NUCLEAR MATTERS HANDBOOK

2020

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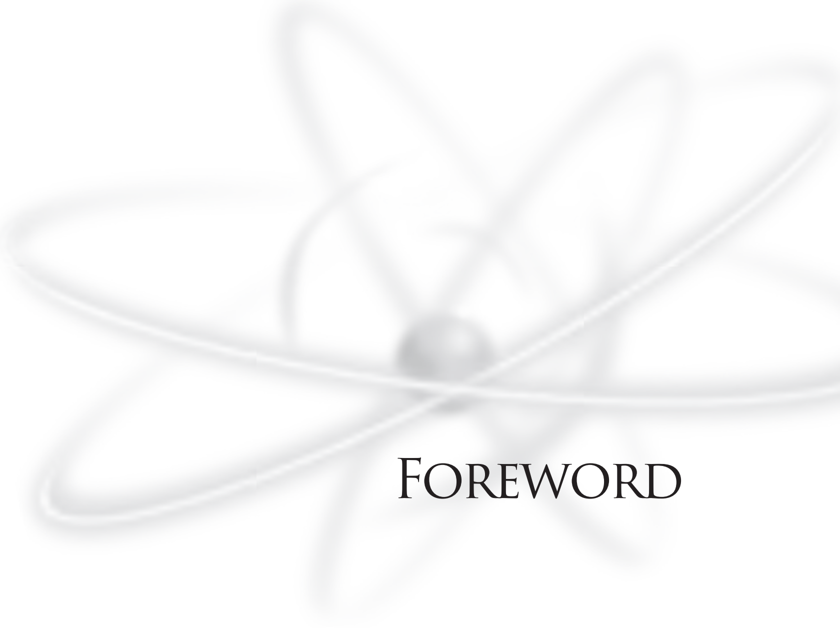
2020

OFFICE OF THE
DEPUTY ASSISTANT SECRETARY OF DEFENSE
FOR NUCLEAR MATTERS



FOREWORD

The Office of the Deputy Assistant Secretary of Defense for Nuclear Matters (ODASD(NM)) is pleased to present the Nuclear Matters Handbook 2020, celebrating over 20 years in print. This book offers an overview of the U.S. nuclear enterprise and how the United States maintains a safe, secure, and effective nuclear deterrent.

The content of this **unofficial** handbook is the sole responsibility of the ODASD(NM). Please refer to the applicable statute, regulation, Department of Defense directives and instructions, or Department of Energy orders for definitive guidance in all areas related to U.S. nuclear weapons. This is an unofficial guide and is therefore neither authoritative nor directive, although every effort has been made to ensure that it is accurate and comprehensive.

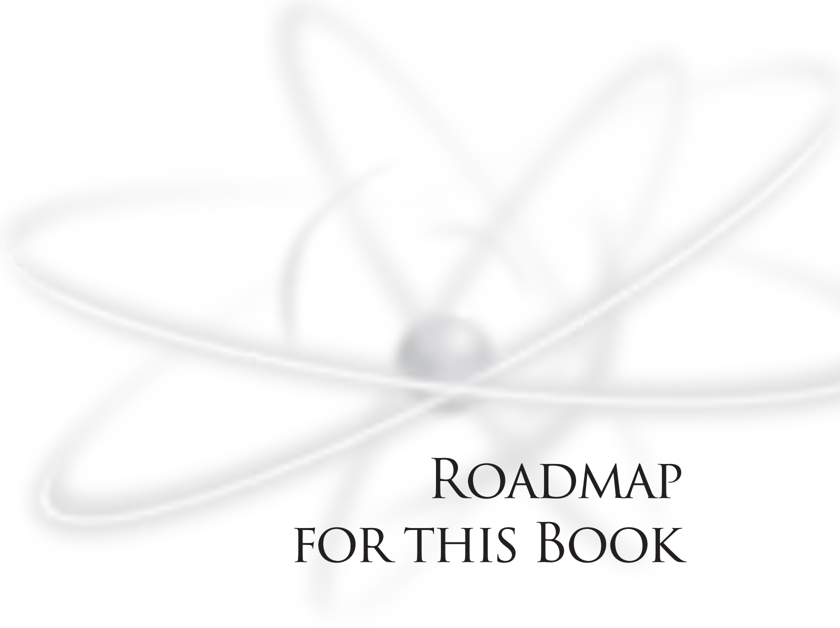
The ODASD(NM) is the successor organization to the Office of the Assistant to the Secretary of Defense for Atomic Energy, first established in 1947. The office oversees and advocates for the safety, security, reliability, survivability, effectiveness, and credibility of the U.S. nuclear deterrent. Nuclear deterrence is the number one priority mission of the Department of Defense.

