demographics are illustrated and discussed in **Figures D–42** through **D–50**.



Notes:

Significant recruiting and hiring efforts replaced vacancies from attrition and built the technical skill base in preparation for the increased workload in FY 2019 and beyond. Attrition at Pantex remains between 5 and 6 percent. Competitive compensation and benefits are important factors in retention. On average, over 50 percent of separations are retirements. FY 2019 will focus on hiring in preparation for the increasing weapons workload. This will include acquiring the necessary security clearances and developing new talent. Pantex is over 98 percent funded by Defense Programs for core work. CNS saw an increase in its Common Occupational Classification System (COCS)-coded Engineers and a decrease in General Management and Scientists, partly as a result of CNS's Compensation Redesign efforts. In addition to efforts to hire Engineers specifically, during Compensation Redesign, managers were tasked with assigning job titles based on job scope; which resulted in a shift among COCS categories. CNS views this as a positive change, that enables having the technical skills needed to fulfill mission work.

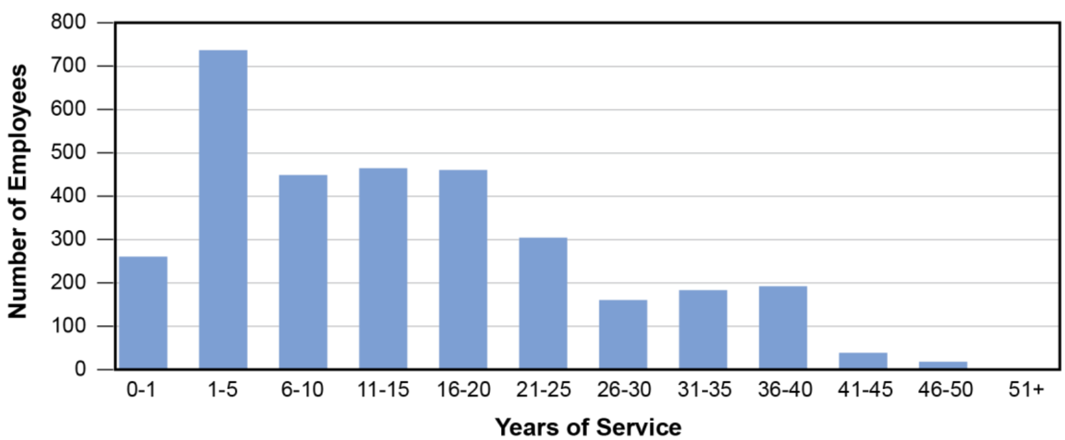
Figure D–42. Pantex total workforce by Common Occupational Classification System (as of September 30, 2018)



Notes:

The average age of the Pantex workforce is 47 years. The percentage eligible to retire at Pantex dropped from FY 2017 (30.22 percent) to FY 2018 (28.38 percent) because of increased hiring and replacement of retirees. Age diversity is well distributed. Pantex hires many retired veterans, which contributes to the experienced talent at the site, yet affects the average age of the workforce. Pantex was recognized by the Texas Workforce Commission and Texas Veterans Commission in 2018 as the large corporation "Veteran Friendly Employer" for the Panhandle area. Although employees are eligible to retire at age 55, the average age of those retiring is 65. Many are choosing to work past normal retirement age. Pantex remains one of the best employers in the area. Craft persons, labor, operators, technicians, and clerical staff are hired locally and tend to remain until retirement.

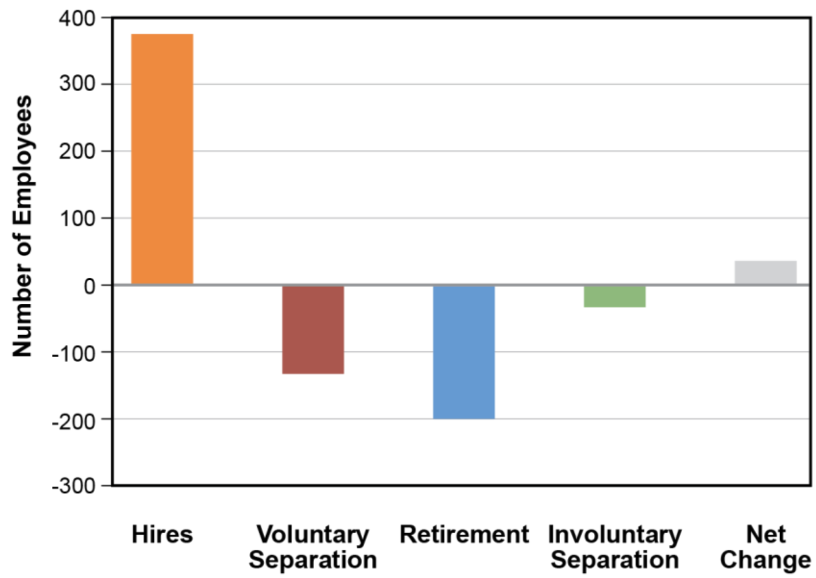
Figure D–43. Pantex employees by age (as of September 30, 2018)



Notes:

Weapons workload funding shifts from year to year, creating peaks and valleys in hiring. During peaks, large classes of Security Police Officers, production technicians, etc., are onboarded in classes of 25-40 at a time for group training. These positions are hired locally and employees stay for many years, creating groupings with the same years of service during hiring peaks. The valleys are created during years with lower funding and limited hiring. The current average term of service at the site is 14.15 years. The down side of hiring peaks is that employees hired at the same time reach retirement eligibility at the same time, creating potential gaps as they retire together in large numbers. Stable funding year to year would level hiring and more evenly distribute years of service and, ultimately, group retirements.

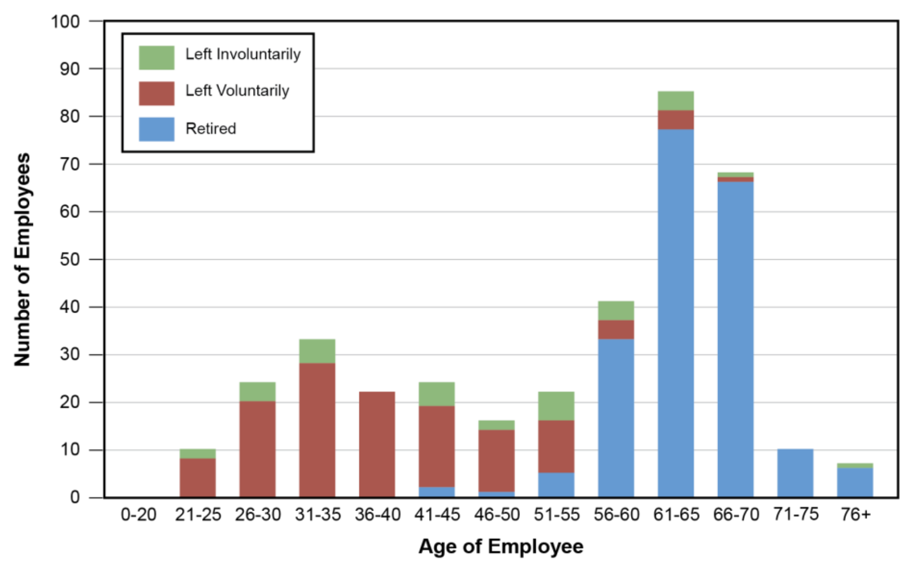
Figure D–44. Pantex employees by years of service (as of September 30, 2018)



Notes:

Fewer employees left voluntarily for other employment in FY 2018. Attrition remains between 5-6 percent. Over half of those who leave are retiring. Competitive pay and benefits aid in retention of talent. In addition, the new John C. Drummond Center administrative complex was completed in FY 2018, and 1,100 employees were able to move to new, modern offices and leave behind less desirable work spaces. Pantex conducted special hiring events in FY 2018 to ramp up hiring in preparation for the increased weapons workload in FY 2019.

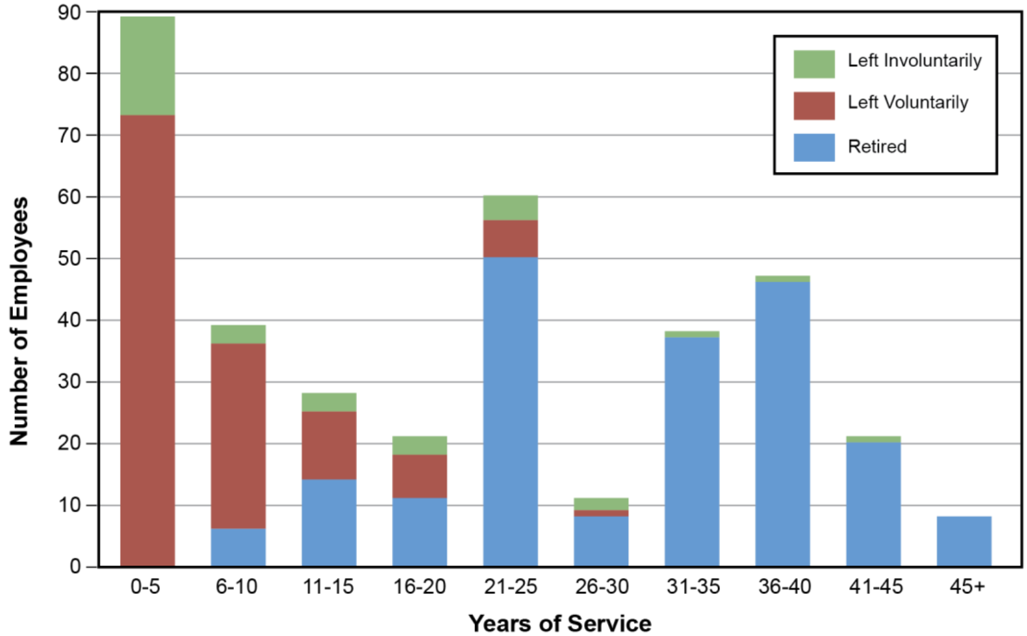
Figure D–45. Change in last 2 fiscal years at Pantex (October 1, 2016 to September 30, 2018)



Notes:

Those voluntarily separating under age 50 are typically engineers and professionals who are more mobile. Those retiring closer to age 65 are spread across all jobs and functions.

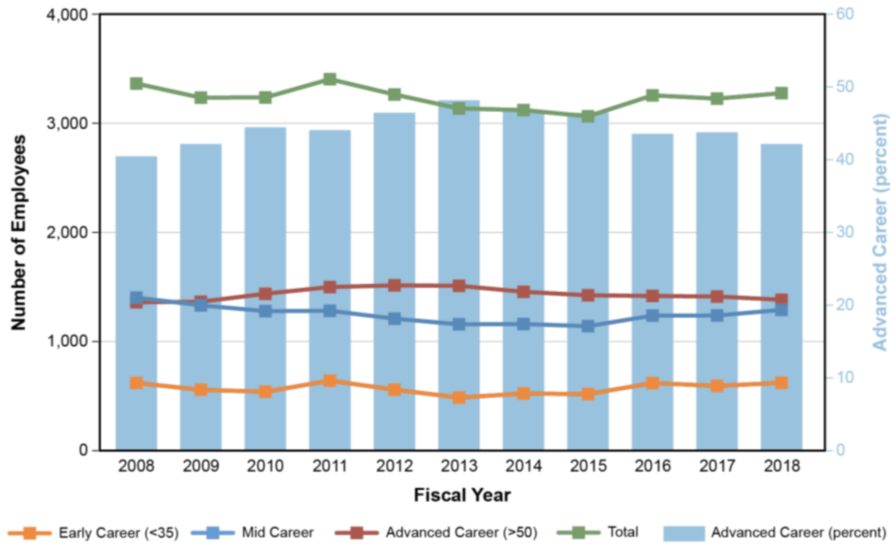
Figure D–46. Age of Pantex employees who left service (October 1, 2016 to September 30, 2018)



Notes:

The majority of those leaving from 0-5 years of service are engineers or professionals who were under age 35. Those leaving with over 20 years of service are typically over 60 years of age. Voluntary separations are usually earlier in the careers of mobile, new graduate professionals who are recruited nationally. Several factors impact retention for this group: (a) the location and commute are less desirable than that of the competition; (b) electronic restrictions for I-Phones, I-Pads, etc.; (c) waiting for security clearances can cause professionals to lose interest; and (d) other high-tech industries compete for the same skilled professionals needed at Pantex. To address these concerns, CNS has increased its presence at military and college career fairs; improved work environments with the new John C. Drummond Center administrative complex; implemented talent management opportunities for career development; enhanced mentoring of new engineers and technical personnel; improved clearance processing cycle time by increasing the number of investigators to address the volume of hiring; and redesigned compensation to attract and retain critical skills. The balance of Common Occupational Classification System-coded employees such as Technicians, Operators, Crafts, and General Administration are hired locally and tend to stay until retirement.

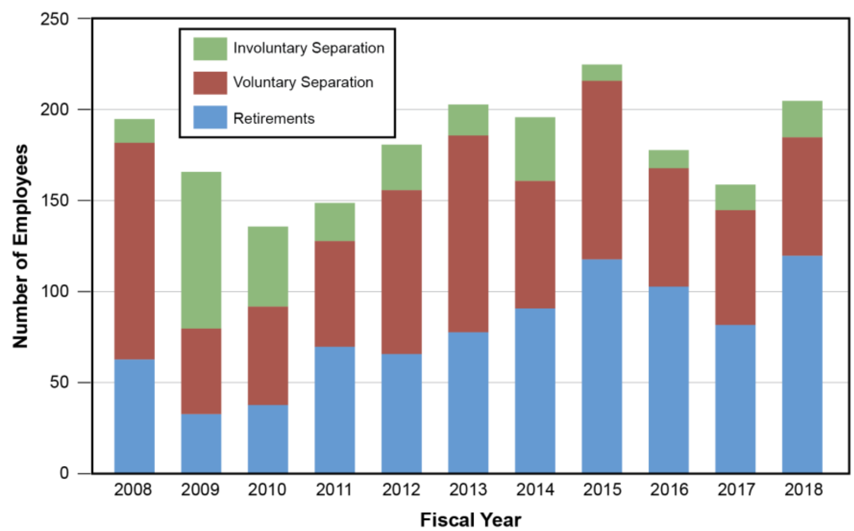
Figure D–47. Years of service of Pantex employees who left service (October 1, 2016 to September 1, 2018)



Notes:

Early careers grew in 2016 because of increased hiring for attrition replacement and the planned weapons workload. In the advanced career stage, employees are working longer, some into their 80s as health allows. The plant population has stayed between 3,000 and 3,400, depending on the workload and prioritization.

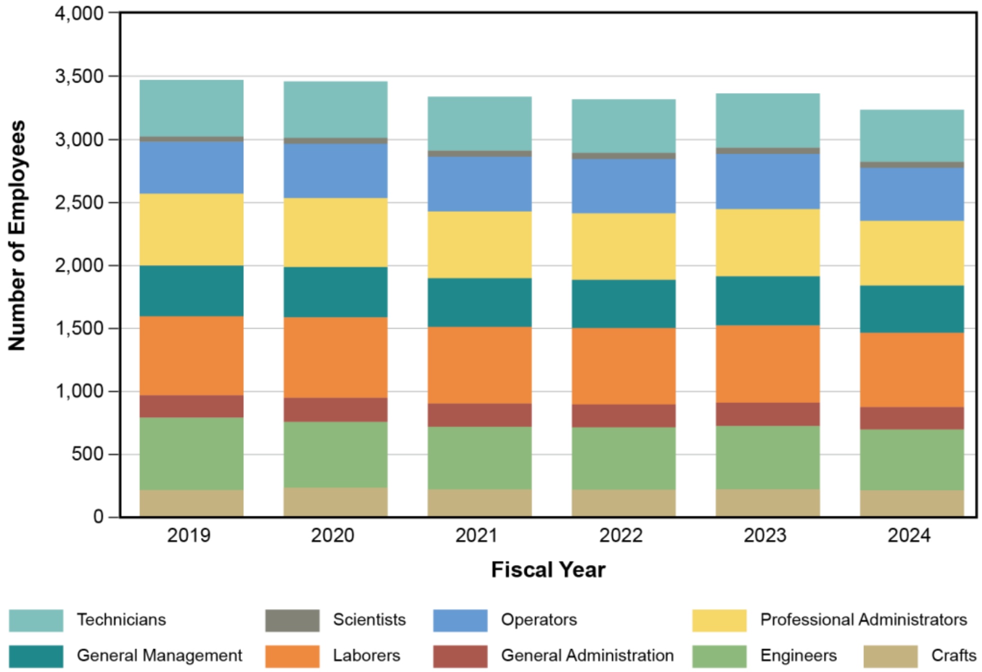
Figure D–48. Pantex trends by career stage (as of September 30, 2018)



Notes:

In recent years, attrition and the percentage of employees leaving voluntarily has decreased. The trend shifted from approximately 30 percent retirees to over 50 percent retirees as a percentage of attrition. This trend is a positive indicator that retention efforts are working. There were small voluntary separation programs in 2009, 2010, and 2017, as shown in the higher numbers of involuntary separations in those years. The economy dipped at the end of FY 2008, causing employees to postpone retirement, as seen by the lower attrition rates in 2009 and 2010 and the more recent increase in retirements. The boom in oil, gas, and alternative energy increased attrition in FY 2015 and tapered off in FY 2016 through FY 2018. Pantex typically experiences higher attrition for Engineers and Professional Administrators. Classifications such as Technicians, Operators, Crafts, and General Administration are hired locally and have lower attrition rates, as they have established family roots in the area and perceive Pantex as one of the best employers in the area.