The ODASD(NM) is the focal point of DoD for the U.S. nuclear weapons stockpile. The office serves as the primary liaison with the Department of Energy/National Nuclear Security Administration (DOE/NNSA) to assure alignment between the two departments that share responsibility for the U.S. nuclear deterrent.

The ODASD(NM) is comprised of representatives from across the U.S. nuclear weapons community, including the Military Departments, NNSA national security laboratories and production sites, Headquarters NNSA, Federal Bureau of Investigation, and contractors with diverse nuclear scientific and operational expertise and experience.

The Nuclear Weapons Council (NWC) Staff is located within the ODASD(NM), as are the staff functions of the Nuclear Deterrent Enterprise Review Group (NDERG), the Strategic Radiation Hardened Electronics Council (SRHREC), and other nuclear-related councils, committees, and groups. It is the only office in the federal government whose area of responsibility includes issues related to both the U.S. nuclear weapons mission and the nuclear threat reduction mission (nuclear counterterrorism and counterproliferation).

For more information, please visit www.acq.osd.mil/ncbdp/nm.



Roadmap for this Book

This handbook provides an **unofficial** but comprehensive overview of the U.S. nuclear deterrent and information relevant to a basic understanding of the many topics and issues related to it. It is intended for anyone seeking an introduction to nuclear weapons and for those who need a more detailed understanding to perform their professional functions.

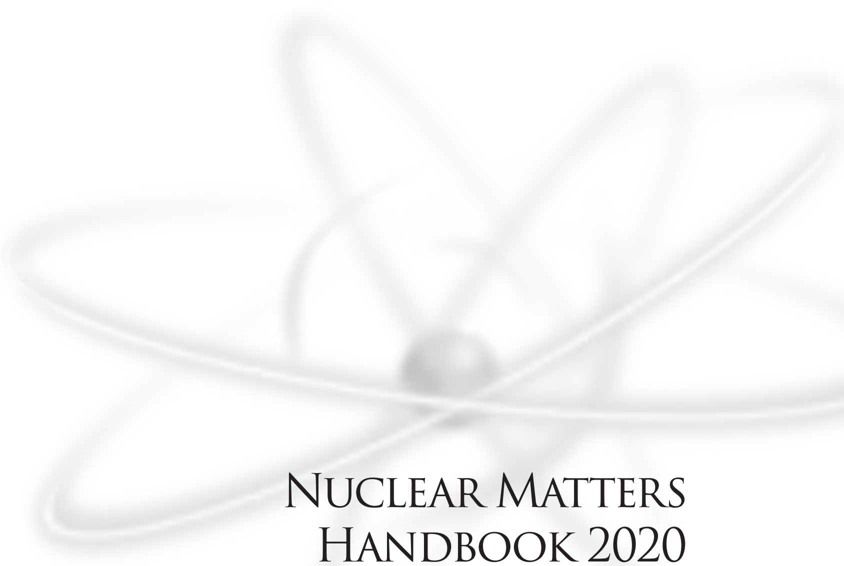
This handbook may be read cover to cover, although each chapter is designed to stand alone in providing information specific to the topics addressed. There are many interdependencies among the various elements of the nuclear deterrent, the authorities under which it operates, and the many organizations that make up the Nuclear Enterprise (DoD) and the Nuclear Security Enterprise (NNSA) as well as other U.S. government agencies and international partners that contribute to the overall health and well-being of the U.S. nuclear deterrent. This handbook makes those connections where feasible, but should be considered more of an unofficial reference document rather than a cohesive narrative.

Chapter 1 offers an overview of the U.S. nuclear deterrent—past, present, and future. Nuclear weapons topics include command and control (Chapter 2), delivery systems (Chapter 3), nuclear weapons (Chapter 4), NNSA infrastructure that supports the deterrent (Chapter 5), and the way in which nuclear weapons are kept safe, secure, and under positive control (Chapter 8). Chapter 9 covers survivability against nuclear weapons effects and nuclear effects testing. Chapter 7 describes the process that drives the development, maintenance, modernization, and retirement of nuclear weapons.

The handbook also covers policies and laws that govern nuclear weapons-related activities undertaken by the U.S. Government. Chapter 6 describes the Nuclear Weapons Council, the DoD-NNSA interagency group that manages the U.S. nuclear deterrent. Chapters 10 and 11 cover international nuclear policy, including nuclear threat reduction efforts and nuclear cooperation with U.S. allies. Chapter 16 covers the budgeting process that supports both DoD and NNSA for nuclear weapons issues.

A brief introduction (for non-technical readers) to the science of nuclear weapons can be found in Chapter 13. Chapter 14 covers the history of nuclear explosive testing, and Chapter 15 details the nuclear fuel cycle and its potential relationship to nuclear proliferation.

The remaining chapters highlight the legal authorities that control various subjects related to nuclear weapons, including nuclear treaties and agreements (Chapter 12), relevant U.S. laws and policies (Chapter 17), and the classification of nuclear information (Chapter 18).



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TRINITY SITE
WHERE
THE WORLD'S FIRST
NUCLEAR DEVICE
WAS EXPLODED ON
JULY 16, 1945

CHAPTER 1

THE U.S. NUCLEAR DETERRENT: PAST, PRESENT, AND FUTURE

> *"Our nuclear deterrent is nearing a crossroads. To date, we have preserved this deterrent by extending the lifespan 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."*
>
> *General Paul Selva, USAF (Ret.),*
> *Former Vice Chairman of the Joint Chiefs of Staff*

OVERVIEW

Nuclear deterrence is the bedrock of U.S. national security, serving as the backstop and foundation of U.S. national defense and the defense of U.S. allies since 1945. The U.S. nuclear deterrent is comprised of nuclear weapons and delivery systems, nuclear command, control, and communications, and the people and infrastructure that support it all. While U.S. nuclear weapons have not been employed since World War II, the United States uses its nuclear deterrent every day to maintain peace around the globe. The U.S. nuclear deterrent underwrites every U.S. military operation.

There have been three distinct eras since the dawn of the nuclear age in the United States. The first era began with the use of an atomic bomb in 1945, followed by a nuclear arms race with the Soviet Union, and ended with the last U.S. nuclear explosive test in 1992 after the end of the Cold War. The second era, from 1992–2018, was characterized by the sustainment of the Cold War legacy deterrent in the absence of underground nuclear testing. This era ended with the publication of the *2018 Nuclear Posture Review* (NPR), which acknowledged the resurgence of Russia and the rise of China as strategic competitors and potential adversaries.

The United States is currently in the midst of transitioning to the third nuclear era, which will be characterized by limited nuclear weapons production without nuclear explosive testing. Once again the United States is doing something that has never been done before—in this case rebuilding its nuclear production capability after decades of inactivity and deferred recapitalization.

During the first nuclear era, the United States focused on developing and refining the military uses of nuclear energy, with increasing sophistication and technical acuity. At the beginning of the second nuclear era, there was hope that the fall of the Soviet Union would lead to global stability and security and, therefore, the United States endeavored to lead the world in reducing the role and number of nuclear weapons. Unfortunately, while the United States was focused on maintaining its existing nuclear systems, Russia and China were emphasizing the role of nuclear weapons in their military strategies and actively increasing the quantity and sophistication of their nuclear forces.

The 2018 NPR recognized this reality and ushered in a third nuclear era, acknowledging the return to Great Power competition and the enduring need for the U.S. nuclear deterrent to be effective in the face of an increasingly complex and dangerous strategic environment. The United States cannot project power against nuclear-armed adversaries without effective, reliable nuclear forces. Today, Russia is modernizing across its nuclear arsenal as well as its other strategic systems. The strategic calculation that once propelled U.S. nuclear strategy during the Cold War has been reversed, and Russia is now building up its nuclear capability in order to counter the perceived dominance of U.S. conventional forces. Additionally, Russia has adopted military strategies and capabilities that rely on nuclear escalation for their success. Russia has been developing, testing, and fielding new systems for its nuclear triad over the past decade. This includes new road-mobile and silo-based intercontinental ballistic missiles (ICBMs), ballistic missile submarines (SSBNs) and missiles, bomber aircraft, and cruise missiles. Russia is also actively testing never-before-seen nuclear capabilities such as hypersonic glide vehicles, nuclear-powered and nuclear-armed cruise missiles, and nuclear-powered unmanned underwater vehicles.

China, too, is modernizing and expanding its already considerable nuclear forces, marking the return to Great Power competition. China is developing, testing, and fielding new generations of land-based ballistic missiles, increasing the range of its submarine-launched ballistic missiles, and pursuing a new bomber. China is also expending significant resources on advanced nuclear-capable systems and hypersonic vehicles. See Figure 1.1 for an overview of the nuclear environment in which the United States is fielding a modern deterrent for the 21st Century.