Figure D–49. Pantex employment separation trends (as of September 30, 2018)



Notes:

The total estimated number of full-time permanent employees will increase to 3,436 in FY 2019. The plant population at the end of FY 2018 was 3,266, with approximately 110 pending or open requisitions, mostly for Engineers, Professionals, Technicians, Crafts, and Laborers (Security). The additional hires will replace attrition and build the workforce to support the increase in production and infrastructure workload in FY 2019 and and beyond. Technicians and craft persons are typically filled quickly from the local market and military. Engineers and Professional Administrators are recruited from job fairs and universities. Internal realignment is used in some cases to fill critical vacancies. Plant attrition is 5-6 percent overall. Craft persons, technicians, and administrative staff have lower attrition rates (less than 5 percent), while Engineers have higher attrition at 9 percent. This higher attrition is an ongoing concern, as other technologies are competing for the limited market of Engineers and technology majors nationally. Based on current hiring/termination statistics, Pantex anticipate gaps in engineering, tooling, and explosives technology in the next 10 years. Pantex is working closely with area universities and military bases to help fill the pipeline for Engineers and technology majors for years to come.

Figure D–50. Total projected Pantex workforce needs by Common Occupational Classification System over the FYNSP period (as of September 30, 2018)

D.3.3 Savannah River Site

D.3.3.1 Mission Overview

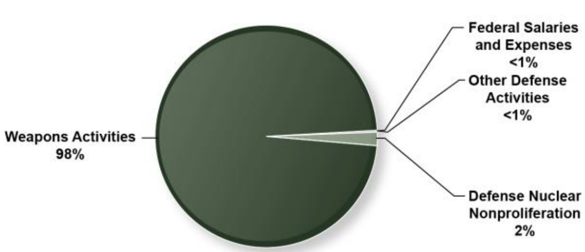
The Savannah River Site (SRS), which spans Aiken, Allendale, and Barnwell Counties in South Carolina, includes mission areas in tritium supply, stockpile maintenance, stockpile evaluation, tritium R&D, and helium-3 recovery.

- Location: Aiken, South Carolina
- Total Employees: 635 direct tritium personnel, plus 889 in site support (as of the end of FY 2018)
- 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 (Fluor, Honeywell, Huntington Ingalls Industries)
- Responsible Field Office: Savannah River Field Office

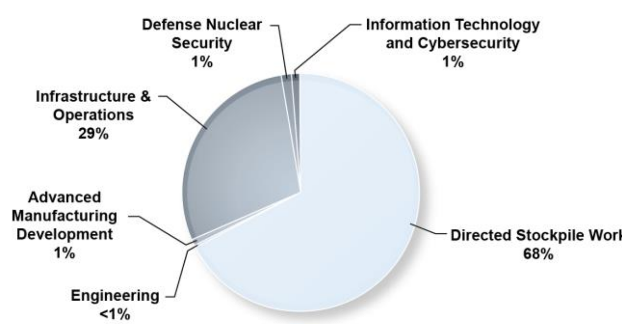
SRS tritium operations are tightly integrated with activities at Savannah River National Laboratory, a DOE Environmental Management Laboratory that also supports NNSA's Offices of Defense Programs, Defense Nuclear Nonproliferation, Emergency Operations, and Counterterrorism and Counterproliferation; DOE's Office of Intelligence and Counterintelligence; DoD's Defense Threat Reduction Agency; the Department of Homeland Security; and the International Atomic Energy Agency.

D.3.3.2 Funding

FY 2020 request – site funding by source
(total SRS FY 2020 request = $2,901 million)



FY 2020 FYNSP request for Weapons Activities
($2,839 million)



D.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 for the United States and its allies. Tritium is a critical component of the Nation's defense systems and must be continually replenished to meet the needs of the U.S. nuclear deterrent. SRS conducts large-scale tritium operations, and the SRS Savannah River Tritium Enterprise (SRTE)[1] is the DOE/NNSA Center of Excellence Involving Large Quantities of Tritium. To sustain the tritium inventory, tritium is recovered from two sources at SRS. One source is end-of-life GTS reservoirs that are returned to SRS. Another source is irradiated tritium-producing burnable absorber rods (TPBARs) received from the Tennessee Valley Authority. SRS's key capabilities and associated challenges and strategies are described in **Table D–6**.

Table D–6. Savannah River Site Capabilities

Tritium Recycling (Material Recycle and Recovery Program)	
Systems for recovering and recycling tritium from returned GTS reservoirs.	
Challenges	***Strategies***
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.	SRTE has short-term and long-term strategies for addressing the challenge of system replacements: • 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 Sustainment Program)	
Tritium extraction from irradiated TPBARs.	
Challenges	***Strategies***
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.
Tritium extraction requires the elimination of impure waste gas. Under current conditions, disposition of this gas is managed through a system obligated to multiple functions. This overdependence on critical infrastructure creates an increasing schedule constraint.	SRTE is executing a small project that will alleviate some dependency on existing resources by allowing waste gas to be managed safely at the source rather than transferred to another facility for disposition.
Replenishing Tritium in Gas Transfer System Reservoirs	
Replenishing tritium in GTS reservoirs.	
Challenges	***Strategies***
Maintain facilities and equipment to support stockpile deliverables and future Alts, Mods, and LEPs.	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. DOE/NNSA's strategy to revitalize the SRTE infrastructure is to (1) relocate and right-size the remaining operational functions from functionally obsolete facilities into existing and new space via

[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.

	the Tritium Responsive Infrastructure Modifications (TRIM) program and (2) recapitalize and sustain enduring facilities.[2] TRIM consists of one line-item project (the Tritium Finishing Facility, formerly the Tritium Production Capability) and a suite of general plant and operating expense-funded projects. Work to achieve CD-1 (Approve Alternative Selection and Cost Range) was halted in FY 2018 and is expected to resume in FY 2019. To address the capacity issue, SRTE will modify the process and infrastructure equipment in multiple facilities and evaluate alternative options for some production areas.
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.
Gas Transfer System Surveillance	
SRTE function testing for GTS surveillance and tritium R&D.	
Challenges	***Strategies***
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.
Tritium Research and Development	
SRTE function testing for GTS surveillance and tritium R&D.	
Challenges	***Strategies***
Provide dedicated R&D capacity for stockpile maintenance, stockpile evaluation, and operations workload in support of new technologies while maintaining and recapitalizing facilities and infrastructure.	SRTE will continue to develop planning options with DOE/NNSA to balance operational and R&D needs and fiscal resources. Current planning is focused on a Tritium Development Laboratory and several smaller new buildings to replace old infrastructure.
Helium-3 Recovery	
Recovering, purifying, and bottling helium-3, the byproduct of tritium decay.	
Challenges	***Strategies***
None	SRTE will continue to maintain and use this capability to meet U.S. Government needs.

Alt = alteration
AoA = Analysis of Alternatives
CD = Critical Decision
GTS = gas transfer system
LLC = limited life component
Mod = modification
SRTE = Savannah River Tritium Enterprise
TPBAR = tritium-producing burnable absorber rods

[2] The preferred alternative from DOE/NNSA's CD-1 AoA for the Tritium Finishing Facility project specifies two new facilities with a combined maximum footprint of 24,000 square feet.

D.3.3.4 Accomplishments

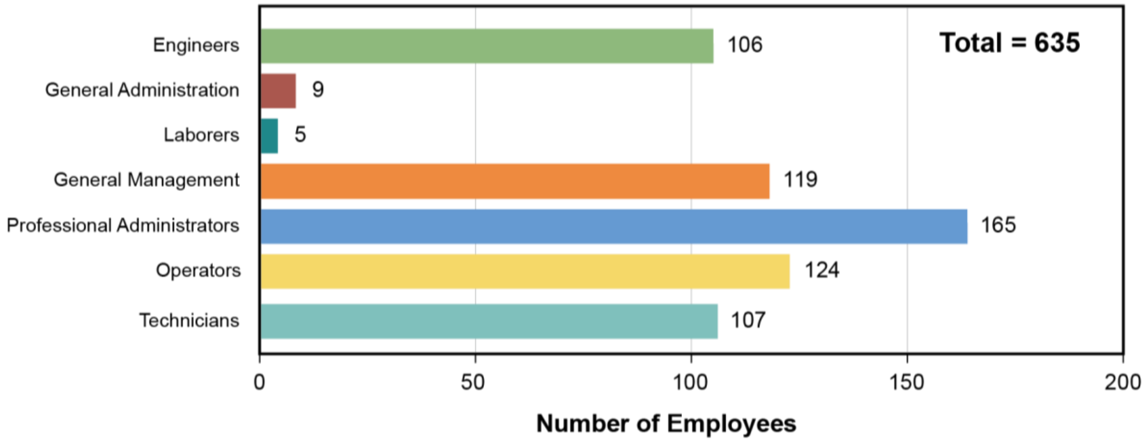
- SRTE reached over 3.2 million safely worked man-hours and improved conduct of operations with no Technical Safety Requirements violations.
- SRTE performed extractions on 600 TPBARs and met established goals safely and ahead of schedule.
- SRTE reduced the average number of days to obtain the necessary Q clearance by 22 percent through targeted hiring, process change, and the use of expedited clearances. On average, SRTE put employees to work 41 days earlier than the previous year.
- SRTE increased small project execution in FY 2018 by 78 percent over FY 2017, and five-fold from FY 2015 in preparation for the upcoming increased production period (FY 2020 – FY 2024), when production requirements will be markedly higher than previous operating levels.
- SRTE replaced its Function Test Station Data Acquisition System to improve reliability and flexibility for future missions. Savannah River National Laboratory also developed a streamlined method to calculate component statistics that reduces the potential for human error.
- Savannah River National Laboratory procured, received, installed, and placed into service an electron beam additive manufacturing metal printer to produce specialized parts in support of defense program activities.

D.3.3.5 Savannah River Site Tritium Workforce

SRTE has 635 employees, with an average age of 45 years. In FY 2018, the employee years-of-service distribution reversed from previous years: 55 percent have less than 10 years of SRS site experience and 41 percent have over 25 years of service. Approximately 15 percent of SRTE's employees are eligible to retire. Since FY 2016, approximately 400 employees were hired or transferred into SRTE reducing and mitigating the loss of knowledge risk associated with an aging workforce. SRTE achieved 101 percent of its staffing goal and ended the year with a net increase of 85 employees. A total of 134 people were hired. The SRTE attrition rate held to 9.8 percent versus the projected rate of 14 percent. This included retirements, terminations, and transfers to other parts of SRS.

SRS is unique relative to other NNSA sites across the complex because it is managed by the DOE Office of Environmental Management. Approximately 10 percent of the M&O workforce is dedicated to the defense mission. DOE/NNSA pays its share of an indirect allocation of M&O personnel to maintain infrastructure and services (e.g., roads, streams, fire water, electricity, medical, emergency personnel). The scope of Defense Programs work resides in the SRTE organization, which is managed as a severable entity within SRS.

To speed the clearance and qualification process, SRTE used an expedited clearance process and put an unclassified training simulator into operation to train personnel awaiting clearances. Advance hiring to provide adequate staffing and knowledge transfer can conflict with budgetary restriction. Addressing the budgetary constraint is critical. SRS's Engineering Leadership Development Program and targeted recruiting of Navy candidates with previous nuclear experience attracted higher quality candidates, many of whom already held DoD clearances. Workforce demographics are illustrated and discussed in **Figures D–51** through **D–59**.

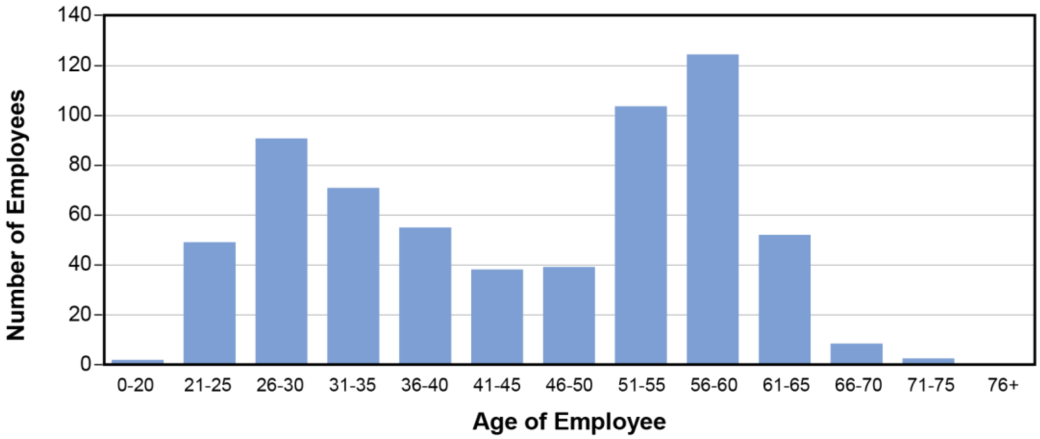


Notes:

With an aggressive strategic hiring plan and steady attrition, the majority of the workforce within SRTE has been stable over the past 2 years. In FY 2018, hiring focused on critical roles required for mission success. Actual attrition was lower than predicted, and SRTE did not experience an anticipated spike in retirement. As the workforce continues to age, replacements are hired who are not pension-eligible; therefore, retention is more difficult. Employee engagement, focus on the national security mission, and efforts to create a compelling workplace are focus points for SRS. Failure to reach and maintain mission-essential staffing in key positions is a risk. SRTE places hiring priority on the top 10 critical positions and remains focused on mission-essential staffing levels in those positions. Attrition at SRTE has been low and primarily reasons related to promotional opportunities at other facilities within SRS. Competition for skilled nuclear workers has diminished because of decreased demand and financial upset in the regional commercial nuclear industry.

Numbers in the Professional Administrators Common Occupational Classification System category increased from FY 2017 because those positions were realigned from the General Administration category.

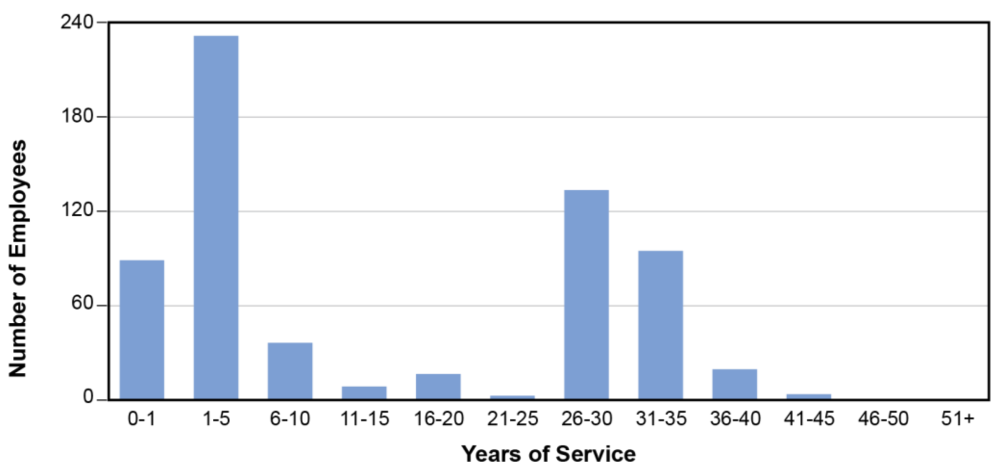
Figure D–51. SRTE total workforce by Common Occupational Classification System (as of September 30, 2018)



Notes:

In FY 2018, the average employee age decreased from 47 to 45 years old. The average age of personnel hired within the last 5 years is 35 years. SRTE-Tritium is addressing workforce replacements to hire, clear, train, and qualify new employees as experienced employees leave the organization. The focus has also expanded to engagement, development, and retention of new employees and knowledge transfer and preservation. SRTE implemented Knowledge Preservation Management software and continues initiatives to retain legacy knowledge. Retirement eligibility has decreased by 3 percent and remains steady. The end of the M&O contract and expanding missions on site could pose a risk. Fifteen percent of the SRTE workforce will be fully retirement-eligible by 2019. To understand the full effect of potential retirements, SRS's NNSA Operations and Programs office updated retirement eligibility and risk analyses, adding Social Security Administration retirement eligibility to the existing pension eligibility as the primary factor to retirement risk.