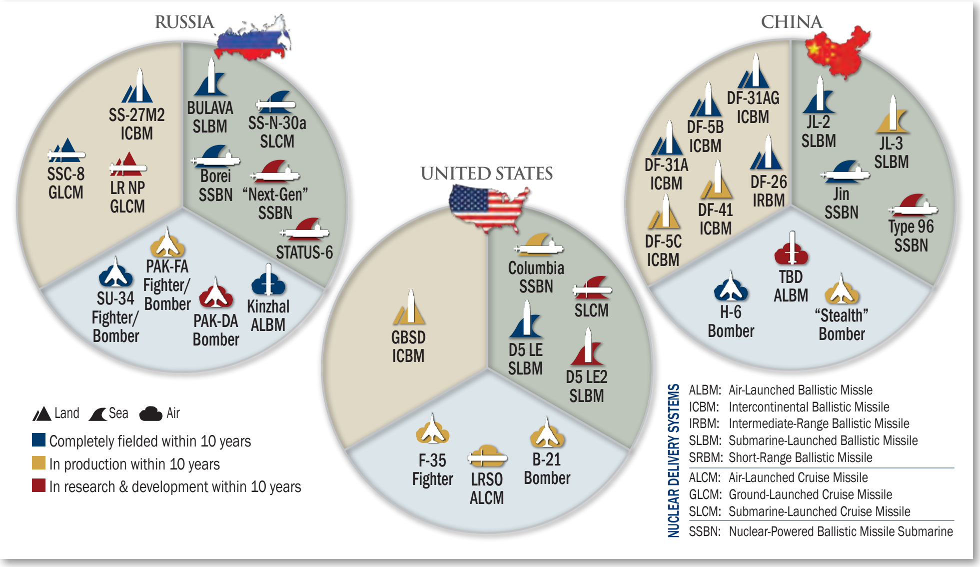

Figure 1.1 Nuclear Delivery System Programs of the United States, Russia, and China

BRIEF HISTORY OF NUCLEAR WEAPONS

FIRST NUCLEAR ERA—1945 TO 1992

Nuclear weapons came into being as a result of a bold attempt to invent a practical way to use an untested technology. The Manhattan Project delivered the world's first atomic bombs in 1945. On July 16, 1945, the United States detonated its first nuclear explosive device, called "the gadget," at the Trinity Site in New Mexico. Twenty-one days later, President Harry S. Truman authorized a specially equipped B-29 bomber named the *Enola Gay* (Figure 1.2) to drop a nuclear bomb, dubbed *Little Boy* (Figure 1.3), on Hiroshima, Japan. When the Japanese failed to surrender, a second B-29 bomber, *Bockscar* (Figure 1.4), dropped a second U.S. atomic weapon, *Fat Man* (Figure 1.5), on Nagasaki.

The use of nuclear weapons shortened the war and reduced the number of potential casualties on both sides by precluding a planned U.S. land invasion of Japan. The atomic bombs dropped on Hiroshima and Nagasaki remain the only nuclear weapons ever used in combat.

The United States did not remain the sole nuclear power for long. The Soviet Union tested its first nuclear device in August 1949. The United Kingdom became the third nuclear weapons state with its first test in October 1952.

The era that followed was defined by the competition between the two nuclear superpowers, the United States and the Soviet Union. New weapon designs were rolled out on a regular basis, and nuclear explosive testing supported continuous innovations in nuclear weapons technology.

At the beginning of the nuclear era, the U.S. nuclear weapons program focused on producing sufficient nuclear material to build enough weapons for a second-strike capability—the ability to attack after absorbing an all-out first strike—as well as fielding weapons on almost every type of military delivery system available, including nuclear depth charges and nuclear artillery shells. By 1967, the United States had over 30,000 nuclear weapons in its arsenal. Many of these were “tactical”—shorter range, lower yield, non-strategic—nuclear weapons. The United States relied on nuclear weapons as the only means available to counter the dominance of Soviet conventional forces, particularly in Europe.

After 1967, U.S. priorities shifted in the face of economic pressures. Because warheads were less expensive than missiles, U.S. strategy emphasized nuclear weapons with high yield-to-weight ratios and the

Figure 1.2 Enola Gay

Figure 1.3 Little Boy

Figure 1.4 Bockscar

Figure 1.5 Fat Man

ability to field Multiple Independently Targetable Reentry Vehicles (MIRVs), allowing several warheads to be mounted on a single missile. This required a shift in the production focus from quantity to sophistication. Modernization programs for many U.S. weapons systems featured improved operations and logistics for the military operator, more modern safety, security, and control features, and better military performance characteristics (e.g., selectable yields and greater accuracy). The United States also drastically reduced its stockpile of non-strategic nuclear weapons. These changes were made possible by a better understanding of nuclear physics and weapon designs provided by nuclear explosive testing.

SECOND NUCLEAR ERA—1992 TO 2018

At the end of the Cold War, with the dissolution of the Soviet Union, there was reduced focus on nuclear weapons without a nuclear superpower rival. With the near simultaneous end of both nuclear weapons production in 1991 and nuclear testing in 1992, the new challenge facing the nuclear enterprise was to maintain and sustain the legacy deterrent without production or testing, and to extend the operational lives of both weapons and delivery systems indefinitely.

In 1991, the United States closed the Rocky Flats plant in Colorado, which had produced up to 1,500 plutonium pits a year for the stockpile. The same year, in an effort to realize the "peace dividend" from the end of the Cold War, President George H.W. Bush ordered the withdrawal and destruction of ground-launched short-range missiles that had carried nuclear weapons, and the removal of all tactical nuclear weapons from surface ships, attack submarines, and naval aircraft. In 1992, in anticipation of a potential comprehensive test ban treaty, the United States voluntarily suspended its program of underground nuclear testing, and has not conducted an explosive nuclear test since.

The abrupt termination of both nuclear weapons production and testing brought an immediate halt to the continuous cycle of modernization programs that included building and subsequently replacing the weapons in the stockpile with newer, more modern designs. A key part of this process was the use of nuclear testing to refine new designs in the development process, to test the yields of weapons after they were fielded, and to define and repair certain types of technical problems. Without an ability to produce new weapons or to test, the United States was faced with the unexpected challenge of sustaining the deterrent in a new and unknown way. It was a time of great uncertainty as well as creativity as new paths were forged.

The *National Defense Authorization Act for Fiscal Year 1994* directed the Department of Energy (DOE) to establish a Stockpile Stewardship Program (SSP) as a substitute for underground nuclear testing, using science-based methods and advanced computing to guarantee that the stockpile remained safe, secure, and effective without the need to conduct nuclear explosive tests. At the time, no one knew exactly how this was going to be accomplished.

Since 1994, DOE, and subsequently the National Nuclear Security Administration (NNSA), have successfully maintained and sustained the safety, security, and effectiveness of the stockpile without nuclear explosive testing. Through the development of new scientific, computational, and technical tools and methodologies, the Secretaries of Defense and Energy have been able to certify the continued viability of the U.S. nuclear deterrent without nuclear explosive testing every year since 1995.

The United States has not produced a new nuclear weapon (with new nuclear components) since 1991. During this time, the United States also significantly reduced its stockpile quantities. In 1991, the U.S. nuclear stockpile had 19,000 nuclear weapons; by 2003, there were approximately 10,000; by 2009, there were roughly 5,000. In 2017, the last time the United States published unclassified stockpile numbers, there was a total of about 3,800 weapons. Figure 1.6 shows the size of the U.S. nuclear stockpile from 1945 to 2017.[1]

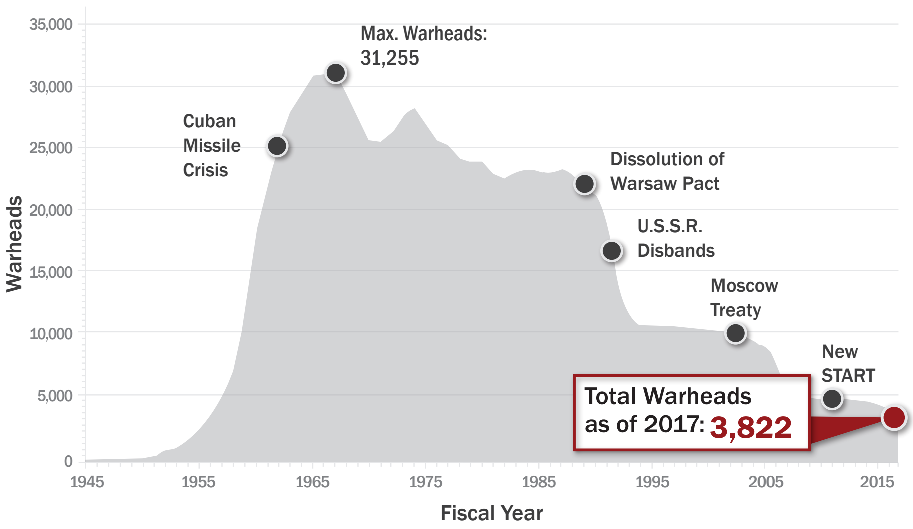

Figure 1.6 U.S. Nuclear Stockpile, 1945–2017

Because the United States has produced no new nuclear weapons, it has instead extended the lives of the weapons in the legacy stockpile. Life extension