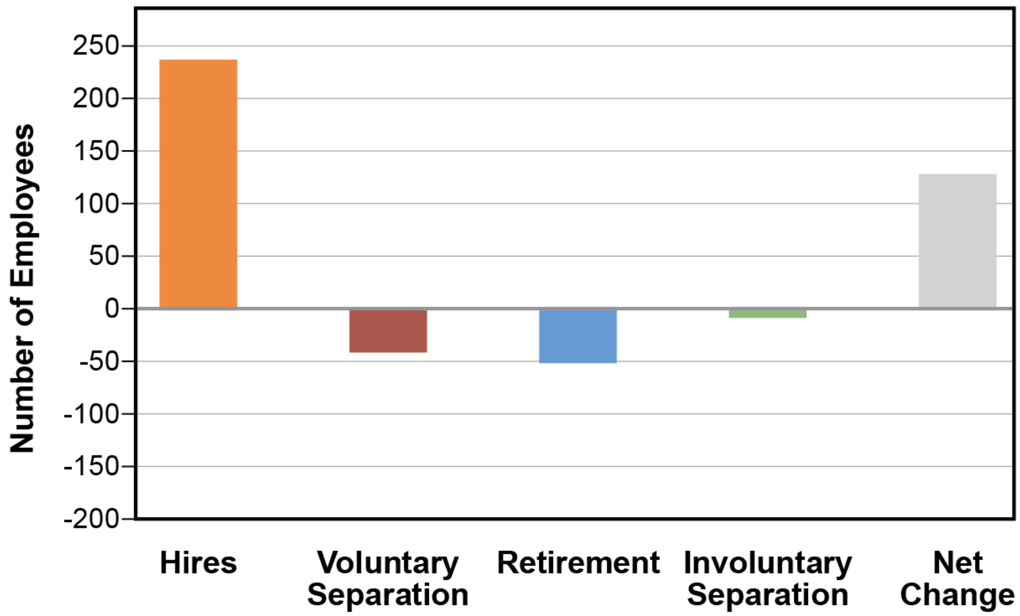
Figure D–52. SRTE employees by age (as of September 30, 2018)



Notes:

The SRTE workforce is in transition. Forty percent of the SRTE workforce has between 21-45 years of experience—a 10 percent decrease from the previous year. Additionally, 51 percent of the workforce has between 0-5 years of service. SRTE has continued aggressive strategic hiring focused on key critical positions, including control room operators, shift operations managers, first line managers, and trainers. SRTE will face steady retirements over the next 5 to 8 years, with an anticipated increase associated with M&O contract transition. Forty percent of the workforce has over 26 years of experience, a decrease of 8 percent from the previous year.

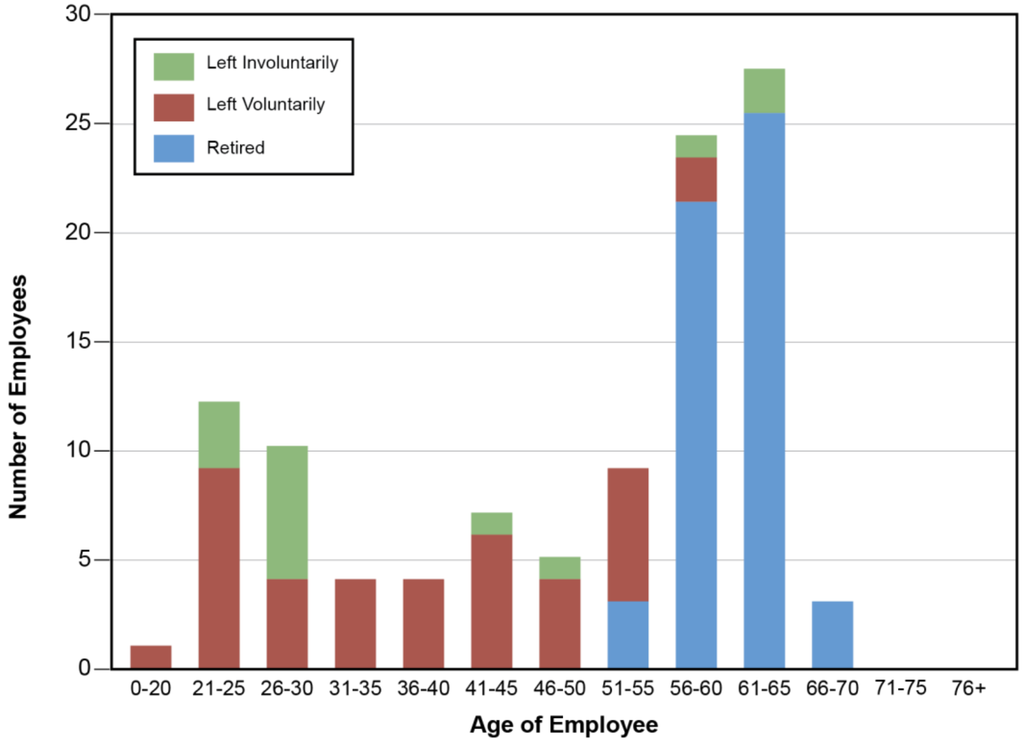
Figure D–53. SRTE employees by years of service (as of September 30, 2018)



Notes:

In FY 2018, hiring for SRTE exceeded its strategic staffing plan in terms of the number hired and the quality of new hires. Attrition was steady, but below expectations, with most leaving for retirement followed by those finding promotional opportunities within SRS. Significant workforce competition was curtailed following redirection in the regional commercial nuclear industry, but could become a concern again. SRTE will also face competition from other missions located at SRS. Hiring key critical positions and keeping new employees engaged in meaningful work until clearances are awarded will continue to be a challenge. With termination of the Mixed Oxide Fuel Fabrication Facility project, the opportunity exists to hire cleared employees with an understanding of the SRS mission. The challenge is to have sufficient funding to hire workers in advance of need. To motivate, recognize, and compensate employees in certain critical positions, SRTE implemented leadership engagement opportunities, retention bonuses for control room operators, and certification stipends. Expediting clearances has decreased overall clearance time, with most employees able to get an L clearance within 6 months and a Q clearance within 1 year. A Tritium-specific New Employee Orientation was implemented in FY 2018 to introduce new hires to the tritium mission and reinforce the importance of the SRTE workforce in mission success.

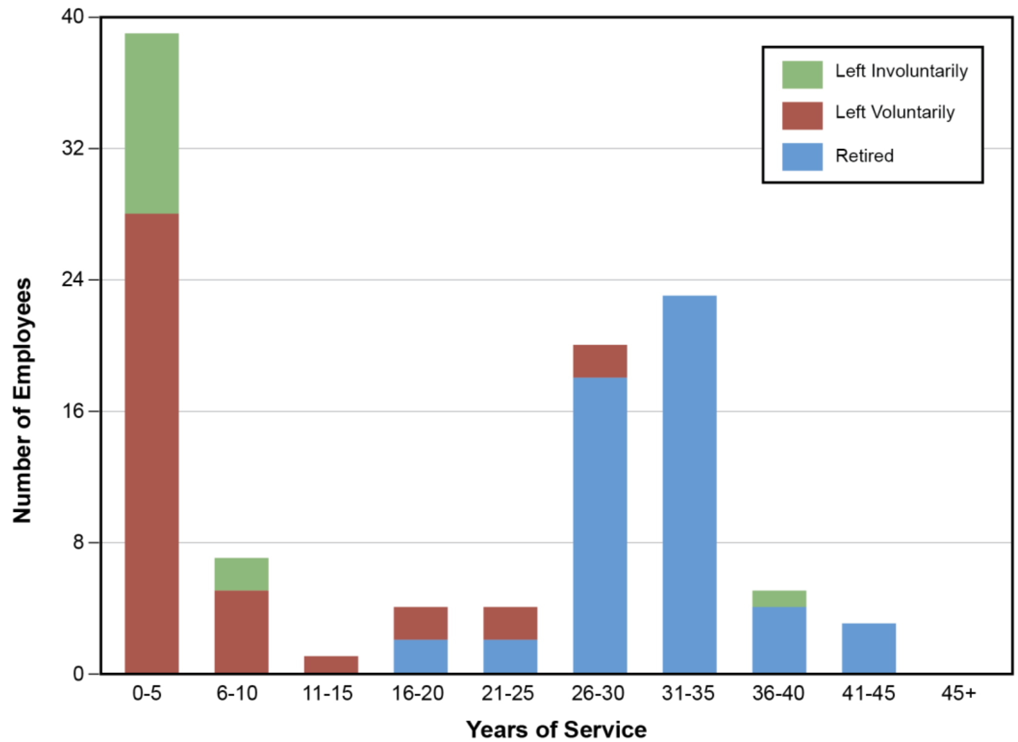
Figure D–54. Change in last 2 fiscal years at SRTE (October 1, 2016 to September 30, 2018)



Notes:

Attrition remained steady in FY 2018, but was less than forecast. Retirement accounted for over 50 percent of all attrition in FY 2018, slightly higher than the prior year. However, there was no spike in retirements as projected. Overall, retirement and voluntary attrition decreased slightly from the prior year, while involuntary attrition decreased significantly. Eight of the 19 voluntary transfers out of SRTE to SRS were for promotions and salary increases. The remainder were for family relocation and personal reasons. Attrition is expected to remain steady and may increase because of M&O contract turnover and as new opportunities arise on site. Managing attrition from key critical positions remains a priority, as well as the ability to hire ahead of need, to allow time for the required clearance and training to occur. SRTE continued to enhance the screening and onboarding processes to identify candidates who may be more aligned to the work that is performed and those who may be more successful in the onboarding and clearance processes. Over the past 2 years, these improvements resulted in no attrition among the 48 non-exempt operators hired. SRTE will also need to hire operators in advance of need to allow existing operators to develop into more senior positions.

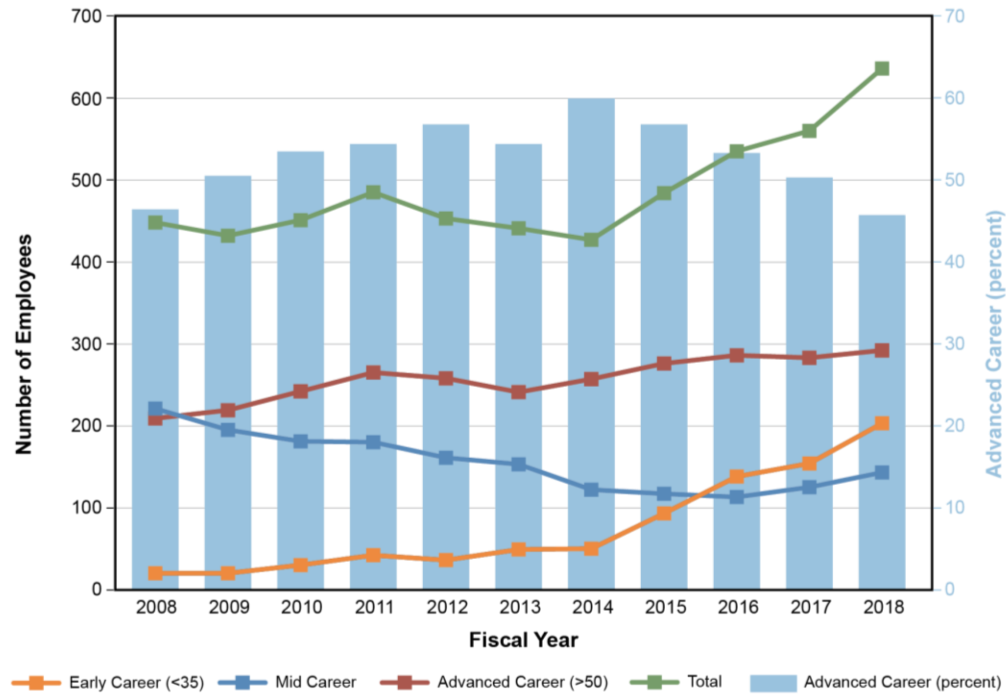
Figure D–55. Age of SRTE employees who left service (October 1, 2016 to September 30, 2018)



Notes:

SRTE experienced a steady level of retirement occurring among employees with 26-35 years of service. There were no concerning trends. Employees leaving voluntarily within the 0-5-year category decreased and separations were primarily related to promotional opportunities on site with associated pay increases. The focus was on continuing retention strategies for early-career employees. Engagement initiatives, including New Employee Orientation, leadership development, and mission-driven focus, are having a positive impact on worker retention.

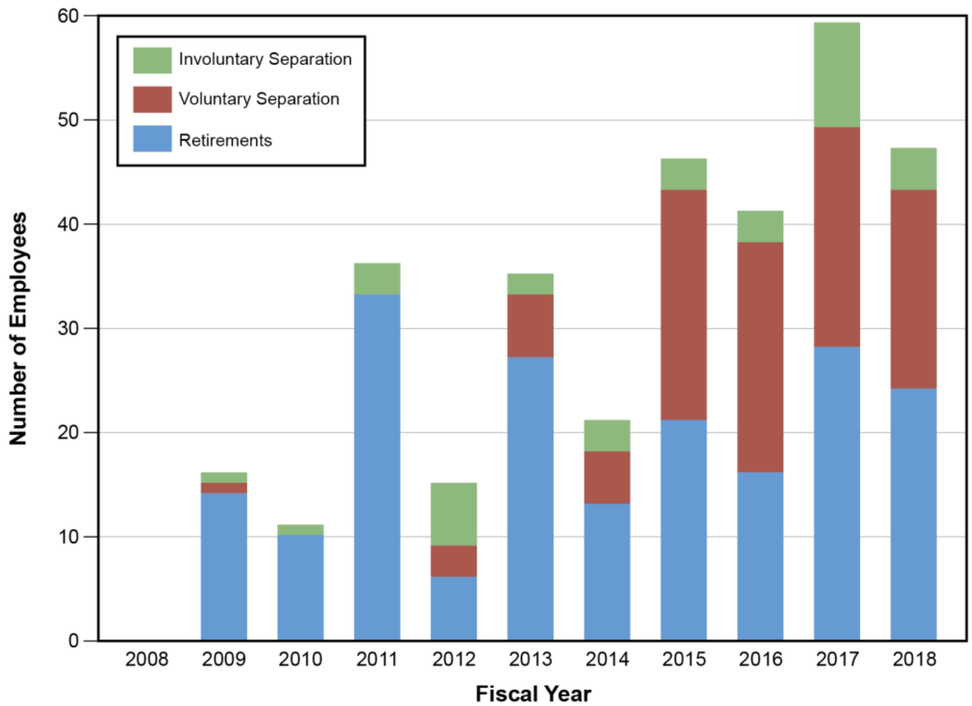
Figure D–56. Years of service of SRTE employees who left service (October 1, 2016 to September 30, 2018)



Notes:

The early-career workforce continues to increase and has surpassed the advanced-career workforce. In FY 2018, the advanced-career workforce continued to hold steady. Leadership training and retention of early-career hires has resulted in an improved number of mid-career employees. In addition, SRS supports a program designed to provide networking and professional development opportunities for mid-career employees. The goal is to cultivate quality talent and recruit leaders to fill future needs.