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[1] The number of warheads depicted in Figure 1.6 include both active and inactive warheads. Several thousand additional nuclear warheads are retired and awaiting dismantlement.

programs (LEPs) have underpinned the ability of the United States to sustain its weapons well beyond their original design lives. Until these legacy weapons are replaced with newly manufactured weapons, which is currently planned to begin in the early 2030s, these weapons will continue to age.

The U.S. nuclear stockpile has continued to decrease in quantity in accordance with arms control treaties with Russia and internal U.S. decisions concerning the appropriate size of the U.S. nuclear deterrent. The New START Treaty, which limits the number of strategic weapons for the United States and Russia, will expire on February 25, 2021. There is an option to extend the treaty for a period of no more than five years if both parties agree.

THIRD NUCLEAR ERA—2018 AND BEYOND

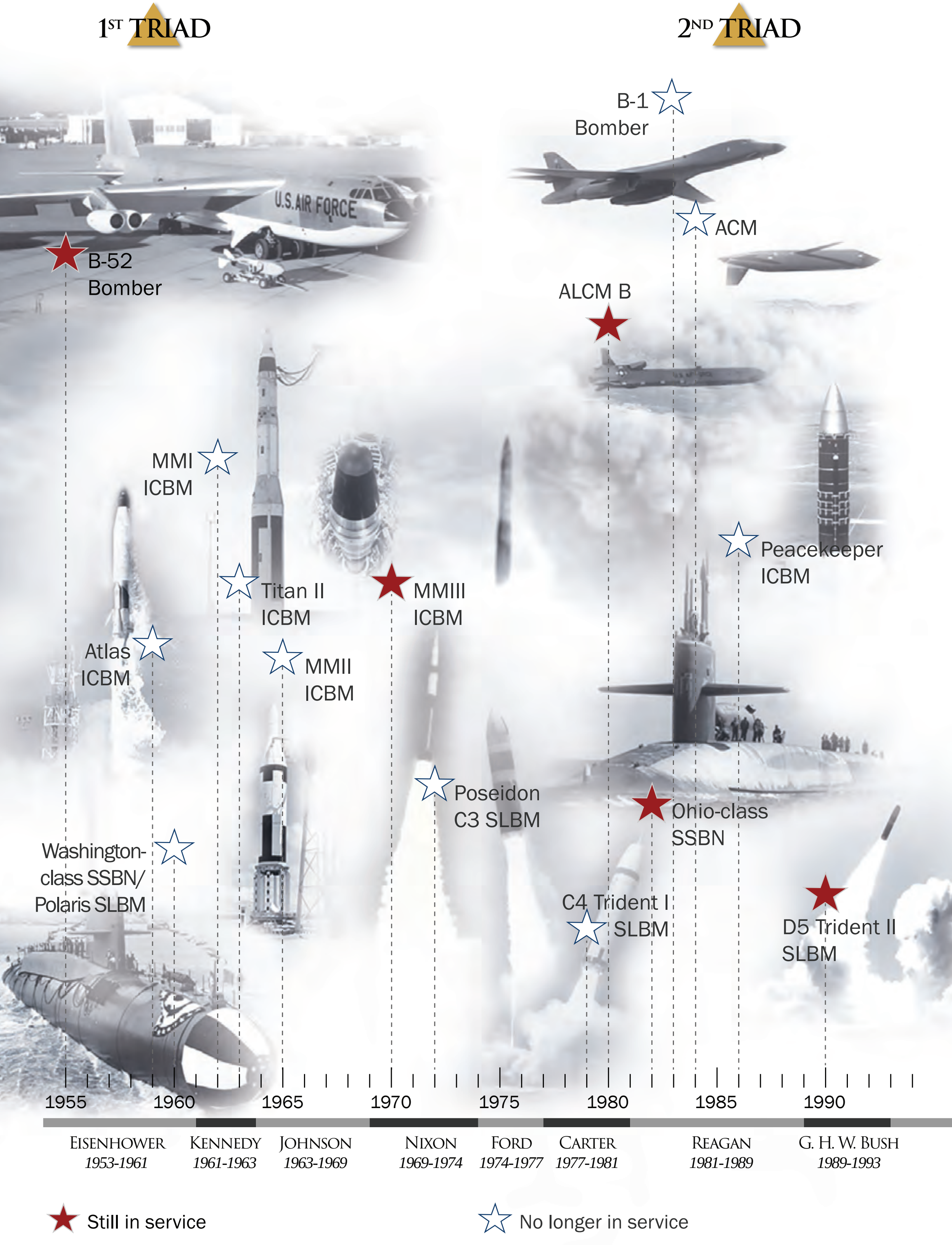
The 2018 NPR recognized that a new era for U.S. nuclear policy has begun. The world is more dangerous than the United States had hoped. Nuclear competition among Great Powers has not gone away. While the NNSA SSP has succeeded in keeping the legacy stockpile safe, secure, and effective up to this point, it cannot continue to do so indefinitely. The United States will once again be faced with the challenge of doing something it has never done before: reconstituting a nuclear weapons production capability without the benefit of nuclear explosive testing. At the same time, the threat is evolving and becoming increasingly complex, including potential cyber threats and threats against the U.S. industrial base and the supporting supply chain. The United States is embarking on the largest, most complex nuclear modernization effort in its history. As illustrated in Figure 1.7, it will be 45 years between the peak of the last modernization effort in 1984 and the next peak, projected for 2029.