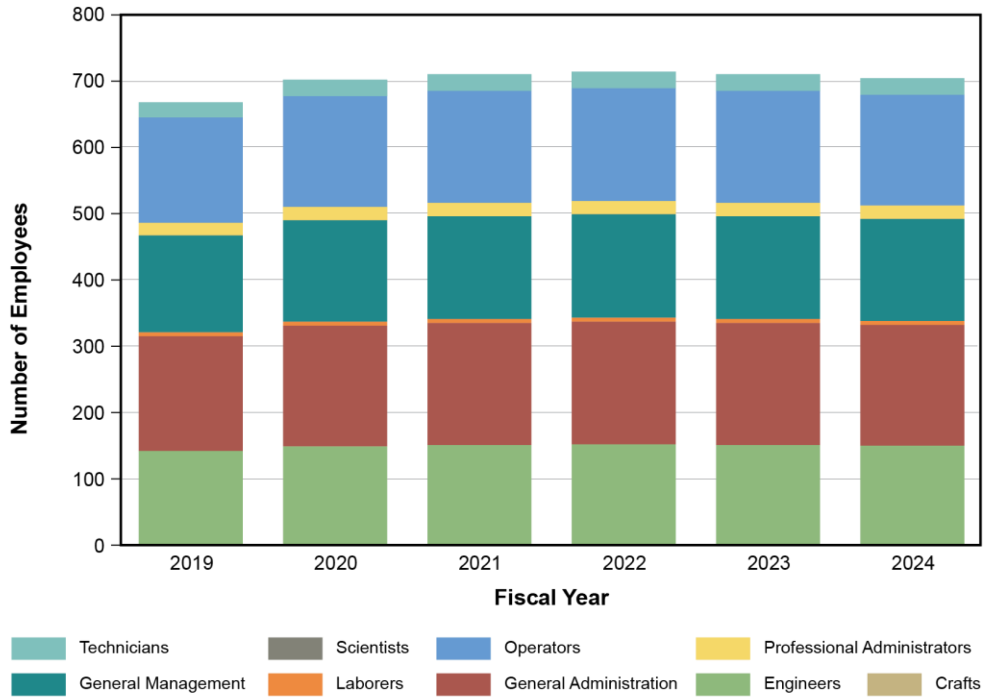
Figure D–57. SRTE trends by career stage (as of September 30, 2018)



Notes:

Workforce retirement is expected to remain steady over the next 5 years. To prepare for the increased production period (FY 2020–FY 2024), SRTE continues to plan and execute workforce growth commensurate with mission requirements to recapitalize process equipment and surrounding infrastructure, increase GTS work scope due to the LEPs, and offset expected retirements with time allowances for clearance and training processes. SRTE-Tritium will continue to hire replacements and to accommodate the increased work scope and will retain the new employees by providing meaningful work, leadership engagement, development opportunities, and a compelling place to work.

Figure D–58. SRTE employment separation trends (as of September 30, 2018)



Notes:

SRTE will experience mission growth because of an increase in Tritium Extraction Facility production, project activity (line item and minor construction projects), maintenance on aging facilities and infrastructure, and implementation of Nuclear Enterprise Assurance requirements. SRTE will also experience growth in reservoir processing and surveillance because of the complexity of new LEPs. SRTE must continue to manage increased attrition (retirements and resignation) and employee retention. If an adequate number of personnel cannot be obtained and cleared prior to the retirement of qualified experienced personnel, SRTE will have a gap in mission support.

Figure D–59. Total projected SRTE workforce needs by Common Occupational Classification System over the FYNSP period (as of September 30, 2018)

D.3.4 Y-12 National Security Complex

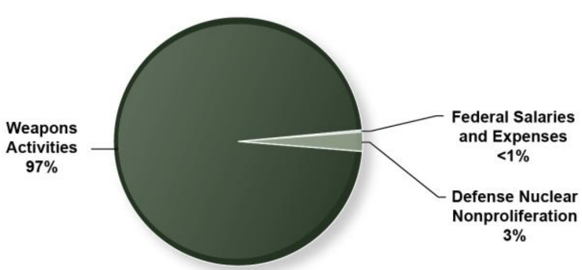
D.3.4.1 Mission Overview

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 is 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.

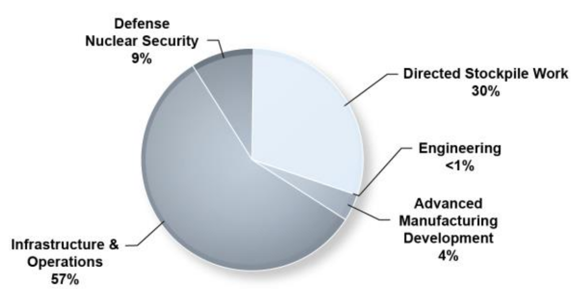
- Location: Oak Ridge, Tennessee
- Total Employees: 4,632 (as of the end of FY 2018)
- Type: Multi-program nuclear weapons production facility
- Website: www.y12.doe.gov
- Contract Operator: Consolidated Nuclear Security, LLC (CNS), a corporate subsidiary of Bechtel National, Leidos, ATK Launch Systems, and SOC, LLC
- Responsible Field Office: NNSA Production Office

D.3.4.2 Funding

FY 2020 request – site funding by source
(total Y-12 FY 2020 request = $1,942 million)



FY 2020 FYNSP request for Weapons Activities
($1,889 million)



D.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 D–7**.

Table D–7. Y-12 National Security Complex Capabilities

Uranium and Canned Subassembly Production Capability	
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 also 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.	
Challenges	***Strategies***
To continue supporting all uranium missions, Y-12 must address its aging infrastructure. Buildings 9215 and 9204-2E are aging and require sustainment through the Extended Life Program. Enriched uranium capabilities must be maintained while the Uranium Processing Facility is being constructed. This requires relocation of enriched uranium functions to other Y-12 facilities and startup and proving of replacement technologies before uranium programmatic operations cease in Building 9212 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.	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 Buildings 9204-2E and 9215.
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 lithium capabilities are housed in Building 9204-2, a Manhattan Project facility built in 1943. The facility infrastructure is well beyond its expected life and is deteriorating rapidly. The process equipment is oversized for today's missions, is also deteriorating rapidly, and has significantly exceeded its life expectancy. In addition, lithium production capabilities will be strained even more because of material availability issues and future increases in mission goals. The age of the infrastructure and the limited material supply pose significant risks to meeting mission deliverables.	Because of the serious degradation of the existing lithium production infrastructure and limited material supply, implementation of the lithium strategy requires DOE/NNSA to sustain the current infrastructure; sustain the supply to meet customer demand; mature and deploy technologies to replace hazardous processes; and develop and deploy the new Lithium Processing Facility line item project to replace Building 9204-2 lithium process capabilities.
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***
Aging electrical, water distribution, and other process support systems in Y-12's infrastructure put mission work at risk as the infrastructure continues to age.	Y-12 is evaluating potential strategies to sustain and ensure material and process R&D capabilities, including moving operations, engineers, and scientists to more modern facilities. Y-12 is implementing electrical and water system recapitalization projects to address these issues.

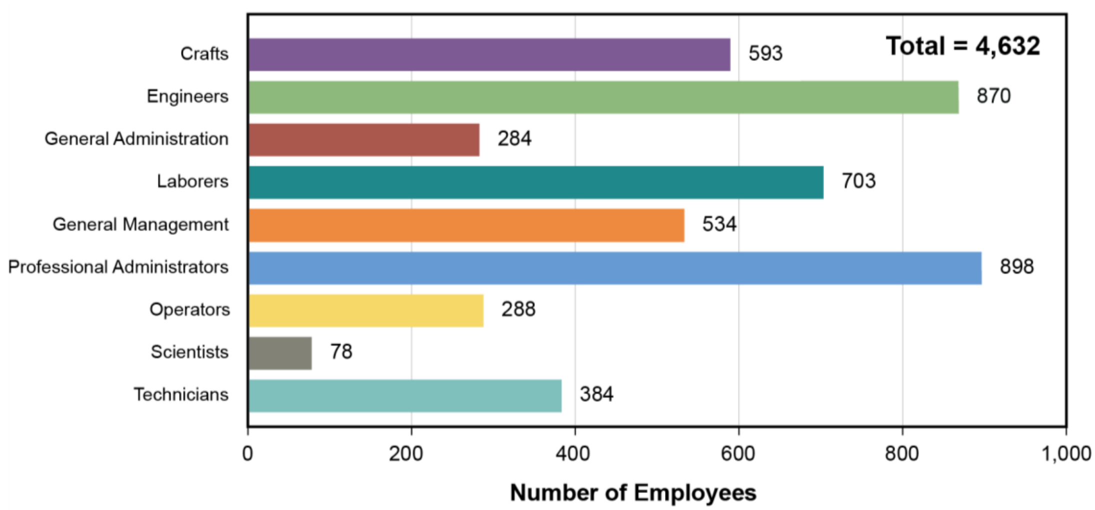
HEU = highly enriched uranium
JTA = joint test assemblies

D.3.4.4 Accomplishments

- Exceeded FY 2018 baselined production deliverables.
- Processed the highest number of canned subassemblies for Stockpile Systems surveillance in the past 6 years.
- Completed the first production unit for the W88 Alt 370 component 15 months ahead of the system first production unit.
- Initiated assembly of the first B61-12 War Reserve canned subassemblies.
- Began construction on the Uranium Processing Facility project.

D.3.4.5 Y-12 National Security Complex Workforce

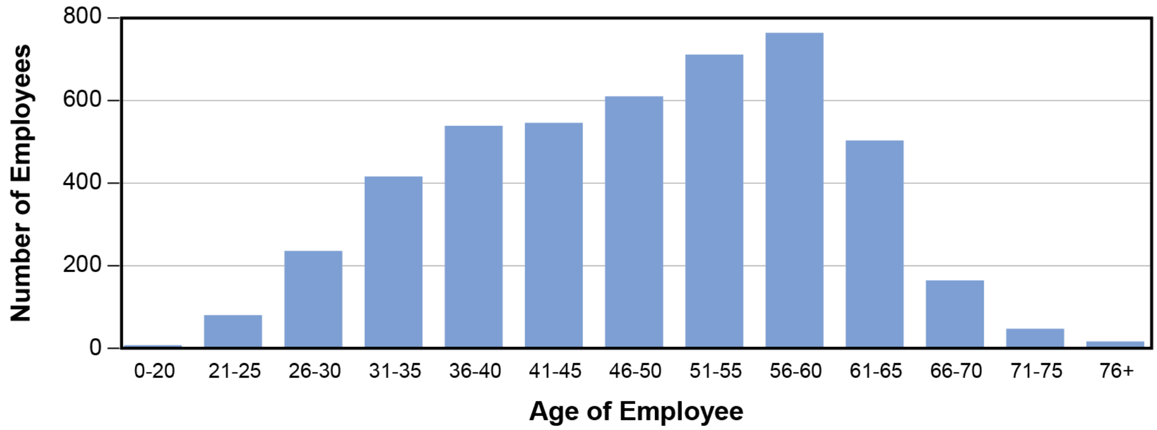
Y-12 has 4,632 employees. The Y-12 workforce's average age is 49 years old, and 37 percent are retirement-eligible. Y-12 is replenishing its workforce for future needs, and half of the population has 10 years or less of service. The average amount of years of service is 13 years. Approximately 45 percent of Y-12's employees are eligible to retire. Most separations are retirements, with about 70 percent of separations occurring at age 56 and above; however, a large number of voluntary separations occur among those with 0-5 years of service. Since FY 2016, the early-career population has increased because of increased hiring, while retirements have led to a slight decrease in the advanced career population. Y-12 anticipates slight increases in the overall population over the FYNSP period, especially from FY 2020 through FY 2022. Workforce demographics are illustrated and discussed in **Figures D–60** through **D–68**.



Notes:

The headcount has stayed consistent this reporting period compared to the last reporting period. CNS saw an increase in our Common Occupational Classification System (COCS)-coded Engineers and a decrease in General Management and Scientists, partly as a result of CNS Compensation Redesign efforts. In addition to hiring efforts within Engineering specifically, during Compensation Redesign, managers were tasked with assigning job titles based on job scope; this resulted in a shift among COCS categories. Y-12 views this as a positive change, enabling CNS to have technical skills needed to fulfill mission work.

Figure D–60. Y-12 total workforce by Common Occupational Classification System (as of September 30, 2018)

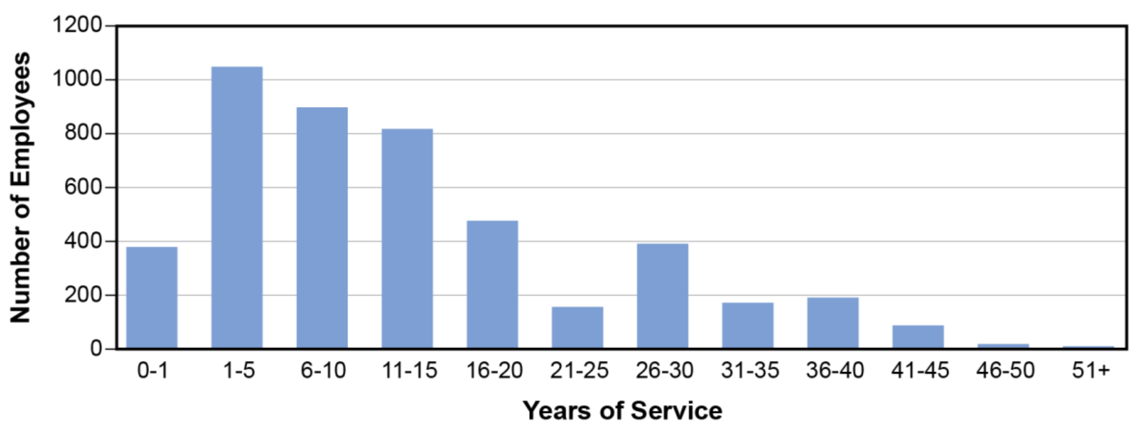


Notes:

Many employees elect to work beyond their earliest eligibility retirement age, as reflected in Y-12's low attrition rate. This demographic shows that Y-12 is steadily replacing the workforce as employees leave. The average age of employees is 48.5, and 52 percent of the workforce are age 50 or below.

The percentage of retirement-eligible employees provided is based on the number of participants eligible to participate in the defined benefit pension plan and enhanced 401k contribution plan.

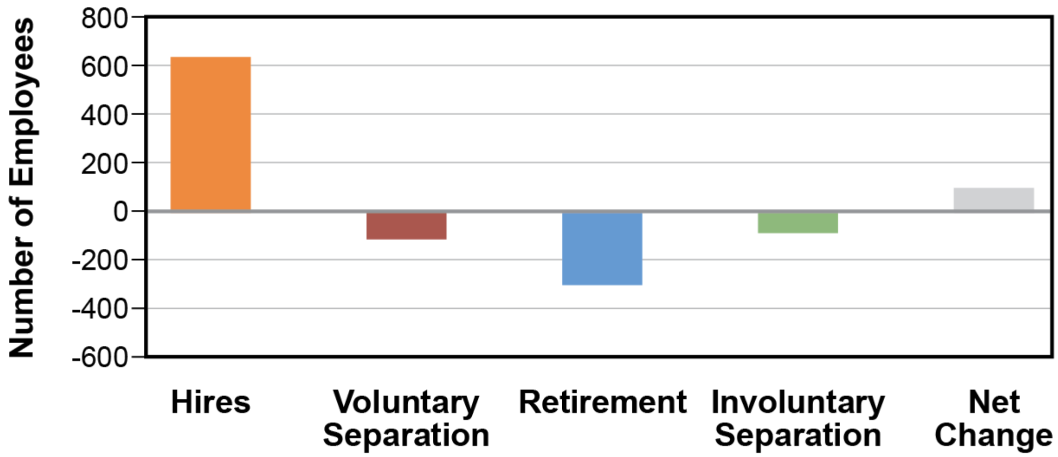
Figure D–61. Y-12 employees by age (as of September 30, 2018)



Notes:

The average years of service at Y-12 is 13.06 years; 50 percent of the population have 10 years or less of service, indicating that Y-12 is replenishing its workforce for future needs. At this time, attrition remains low, thereby facilitating Y-12's ability to retain a skilled workforce.

Figure D–62. Y-12 employees by years of service (as of September 30, 2018)

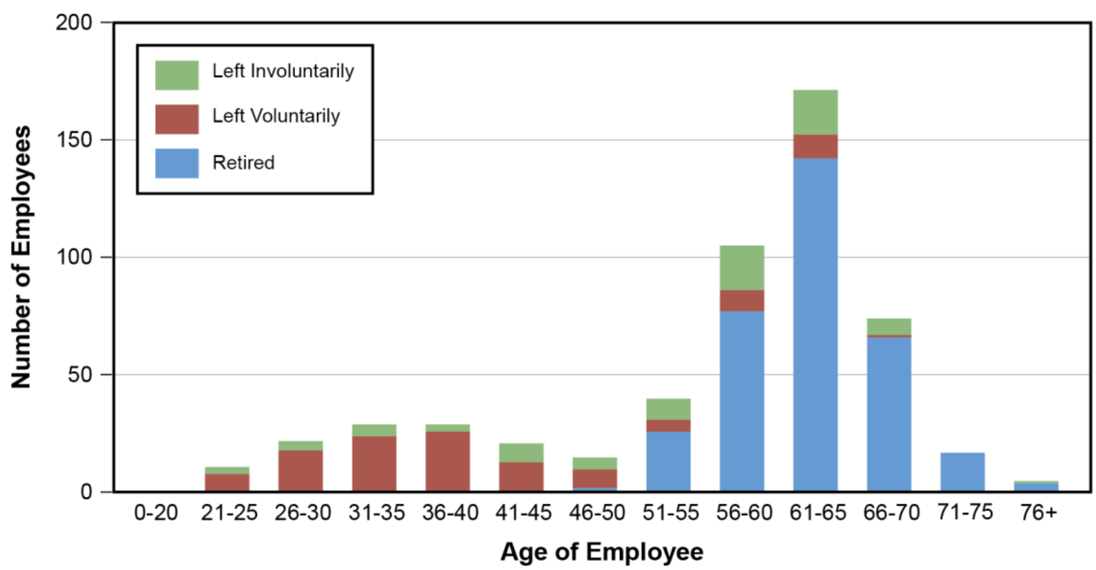


Notes:

The net change was positive over this reporting period because of increased hiring. Over half of those who leave are retiring. Competitive pay and benefits aid in retaining talent.

As counted in years past, involuntary separation includes people who died, those who went out on disability, and those who were terminated for cause.

Figure D–63. Change in last 2 fiscal years (October 1, 2016 to September 30, 2018)

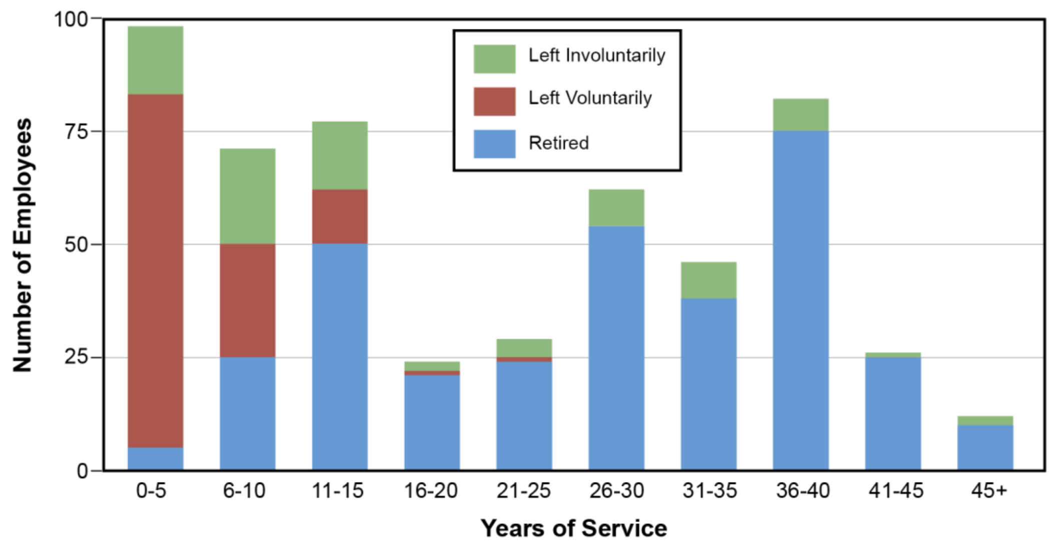


Notes:

There are no irregularities with 70 percent of the terminations being age 56 and above. The largest group of terminations were in the 61-65 age band.

Involuntary separations are those people that "left involuntarily" from the site, including death disability, and those terminated for cause (clearance denied, conduct, etc.).

Figure D–64. Age of Y-12 employees who left service (October 1, 2016 to September 30, 2018)

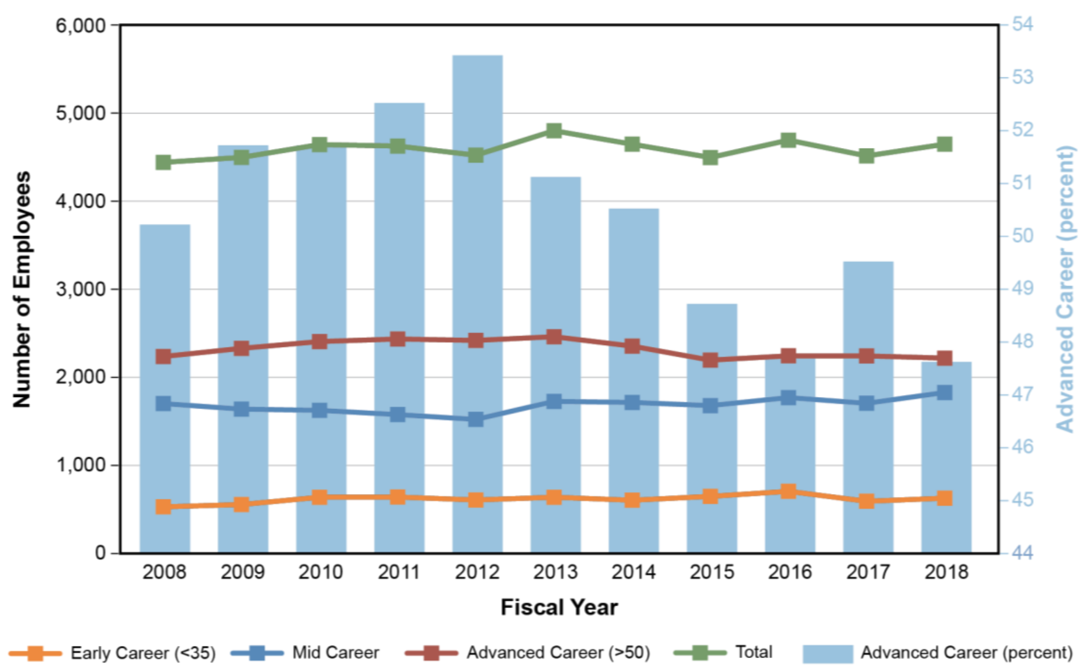


Notes:

The data show no irregularities. Most voluntary separations are employees under the age of 40 with less than 5 years company service, and most retirees leave with 36-40 years of service.

Involuntary count includes people who died, those who went out on disability, and those terminated for cause.

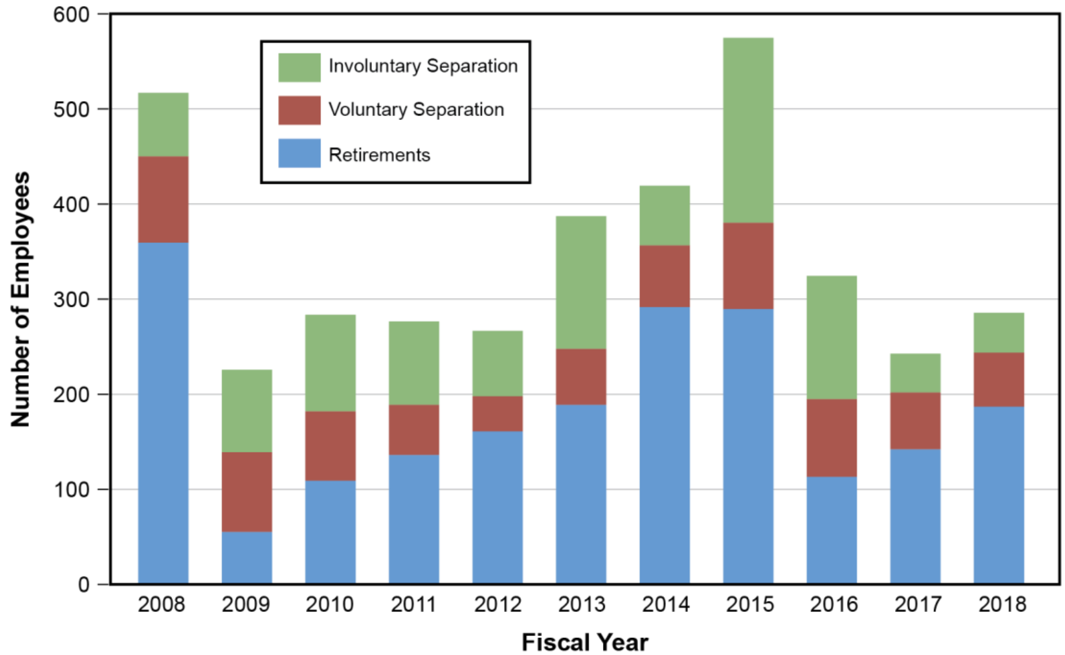
Figure D–65. Years of service of Y-12 employees who left service (October 1, 2016 to September 30, 2018)



Notes:

The early-career population grew in 2018 because of increased hiring. The slight decrease in the percentage of the advanced-career population is due to increased retirements.

Figure D–66. Y-12 trends by career stage (as of September 30, 2018)



Notes:

In FY 2008, a voluntary retirement incentive program was offered, which accounts for the high number of retirements that year. Effective July 1, 2014, CNS became the new managing contractor for both Y-12 and Pantex. A Voluntary Separation Program was offered April 24, 2014, with terminations effective no later than June 30, 2014. The Voluntary Separation Program at Y-12 resulted in 105 terminations, and there were seven involuntary reductions in forces during FY 2014. During FY 2015, the scope of work for the Uranium Processing Facility was transitioned to Bechtel National. With this transition, 169 employees left the CNS Y-12 payroll and joined Bechtel National. Voluntary Separation Programs involve incentives to leave a company's payroll or take early retirement. During FY 2018, another Voluntary Separation Program was offered. 37 of these separations resulted in retirements accounting for the higher retirement number in FY 2018.

Figure D–67. Y-12 employment separation trends (as of September 30, 2018)

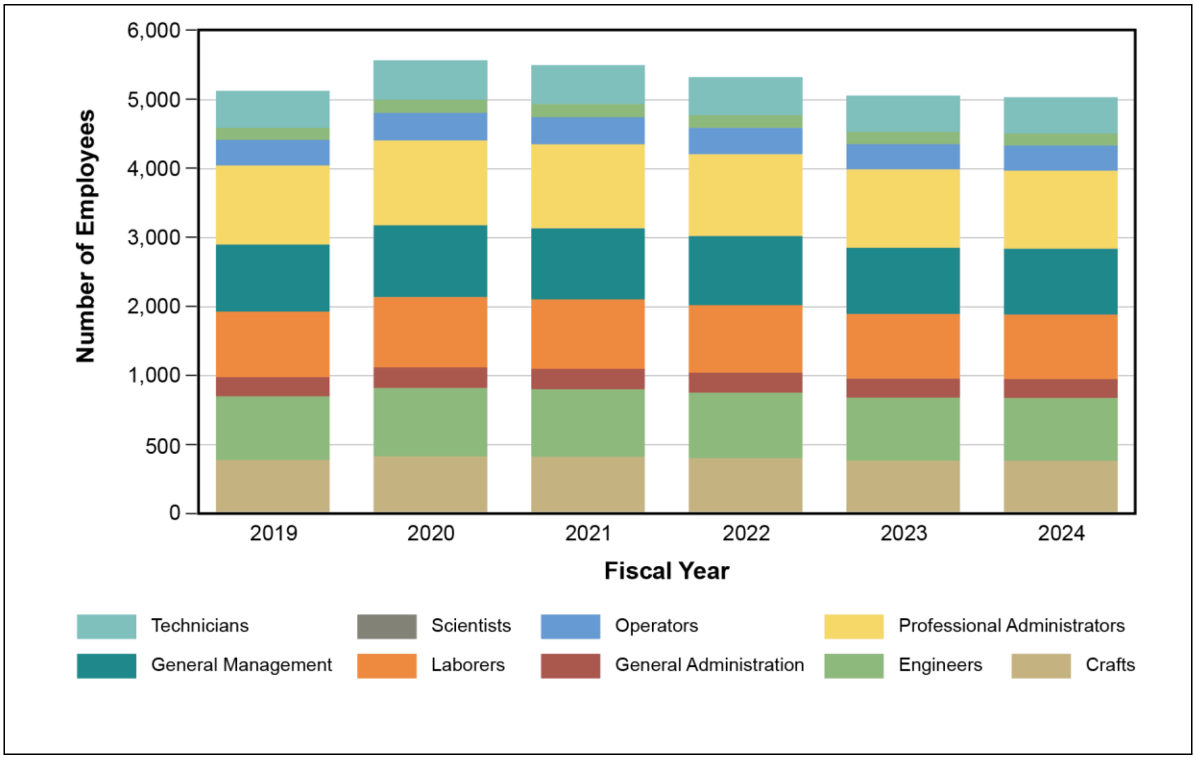


Figure D–68. Total projected Y-12 workforce needs by Common Occupational Classification System over the FYNSP period (as of September 30, 2018)

D.4 The National Security Site

D.4.1 Nevada National Security Site

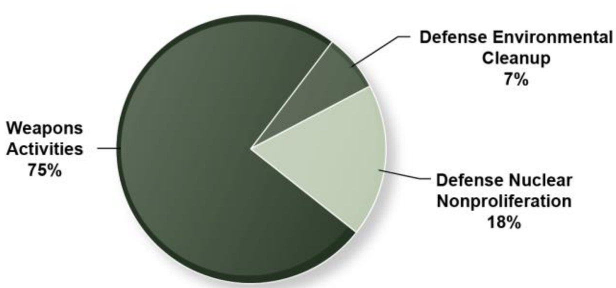
D.4.1.1 Mission Overview

The Nevada National Security Site (NNSS) 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 both HE and weapons-relevant quantities of plutonium.

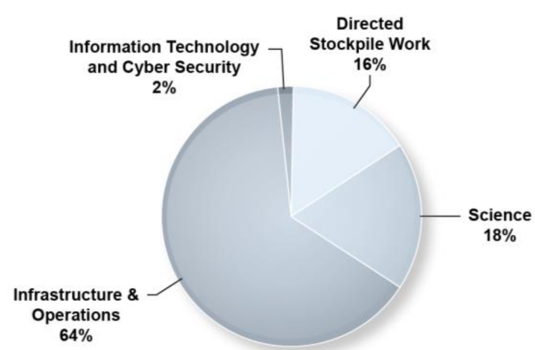
- Location: Las Vegas, Nevada
- Additional Operating Capabilities: Offices at LANL, LLNL, and SNL; Remote Sensing Laboratory at Nellis Air Force Base and Andrews Air Force Base; and the Special Technologies Laboratory in Santa Barbara, California
- Total Employees: 2,205 (as of the end of FY 2018)
- 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 Ingals Industries Nuclear, Inc.

D.4.1.2 Funding

FY 2020 request – site funding by source
(total NNSS FY 2020 Request = $495 million)



FY 2020 FYNSP request for Weapons Activities
($369 million)



D.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 D–8**.

Table D–8. Nevada National Security Site Capabilities

Hydrodynamic and Subcritical Experiments at Weapon's Relevant Scales	
NNSS performs subcritical experiments at U1a focus on early explosion-time hydrodynamic characterization of plutonium and plutonium surrogates 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 are the bases for assessing the effects of aging and manufacturing processes on stockpile weapons.	
Challenges	***Strategies***
Increasing the tempo, variety, and sophistication of subcritical experiments and enhanced capability for subcritical experiments by exploring major improvements in experiment and U1a operations efficiencies.	Implement a multi-user U1a operating model and an integrated, logic-linked framework schedule to optimize critical path contributors. Invest in U1a, Device Assembly Facility (DAF), diagnostics, and transportation for future subcritical experiments.
Weapons Science Experiments Using High-Hazard Materials	
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 JASPER, the Dynamic Science Launcher, Z; and a variety of shock physics platforms at NNSS and 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.	
Challenges	***Strategies***
Breakthroughs in materials science are limited by the rate of experimentation, staffing constraints, the range of dynamic conditions that are available to DOE/NNSA, and 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.	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. 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.
Device Assembly Facility	
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 glove box, downdraft table, and radiography capabilities support assembly of SNM targets JASPER, and 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.	
Challenges	***Strategies***
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 to accommodate the number and breadth of programs hosted by the complex.	This capability 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).