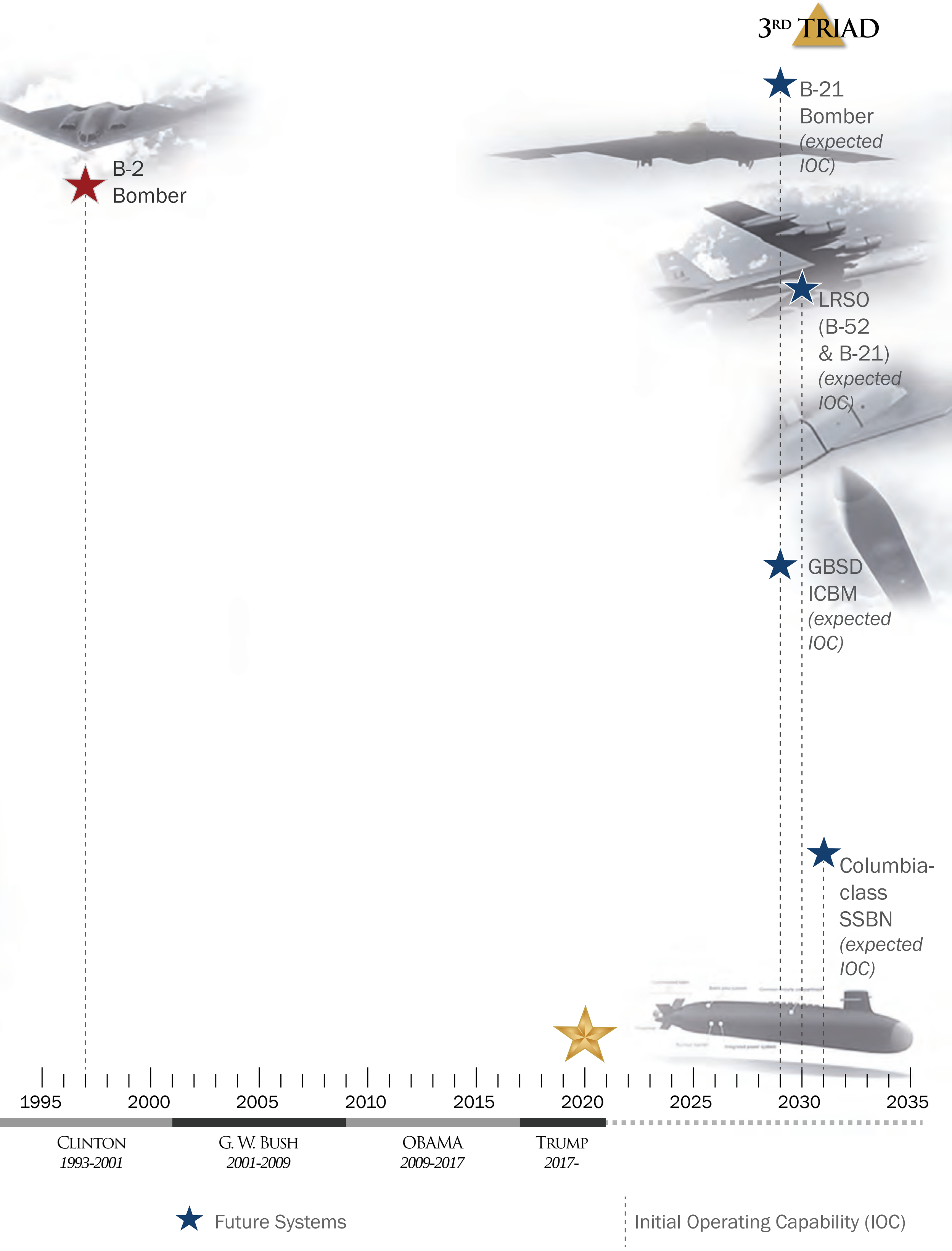
NUCLEAR MODERNIZATION PROGRAMS

The United States is modernizing all three legs of its nuclear triad, and is also reconstituting its weapons production capability at roughly the same time. The average age of U.S. nuclear weapons will be more than 40 years old at life extension or planned retirement—more than twice their original design lives. All life-extended weapons in the stockpile will reach the end of their planned lifetimes by mid-century, which in some cases is more than three times as long as they were designed to operate. Some components of those life-extended weapons (e.g., plutonium pits) have been reused as-is, meaning that those components have been in the stockpile for many decades beyond their originally projected lifespans, and will remain in the stockpile until they can be replaced.

U.S. nuclear delivery systems are similarly situated, with all of them being sustained beyond their design lives. By 2035, 100% of U.S. nuclear delivery