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***
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. The current expense and pace for advanced diagnostics will require continued congressional support.	NNSS will involve nuclear security enterprise laboratories in defining and prioritizing diagnostic needs for future experiments, (subcritical experiments, Enhanced Capabilities for Subcritical Experiments, JASPER, the Big Explosives Experimental Facility, etc.).

HE = high explosives
JASPER = Joint Actinide Shock Physics Experimental Research
SNM = special nuclear material
U1a = U1a Complex
Z = Z pulsed power facility

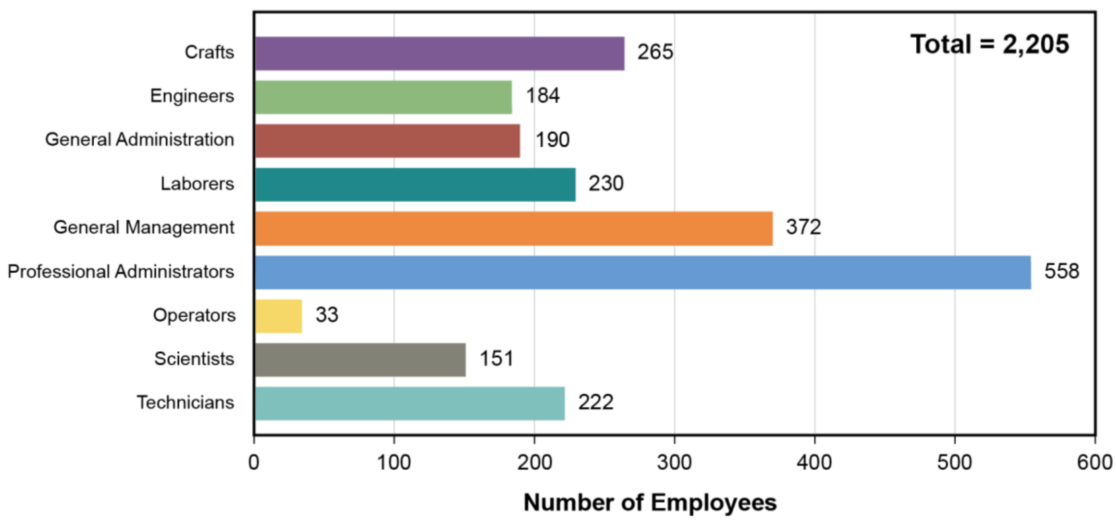
D.4.1.4 Accomplishments

- Vega, the final subcritical experiment in the Lyra series, was conducted on December 13, 2017. Vega used plutonium and IHE, and will be compared with previous Lyra experiments, completing a fundamental experimental assessment of surrogate/plutonium and CHE/IHE issues.
- The Lamarck confirmatory was conducted at the U1a Complex on August 15, 2018. Lamarck represented the final preparatory experiment for Ediza, a plutonium subcritical experiment that occurred during February of FY 2019. The Ediza experiment provided essential data in support of the safety science programs within the DOE/NNSA.
- Diagnostic development – broadband laser ranging. NNSS continued collaborating with the national security laboratories to develop the broadband laser ranging diagnostic as the next generation of experimental probe. When paired with photon Doppler velocimetry, broadband laser ranging will provide unprecedented velocity and position measurements of imploding surfaces; this diagnostic was fielded successfully in the Vega subcritical experiments and Lamarck confirmatory. The development of photon Doppler velocimetry revolutionized the field of shock physics; this trend continues with the joint deployment of broadband laser ranging with photon Doppler velocimetry.
- JASPER Experimental Program. Supporting the accomplishment of an accelerated cadence, Nevada developed an integrated management system that includes all elements of preparing, conducting, and facility readiness needed to support national program initiatives. Twenty-nine experiments were completed in FY 2018, representing an 81 percent increase in cadence from FY 2017 and efforts are on track to increase cadence further. These experiments provided precise plutonium property data under dynamic conditions.
- Dense Plasma Focus. Nevada continued to execute experiments using the dense plasma focus pulsed energy source. A series of experiments testing the reliability of the dense plasma focus for use on a neutron diagnosed subcritical experiment were completed. This research has proven to be pivotal in developing a major diagnostic tool as a mainstay of subcritical experiments. This diagnostic 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.

D.4.1.5 Nevada National Security Site Workforce

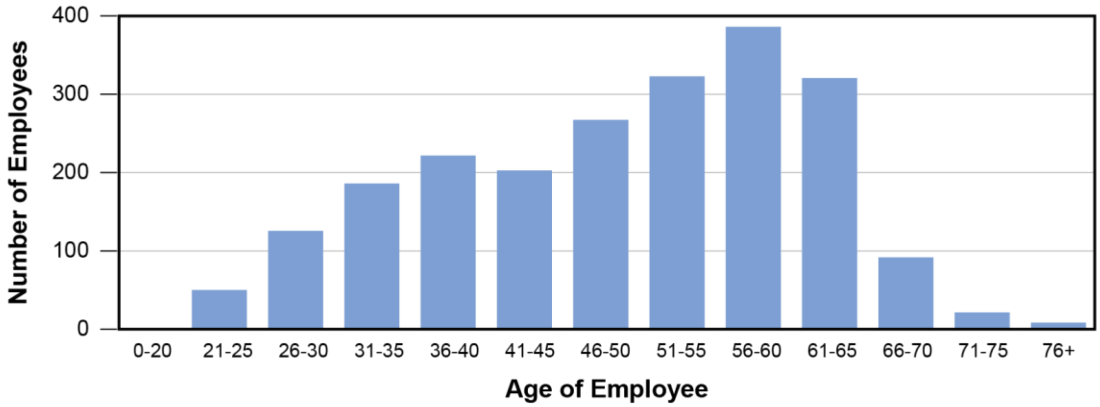
NNSS had 2,205 employees at the end of FY 2018. The age of the workforce is heavily concentrated between the ages of 46 and 65 years, with an average age of 59 years. The percent of employees eligible for retirement is around 30 percent. The average years of service is around 11 years, while the population is concentrated below 20 years of service. The largest experience group consists of those with 1-5 years of service. Voluntary separations were the largest overall category of separations, were spread among several age groups, and were concentrated among those with less than 15 years of service. About 26 percent of separations were retirements, and another 23 percent were involuntary terminations, many of which resulted from contract transition. Since FY 2016, early-, mid-, and advanced-career trend populations have slowly increased, while the overall percentage of advanced-career employees declined. Workforce demographics are illustrated and discussed in **Figures D–69** through **D–77**.



Notes:

Total site headcount increased by approximately 3 percent in FY 2018. The number of hires went down from last year because of limited hiring that occurred during and after a recent M&O contractor transition. The Business Professional job group (Professional Administrators COCS category) experienced the highest hiring rates (26 percent of all FY 2018 hires), especially with Safeguards and Security Specialists and Project Controls Specialists. On July 1, 2018, MSTS took over the responsibilities that TechSource and Pro2Serve provided for NNSS, including operation of the badge offices, the operations security program, and security awareness. This action added 10 new Safeguards and Securities Specialists to the current workforce. MSTS has also experienced a large turnover of Project Controls Specialists, spurring the hiring of several new Specialists in that group. The next job groups experiencing large hiring rates were Scientists and Engineers (11 percent of all fiscal year hires). Most of these hires were Engineer I level. As predicted, the number of retirements went up in FY 2018 because of the site's aging workforce and the contract transition. Both voluntary and involuntary terminations also increased in FY 2018.

Figure D–69. NNSS total workforce by Common Occupational Classification System (as of September 30, 2018)

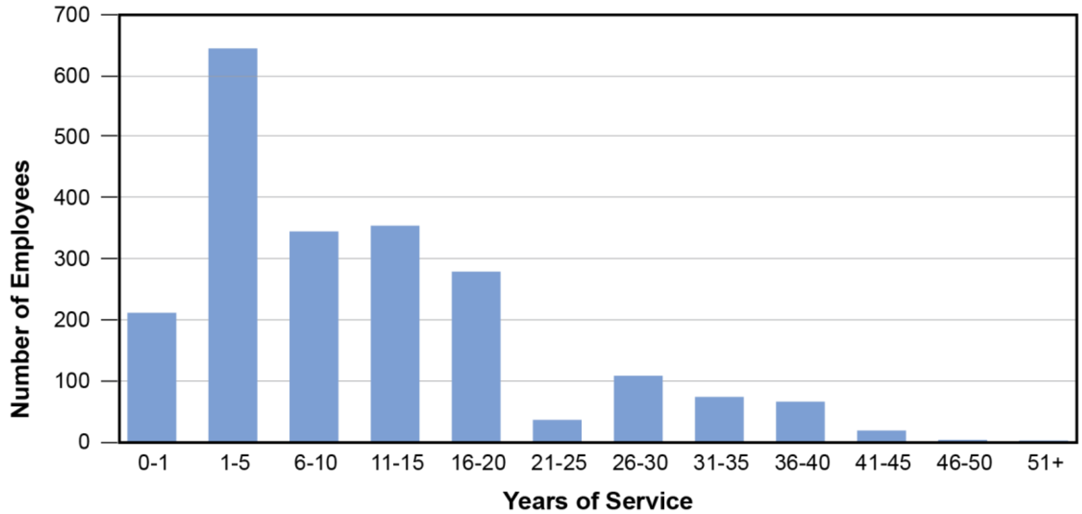


Notes:

The age of the workforce is still heavily concentrated between the ages of 46 and 65 years, which explains the high average age of 49.4 years and the percentage of retirement-eligible employees at 29.6 percent. These numbers decreased slightly from the FY 2017 numbers. The non-represented[3] employee average age is 49.9 years old, and retirement-eligible employees number 33.2 percent. The represented employee average age is 47.7 years old, and retirement-eligible employees number 18 percent. The drastic difference in retirement eligibility between the non-represented and represented employees is because non-represented employees have longer tenure and are an older population. The population of early-career employees (less than 35 years old) increased by 11 percent during FY 2017 as NNSS implemented strategic college hiring goals and site-level internship programs that have expanded the technical and critical skill talent pipelines. As the site continues hiring early-career employees and retirements continue, the average age and percentage of those eligible for retirement will decrease slightly.

Figure D–70. NNSS employees by age (as of September 30, 2018)

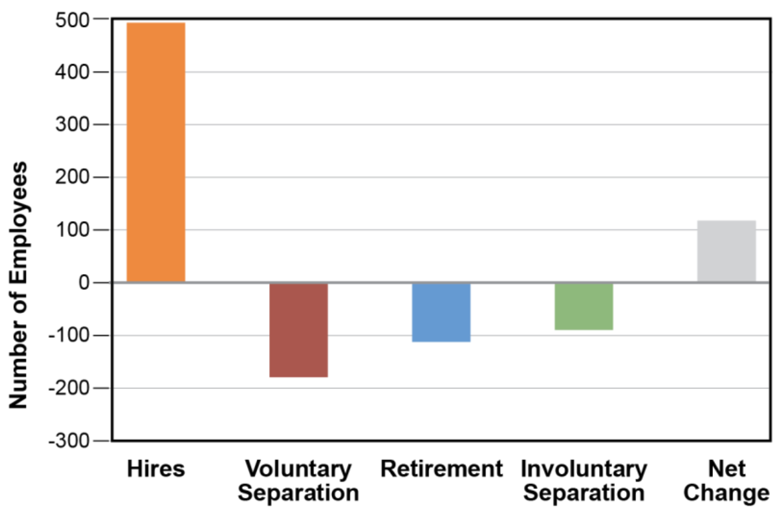
[3] The Nevada Nuclear Security Site's Occupational Safety and Health Division has several key safety committees representing the workforce. These include the Labor Alliance and Safety Committee that represent site workers, the Downtown Safety Committee, representing those in North Las Vegas and the Continuous Safety Improvement Committee for non-bargaining administrative employees.



Notes:

The years of service of NNSS' workforce stayed relatively constant from the end of FY 2017 to the end of FY 2018. Employees with 16-20 years of service experienced the largest increase, at 40 percent, followed by employees with 1-5 years of service, who increased by 14 percent. Most of the other service categories experienced a decrease or remained relatively stagnant. Employees with 1-15 years of service make up more than 75 percent of the employee population.

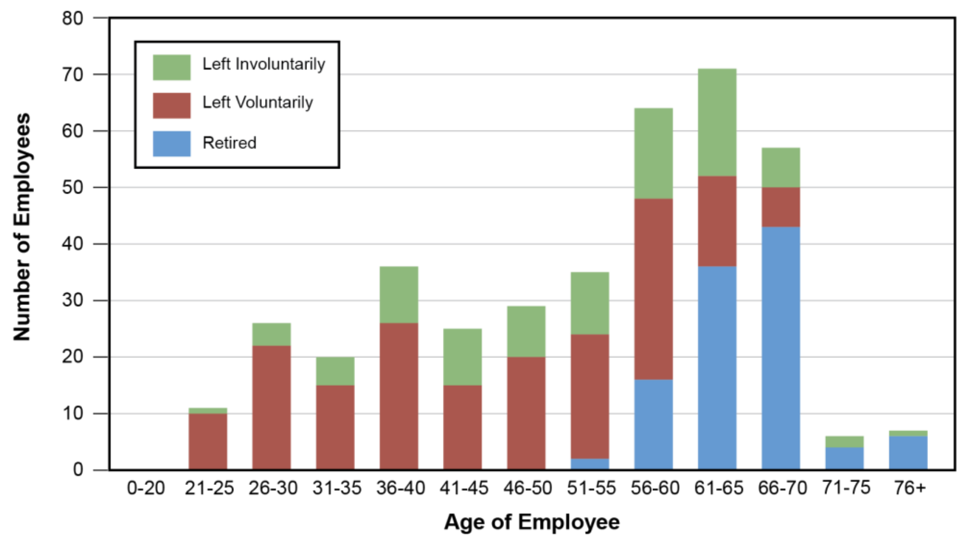
Figure D–71. NNSS employees by years of service (as of September 30, 2018)



Notes:

NNSS experienced a positive net increase in FY 2017 and FY 2018 and expects this trend to continue into FY 2019. As the site continues to make strategic organizational changes and analyze hiring needs, hires in most job groups will continue to increase. The site experienced several involuntary reductions in employment because of transition in FY 2018, although it is common to see an increase in voluntary terminations during a contract transition.

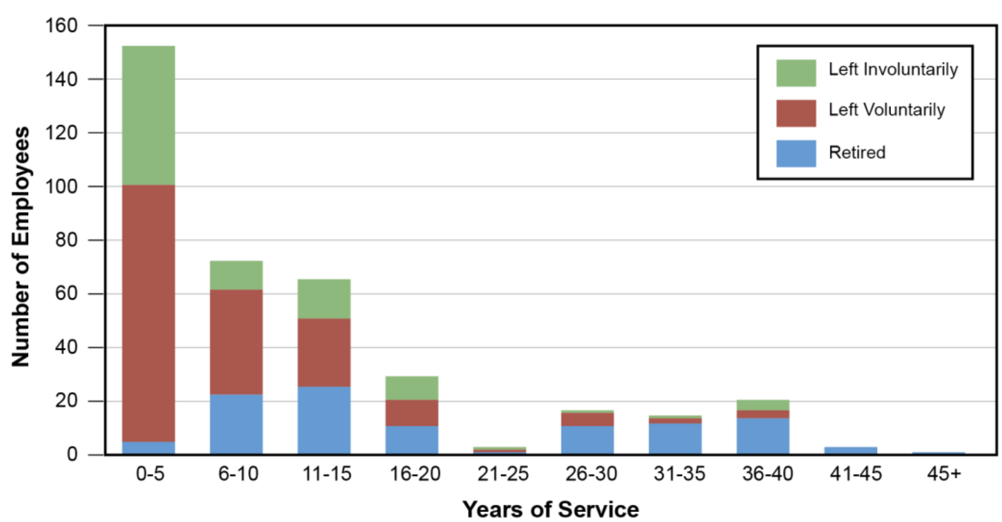
Figure D–72. Change in last 2 fiscal years (October 1, 2016 to September 30, 2018)



Notes:

In FY 2018, 26 percent of all NNSS terminations were retirements, both early and normal. This is expected to increase as the percentage of the population eligible to retire does. Approximately half of all terminations in FY 2018 were voluntary terminations; a quarter were involuntary terminations. On the non-bargaining side, 74 percent of involuntary terminations were involuntary reductions in employment due to contract transition. No other reductions in employment took place in FY 2018 on the non-bargaining-side. NNSS does not foresee many reductions in employment in FY 2019. Fifty percent of all terminations in FY 2018 were voluntary terminations; resignations and career advancement opportunities were the primary reasons for leaving service.

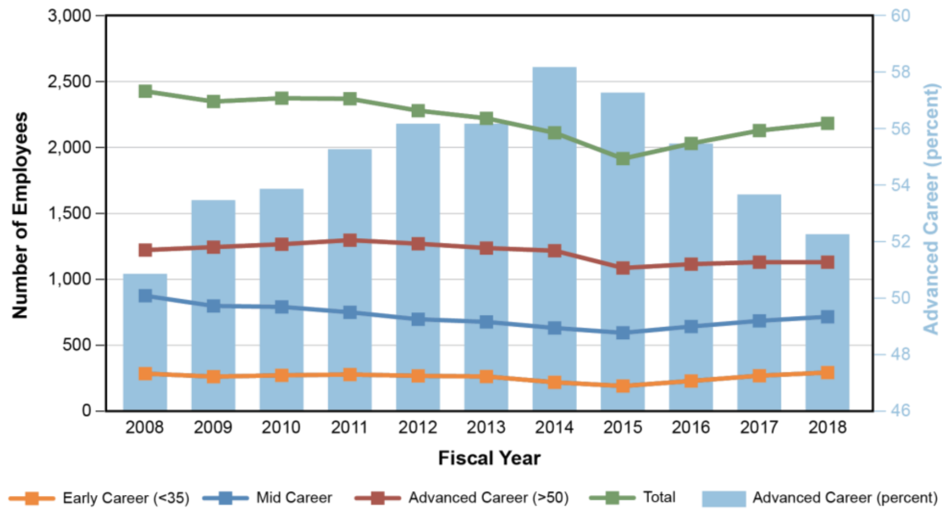
Figure D–73. Age of NNSS employees who left service (October 1, 2016 to September 30, 2018)



Notes:

Of all terminations for FY 2017 and FY 2018, 40 percent had 0-5 years of service; 19 percent had 6-10 years of service; and 17 percent had 11-15 years of service. In total, those with 0-15 years of service made up almost 77 percent of all terminations in FY 2017 and FY 2018. In both FYs 2017 and 2018, more retirements occurred among employees with 6-15 years of service.

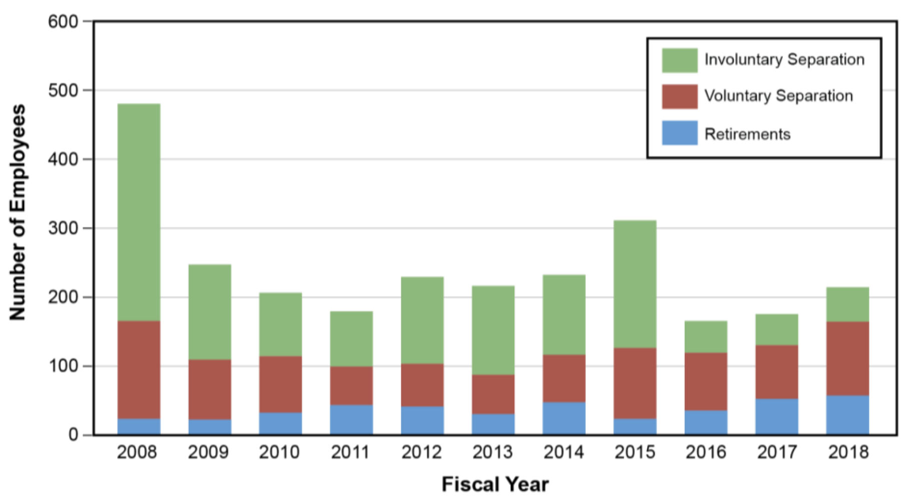
Figure D–74. Years of service of NNSS employees who left service (October 1, 2016 to September 30, 2018)



Notes:

The percentage of employees considered to be in their early- and mid-career stage went up slightly from FY 2017. The percentage of employees in the advanced-career stage went down 1.4 percent from FY 2017. Similar to FY 2017, the largest percentage of employees are in the advanced-career stage, which is consistent with the high average age of the employee population. NNSS implemented strategic college hiring goals and site-level internship programs that are increasing the early-career talent pipeline, particularly for technical positions. Thirty-five percent of all hires in FY 2018 were filled by employees considered early-career, while 36 percent of all hires in FY 2018 were filled by employees considered mid-career.

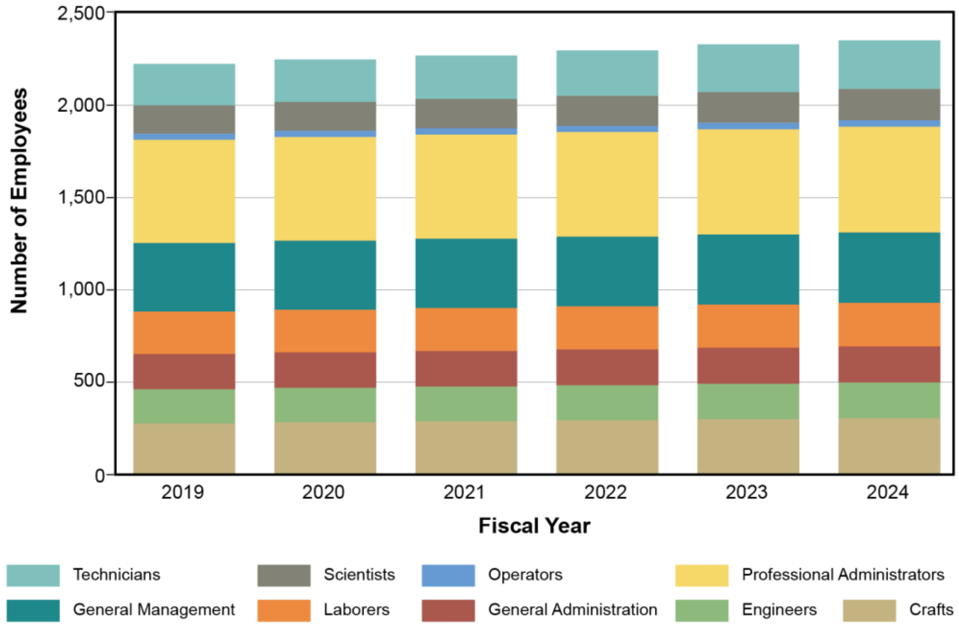
Figure D–75. NNSS trends by career stage (as of September 30, 2018)



Notes:

As expected, retirements and involuntary terminations increased slightly in FY 2018 from FY 2017 due to employment reductions. Most of this increase can be attributed to contract transition. Retirements are expected to increase throughout FY 2019 as the population ages. Voluntary terminations also increased in FY 2018. Similar to FY 2017, the primary reasons given for voluntary turnover were resignations and career advancement opportunities. This is consistent with industry survey data citing the primary reason people voluntarily separate. Other major reasons for voluntary turnover included company culture, compensation, and family circumstances. 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 D–76. NNSS employment separation trends (as of September 30, 2018)



Notes:

NNSS continues to use subcontractors and other staff augmentation strategies to address peak workloads, but is implementing an initiative to decrease these in core and critical skill areas. A major projected need is a ramp-up in the number of technicians and engineers over the next 5 years to support anticipated Enhanced Capabilities for Subcritical Experiments capabilities.

Figure D–77. Total projected NNSS workforce needs by Common Occupational Classification System over the FYNSP period (as of September 30, 2018)

Appendix E
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 (AF&F) system—The electronic and mechanical functions that ensure a nuclear weapon does not operate when not intended during any part of its manufacture and lifetime, but do ensure the weapon will operate correctly when a unique signal to do so is properly activated.

B61—An air-delivered gravity bomb.

B61-12 Life Extension Program (LEP)—An LEP to consolidate four families of the B61 bomb into one and improve the safety and security of the oldest weapon system in the U.S. arsenal.

B83-1—An air-delivered gravity bomb.

Boost—The process that increases the yield of a nuclear weapon's primary stage through fusion reactions.

canned subassembly (CSA)—A component of a nuclear weapon that is hermetically sealed in a metal container. A CSA and the primary make up a weapon's nuclear explosive package.

certification—The process whereby all available information on the performance of a weapon system is considered and the Laboratory Directors responsible for that system certify, before the weapon enters the stockpile, that it will meet, with noted exceptions, the military characteristics within the environments defined by the stockpile-to-target sequence.

co-design—An inclusive process to develop designs that encourages participants to find solutions within the context of the total system rather than based upon individual areas of expertise and interest.

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 Diagnostics and Mitigation (CDM)—A dynamic approach to fortifying the cybersecurity of government networks and systems. CDM provides Federal departments and agencies with capabilities and tools that identify cybersecurity risks on an ongoing basis, prioritize these risks based upon potential impacts, and enable cybersecurity personnel to mitigate the most significant problems first. Congress established the CDM program to provide adequate, risk-based, and cost-effective cybersecurity and to allocate cybersecurity resources more efficiently.

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

conventional high explosive (CHE)—A high explosive that detonates when given sufficient stimulus via a high-pressure shock. Stimuli from severe accident environments involving impact, fire, or electrical discharge may also initiate a CHE. See also "insensitive high explosive."

critical decision (CD)—The five levels a DOE project typically progresses through, which serve as major milestones approved by the Chief Executive for Project Management. Each CD marks an authorization to increase the commitment of resources and requires successful completion of the preceding phase. These five phases are CD-0, Approve Mission Need; CD-1, Approve Alternative Selection and Cost Range; CD-2, Approve Performance Baseline; CD-3, Approve Start of Construction/Execution; CD-4, Approve Start of Operations or Project Completion.

cybersecurity—The physical, technical, administrative, and management controls for providing the required and appropriate levels of protections of information and information assets against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional. Cybersecurity also ensures the required and appropriate level of confidentiality, integrity, availability, and accountability for the information stored, processed, or transmitted on electronic systems and networks.

data loss prevention (DLP)—DLP is a strategy for making sure that end users do not send sensitive or critical information outside the corporate network. DLP also includes software products that aid network administrators in controlling what data end users can transfer.

defense-in-depth—The security approach whereby layers of cybersecurity and information assurance solutions are used to establish an adequate security posture. Implementation of this strategy also is recognized due to the highly interactive nature of the various systems and networks. Cybersecurity defense-in-depth must be considered within the context of the shared risk environment, given that any single system cannot be adequately secured unless all interconnected systems are adequately secured.

design life—The length of time, starting from the date of manufacture, during which a nuclear weapon is designed to meet its stated military requirements.

deuterium—An isotope of hydrogen whose nucleus contains one neutron and one proton.

down-select—The process of narrowing the range of design options during the *Phase 6.x Process*, culminating in a final design (normally exercised when moving from Phase 6.1 to 6.2, from Phase 6.2 to 6.2A, and from Phase 6.2A to 6.3) through analysis of the ability to meet military requirements and assessment of schedule, cost, material, and production impacts.

encryption—Technical controls to protect information as it passes throughout a network and resides on computers. These methods protect sensitive information during storage and transmission and provide functionality to reduce the risk of both intentional and accidental data compromise and alteration.

enterprise forensics—The performance of real-time, remote inspections at the binary level of all data on a given system. The inspections include operating memory, physical storage devices, and virtualization mechanisms on any machine at a given time.

Enterprise Governance, Risk, and Compliance—The official corporate and enterprise program repository used to conduct continuous performance monitoring and reporting of information security program management, operations, and technical controls (e.g., authority-to-operate packages, deviations, incident management reporting).

Enterprise Information System—Systems within NNSA for which the authorization boundary covers multiple sites and multiple local Authorization Official jurisdictions.

exascale computing—Computing systems capable of at least 1 exaFLOPS, or a billion calculations per second. Such capacity represents a thousand-fold increase over the first petascale computer that came into operation in 2008. See also "floating point operations per second (FLOPS)."

firewalls—Systems that can be implemented in hardware and/or software that are designed to prevent unauthorized access to or from private networks connected to the Internet.

first production unit—The first system, subsystem, or component manufactured and accepted by NNSA as verifiably meeting all applicable quality and qualification requirements. The first production unit for a weapon is a production milestone. For milestone completion, two events must occur: (1) DoD or the Nuclear Weapons Council accepts the design and (2) DOE/NNSA verifies that the first produced weapon meets the design specifications.

fiscal year—The Federal budget and funding year that starts on October 1 and goes to the following September 30.

fission—The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial energy.

floating point operations per second (FLOPS)—The number of arithmetic operations performed on real numbers in a second; used as a measure of the performance of a computer system.

fusion—The process whereby the nuclei of two light elements, especially the isotopes of hydrogen (i.e., deuterium and tritium), combine to form the nucleus of a heavier element with the release of substantial energy and a high-energy neutron.

Future Years Nuclear Security Program (FYNSP)—A detailed description of the program elements (and associated projects and activities) for the fiscal year for which the annual budget is submitted and the four succeeding fiscal years.

general purpose infrastructure—The buildings, equipment, utilities, roads, etc., that support operation of the nuclear security enterprise, but are not specifically program-focused.

high explosives (HE)—Materials that detonate, with the chemical reaction components propagating at supersonic speeds. HE are used in the main charge of a weapon primary to compress the fissile material and initiate the chain of events leading to nuclear yield. See also "conventional high explosive" and "insensitive high explosive."

high performance computing (HPC)—The use of supercomputers and parallel processing techniques with multiple computers to perform computational tasks.

ignition—The point at which a nuclear fusion reaction becomes self-sustaining—that is, more energy is produced and retained in the fusion target than the energy used to initiate the nuclear reaction.

Information 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 (IT)—The equipment or interconnected system or subsystem of equipment used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information. IT includes computers, ancillary equipment, software, firmware, and related procedures, services, and resources.

Information Technology Infrastructure—The shared technology resources that provide the platform for the specific information system applications at a site or NNSA/DOE-wide. It consists of a set of physical devices and software applications that are required to operate the entire nuclear security enterprise.

insensitive high explosive (IHE)—A high explosive substance that is so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible.

integrated design code (IDC)—A simulation code containing multiple physics and engineering models that have been validated experimentally and computationally. An IDC is used to simulate, understand, and predict the behavior of nuclear and non-nuclear components and nuclear weapons under normal, abnormal, and hostile conditions.

intrusion prevention—A network security device that monitors network activities for malicious activities such as security threats or policy violations. The main function of an intrusion prevention system is to identify suspicious activity, log the information, and report it.

Joint Cybersecurity Coordination Center (JC3)—The cybersecurity incident response coordination, reporting, and tracking element for the entire DOE enterprise. JC3 provides computer security support to collect, analyze, and share cybersecurity information for all of DOE, including DOE's Energy Information Administration and Power Marketing Administration, as well as NNSA's national security laboratories, nuclear weapons production facilities, and Nevada National Security Site. JC3 is managed and operated by the DOE Chief Information Officer.

joint test assembly (JTA)—(1) An electronic unit that contains sensors and instrumentation that monitor the weapon hardware performance during flight tests to ensure that the weapon components will function as designed. (2) An NNSA-developed configuration, based on NNSA-DoD requirements, for use in the flight test program.

life cycle—The series of stages through which a component, system, or weapon passes from initial development until it is consumed, disposed of, or altered in order to extend its lifetime.

life extension program (LEP)—A program that refurbishes warheads of a specific weapon type by replacing aged components 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 and addressing defects.

lightning arrestor connector—Advanced interconnected nuclear safety devices designed to limit voltage during lightning strikes and other extreme high-voltage, high-temperature environments.

limited life component—A weapon component or subsystem whose performance degrades with age and must be replaced.

manufacturing readiness level (MRL)—A means of communicating the degree to which a component or subsystem is ready to be produced. MRLs represent many attributes of a manufacturing system (e.g., people, manufacturing capability, facilities, conduct of operations, and tooling). There are nine MRLs, with the lowest beginning at product development and ending with the highest, which is steady-state production.

mark quality—Weapon or weapon-related material that is certified by DOE/NNSA or its prime contractor quality organization to meet all applicable design requirements, drawings, and known design intent. Sometimes called "Diamond Stamp."

modernization—The changes to nuclear weapons or infrastructure due to aging, unavailability of replacement parts, or the need to enhance safety, security, and operational design features.

modification (Mod)—A modernization program that changes a weapon's operational capabilities. A Mod may enhance the margin against failure, increase safety, improve security, replace limited life components, and/or address identified defects and component obsolescence.

multilayered malware protection—Commercial software that guards against multiple threat vectors such as viruses, spyware, and Trojans. The software searches a hard disk or other media for known threat vectors and removes any that are found.

national security laboratory—Los Alamos National Laboratory, Sandia National Laboratories, or Lawrence Livermore National Laboratory.

national security system—Any telecommunications or information system operated by the U.S. Government whose function, operation, or use involves intelligence activities, cryptologic activities related to national security, command and control of military forces, or equipment that is an integral part of a weapon or weapons system or is critical to the direct fulfillment of military or intelligence missions. The term excludes any system used for routine administrative and business applications (including payroll, finance, logistics, and personnel management applications).

network—In relation to information technology and cybersecurity, a network is composed of a communications medium responsible for the transfer of information and all components attached to that medium.

network intrusion detection (NID)—An intrusion detection system inspects all inbound and outbound network activity and identifies suspicious patterns that may indicate an attempt to break into or compromise a system. NID systems (1) monitor all network traffic by inspecting and screening all inbound and outbound information technology network activity for patterns that may indicate an attempt to break in or compromise a system and (2) provide alerts based on predefined rules. These rules or signatures are updated as needed to reflect information learned from exploitation or attack attempts. When triggered, an NID system begins capturing network traffic related to the event in question, and the data are made available to security analysts. Notification is also sent to the Security Information and Event Management tool.

network monitoring—The use of a system that constantly monitors a computer network, providing vulnerability management and policy compliance tools; operating system, database, and application logs; and compilation of external threat data. A key focus is monitoring and managing user and service privileges, directory services, and other system configuration changes. Network monitoring also provides log auditing and review of incident responses.

NNSA Information Technology System—An information system that is owned and/or operated by NNSA or by contractors on behalf of NNSA to accomplish a Federal function. Regardless of whether NNSA Federal employees have access, this does not include information systems operated by management and operating contractors unless such systems' primary purposes are to accomplish Federal functions.

non-nuclear components—The parts or assemblies designed for use in nuclear weapons or in nuclear weapons training that do not contain special nuclear material; such components (e.g., radiation-hardened electronic circuits or arming, fuzing, and firing components) are not available commercially.

non-War Reserve—Weapon material that is not designated for the War Reserve stockpile, but is to be used by DOE/NNSA or delivered to DoD for the purpose of training, testing, and evaluating War Reserve material.

nuclear explosive package (NEP)—An assembly containing fissionable and/or fusionable materials, as well as the main charge high-explosive parts or propellants capable of producing a nuclear detonation.

nuclear forensics—The investigation of nuclear materials to find evidence for the source, trafficking, and enrichment of the material.

nuclear security enterprise—The physical infrastructure, technology, and workforce at the national security laboratories, the nuclear weapons production sites, and the Nevada National Security Site.

Nuclear Weapons Council—The joint DOE/DoD Council composed of senior officials from both Departments who recommend the stockpile options and research priorities that shape national policies and budgets to develop, produce, surveil, and retire nuclear warheads and weapon delivery platforms and who consider the safety, security, and control issues for existing and proposed weapons programs.

nuclear weapons production site—The Kansas City National Security Campus, Pantex Plant, Y-12 National Security Complex, or Savannah River Site. Los Alamos National Laboratory and Sandia National Laboratories also perform some specific weapons production activities.

Other Program Money—Funding that is found outside of 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 basically correspond to Phases 1 through 6 of the nuclear weapons life cycle.

physical security—The application of physical or technical methods that protect personnel; prevent or detect unauthorized access to facilities, material, and documents; protect against espionage, sabotage, damage, and theft; and respond to any such acts that occur.

pit—The critical core component in the primary of a nuclear weapon that contains fissile material.

Predictive Capability Framework (PCF)—A framework that defines high-level research, development, test, and evaluation activities to be executed by Defense Programs. The PCF identifies the complex set of interlinked analytical, computational, and experimental activities needed for stockpile assessment, the evaluation of some surveillance data, and the coordination of related efforts. See also "Stewardship Capability Delivery Schedule."

primary—The first stage of a two-stage nuclear weapon.

programmatic infrastructure—Specialized experimental facilities, computers, diagnostic instruments, processes, and capabilities that allow the nuclear security enterprise to carry out research, testing, production, sustainment, and other direct programmatic activities to meet national security missions.

Protected Distribution Systems—Wireline or fiber optic distribution systems used to transmit and protect unencrypted classified signal and data lines that exit secure areas and traverse through areas of lesser classification or security control.

qualification—The process of ensuring that design, product, and all associated processes are capable of meeting customer requirements. Authorizes the listed items for an intended use (i.e., War Reserve, Training, Evaluation, etc.). Generally includes Laboratory (Design Agency) review of production and inspection processes. Qualified items are reviewed for possible requalification after a significant process change or if production is inactive for 12 months.

quantification of margins and uncertainties—The methodology used in the post-nuclear-testing era to facilitate analysis and communicate confidence in assessing and certifying that stockpile weapons will perform safely, securely, and reliably. Scientific judgment of experts at the national security laboratories plays a crucial role in this determination, which is based on metrics that use experimental data, physical models, and numerical simulations.

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

radiation case—A vessel that confines the radiation generated in a staged nuclear weapon.

reservoir—A vessel containing deuterium and tritium that permits its transfer as a gas in a nuclear weapon.

Retrofit Evaluation System Test—A test program conducted during retrofit of an NNSA weapon system on randomly selected, newly retrofitted weapons to determine the effect of the retrofit on the weapon system's reliability and to verify that the purpose of the retrofit is fully achieved. The program may consist of flight testing and/or laboratory testing.

Safeguards Transporter (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). The terms "stockpile life," "deployed life," and "useful life" are subsumed by service 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-to-target sequence—A document that defines the logistical and employment concepts and related physical environments involved in delivering a nuclear weapon from storage and assembly, testing it, transporting it, and delivering the weapon to a target.

subcritical experiment—An experiment specifically designed to obtain data on nuclear weapons for which less than a critical mass of fissionable material is present and, hence, no self-sustaining nuclear fission chain reaction can occur, consistent with the Comprehensive Nuclear Test Ban Treaty.

supply chain risk management (SCRM)—The coordinated efforts of an organization to help identify, monitor, detect, and mitigate threats to supply chain continuity. Threats to the supply chain include cost volatility, material shortages, supplier financial issues and failures, and natural and manmade disasters. SCRM strategies and software help an organization foresee potential issues and adapt to both those risks and unforeseeable supply chain disruptions as quickly and efficiently as possible.

surety—The assurance that a nuclear weapon will operate safely, securely, and reliably if deliberately activated and that no accidents, incidents, or unauthorized detonations will occur. Factors contributing to that assurance include model validation for weapon performance based on experiments and simulations, material (e.g., military equipment and supplies), personnel, and execution of procedures.

surveillance—Activities that provide data for evaluation of the stockpile, giving confidence in the Nation's deterrent by demonstrating mission readiness and assessment of safety, security, and reliability standards. These activities may include laboratory and flight testing of systems, subsystems, and components (including those of weapons in the existing stockpile, newly produced weapons, or weapons being disassembled); inspection for unexpected wear or signs of material aging; and destructive or nondestructive testing.

sustainment—A program to modify and maintain a set of nuclear weapon systems.

technology maturation—Advancing laboratory-developed technology to the point where it can be adopted and used by U.S. industry.

technology readiness level (TRL)—A measurement system to assess the maturity level of a particular technology that includes nine levels, where TRL 1 is the lowest (the associated scientific research is beginning) and TRL 9 is the highest (a technology has been proven through successful operation).

test readiness—The preparedness to conduct underground nuclear explosive testing if required to ensure the safety and effectiveness of the stockpile or if directed by the President for policy reasons.

threat information—Any information related to a threat that might help an organization protect itself against a threat or detect the activities of an actor. Major types of threat information include indicators; tactics, techniques, and procedures; security alerts; threat intelligence reports; and tool configurations.

tractor—A modified and armored vehicle to transport the Safeguards Transporter trailer.

tritium—A radioactive isotope of hydrogen whose nucleus contains two neutrons and one proton and is produced in nuclear reactors by the action of neutrons on lithium nuclei.

virtual desktop infrastructure—Software technology that separates the desktop environment and associated application software from the physical client device used to access it.

vulnerability scanning—The application of software that seeks out security flaws based on a database of known flaws, testing systems for the occurrence of these flaws, and generation of a report of the findings that can be used to tighten a networks security.

W76-1 Life Extension Program (LEP)—An LEP for the W76 submarine-launched ballistic missile warhead, delivered by a Navy Trident II.

W78—An intercontinental ballistic missile warhead, delivered by an Air Force Minute Man III LGM-30.

W80-4 Life Extension Program (LEP)—An LEP for the W80 warhead aboard a cruise missile, delivered by the Air Force B-52 bomber and future launch platforms.

W88—A submarine-launched ballistic missile warhead, delivered by a Navy Trident II.

W88 Alt 370—An alteration of the W88 warhead to replace the arming, fuzing, and firing components and to refresh the conventional high explosive main charge.

W87-1—An intercontinental ballistic missile warhead designed to replace the W78 and support the Air Force’s Ground-Based Strategic Deterrent missile system planned to replace the Minuteman III.

warhead—The part of a missile, projectile, torpedo, rocket, or other munitions that contains either the nuclear or thermonuclear system intended to inflict damage.

War Reserve (WR)—Nuclear weapons and nuclear weapon material intended for use in the event of war.

wireless security—Security solution designed to test and evaluate the impact of mobile and fixed wireless communication devices used in or near classified and sensitive unclassified activity areas for the purpose of determining risks and countermeasures.

Appendix F
Acronyms and Abbreviations

3D	three-dimensional
ACRR	Annular Core Research Reactor
AF&F	arming, fuzing, and firing
Alt	alteration
AM	Additive Manufacturing
AoA	Analysis of Alternatives
ARES	Advanced Radio Enterprise System
ASC	Advanced Simulation and Computing
ASD	Advanced Sources and Detectors
ASIC	application-specific integrated circuit
ATDM	Advanced Technology Development and Mitigation
ATS	Advanced Technology System
BCR	Baseline Cost Report
CapAx	Capital Acquisition Process
CBI	Capabilities Based Investments
CD	Critical Decision
CHAMP	Cooling and Heating Asset Management Program
CHE	conventional high explosive
CMD	Component Manufacturing Development
CMR	Chemistry and Metallurgy Research
CMRR	Chemistry and Metallurgy Research Replacement
COCS	Common Occupational Classification System
CoLOSSIS	Confined Large Optical Scintillator Screen and Imaging System
CORAL	Collaboration of Oak Ridge National laboratory, Argonne National Laboratory, and Lawrence Livermore National Laboratory
COTS	commercially available off-the shelf
CSA	canned subassembly
CSTART	Center for Security Technology, Analysis, Response, and Testing
CTCP	Counterterrorism and Counterproliferation
D&I	disassembly and inspection
DAF	Devise Assembly Facility
DARHT	Dual-Axis Radiographic Hydrodynamic Test
DASO	Demonstration and Shakedown Operation
DNN	Defense Nuclear Nonproliferation
DNS	Office of Defense Nuclear Security
DoD	Department of Defense
DOE	Department of Energy

DSW	Directed Stockpile Work
DUF_4	depleted uranium tetrafluoride
DUF_6	depleted uranium hexafluoride
ECFM	Exascale Computing Facility Modernization
ECP	Exascale Computing Project
ECSE	Enhanced Capabilities for Subcritical Experiments
ELNG	Electronic Neutron Generator
EMETL	Enterprise Mission Essential Task List
ESC	Enterprise Secure Computing
ESN	Enterprise Secure Network
ESSPAP	Enterprise Safeguards and Security Planning and Analysis Program
ETU	Environmental Test Unit
FFRDC	Federally Funded Research and Development Center
FISMA	*Federal Information Security Management Act*
FITARA	*Federal Information Technology Acquisition and Reform Act*
FTE	full-time equivalent
FY	fiscal year
FYNSP	Future Years Nuclear Security Program
G2	Generation 2
GAO	Government Accountability Office
GTS	gas transfer system
HE	high explosives
HED	high energy density
HERMES	High-Energy Radiation Megavolt Electron Source
HEU	highly enriched uranium
HOT SHOT	High Operational Tempo Sounding Rocket Flight Test Program
HPC	high performance computing
HVAC	heating, ventilation, and air conditioning
I&O	Infrastructure and Operations
ICAM	Identity, Credential, and Access Management
ICE	independent cost estimate
ICF	Inertial Confinement Fusion Ignition and High Yield
IDS	Intrusion Detection Systems
IGPP	Institutional General Plant Project
IHE	insensitive high explosive
iJC3	integrated Joint Cybersecurity Coordination Center
IT	information technology
JASPER	Joint Actinide Shock Physics Experimental Research
JODE	Joint Development Environment
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
LDRD	Laboratory Directed Research and Development
LEP	life extension program
LEU	low-enriched uranium
LEU-Mo	low-enriched uranium-molybdenum
LLC	limited life component
LLNL	Lawrence Livermore National Laboratory
LRSO	Long Range Standoff
M&O	management and operating
M/U	margin to uncertainty
MESA	Microsystems Engineering, Science and Applications
MFA	multifactor authentication
MFFF	Mixed Oxide Fuel Fabrication Facility
MGT	Mobile Guardian Transporter
Mod	modification
MRR	Material Recycle and Recovery
MTP	Management, Technology, and Production
NEP	nuclear explosive package
NGFP	NNSA Graduate Fellowship Program
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NPAC	Nonproliferation and Arms Control
NSCI	National Strategic Computing Initiative
OCIO	Office of the Chief Information Officer
OMB	Office of Management and Budget
Omega	Omega Laser Facility
PACS	Physical Access Controls
Pantex	Pantex Plant
PDRD	Plant Directed Research and Development
petaFLOPS	quadrillion floating point operations per second
PF-4	Plutonium Facility
PIDAS	Perimeter Intrusion Detection and Assessment System
ppy	pits per year
pRad	proton radiography
PRIDE	Product Realization Integrated Digital Enterprise
R&D	research and development
RAMP	Roof Asset Management Program
RD	restricted data
RDT&E	research, development, test and evaluation
SAR	Selected Acquisition Report
SCDS	Stewardship Capability Delivery Schedule
SDRD	Site Directed Research and Development
SFI	significant finding investigation
SGT	Safeguards Transporter

SiFab	Silicon Fabrication facility
SIRP	Security Infrastructure Revitalization Program
SMIP	Security Management Improvement Program
SNL	Sandia National Laboratories
SNM	special nuclear material
SRPPF	Savannah River Plutonium Processing Facility
SRS	Savannah River Site
SRTE	Savannah River Tritium Enterprise
SSMP	Stockpile Stewardship and Management Plan
ST&E	science, technology, and engineering
STA	Secure Transportation Asset
STS	stockpile-to-target sequence
TA	Technical Area
TEMPEST	Telecommunications Electronics Material Protected from Emanating Spurious Transmissions
TPBARs	tritium-producing burnable absorber rods
TVA	Tennessee Valley Authority
U.S.	United States
U.S.C.	United States Code
U1a	U1a Complex
UAS	unmanned aircraft system
UK	United Kingdom
USSTRATCOM	U.S. Strategic Command
WBN1	Watts Bar Nuclear Plant Unit 1
WBN2	Watts Bar Nuclear Plant Unit 2
WDCR	Weapon Design and Cost Report
WDD	Weapons Dismantlement and Disposition
WEPAR	West End Protected Area Reduction
WIPP	Waste Isolation Pilot Plant
Y-12	Y-12 National Security Complex
Z	Z pulsed power facility

Appendix G
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A Report to Congress

Fiscal Year 2020 Stockpile Stewardship and Management Plan

July 2019

U.S. Department of Energy
National Nuclear Security Administration
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Washington, DC 20585