NUCLEAR MODERNIZATION - 1955 TO 2035




3RD TRIAD
B-21 Bomber (expected IOC)
B-2 Bomber
LRSO (B-52 & B-21) (expected IOC)
GBSD ICBM (expected IOC)
Columbia-class SSBN (expected IOC)
1995
2000
2005
2010
2015
2020
2025
2030
2035
CLINTON 1993-2001
G. W. BUSH 2001-2009
OBAMA 2009-2017
TRUMP 2017-
Future Systems
Initial Operating Capability (IOC)

systems will have exceeded their design lives by an average of 30 years. By the early 2040s, 100% of U.S. nuclear delivery vehicles will have reached end of life. At retirement, both the air-launched cruise missile (ALCM) and the Minuteman III ICBM will be over 50 years into their 10-year design life. The Ohio-class SSBN is already beyond its projected lifetime, and the B-2A bomber and the F-15E dual-capable aircraft will both be approaching 40 years old before they are retired. The B-52 bomber will be about 100 years old when it is finally scheduled to retire in the mid-2050s.

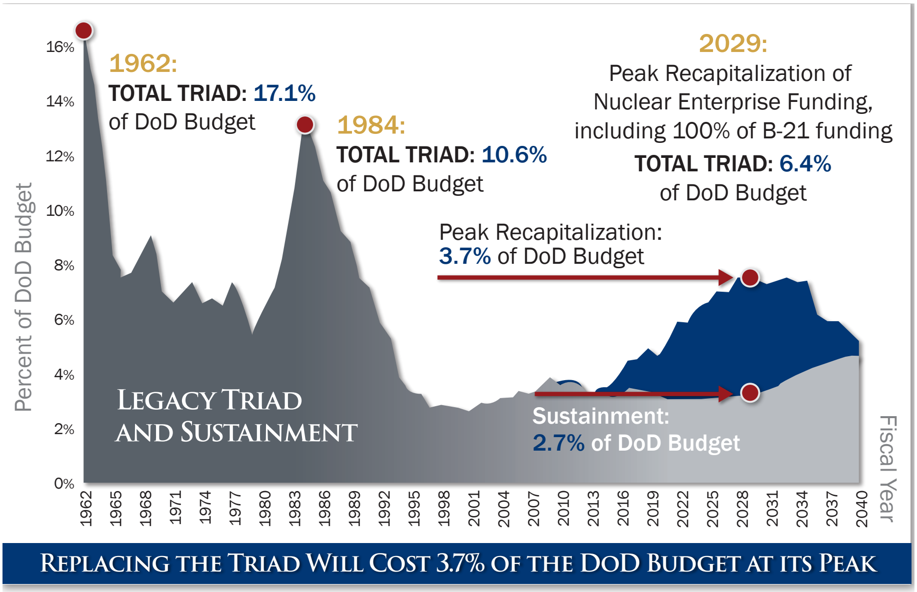
All current U.S. ballistic missile warheads were designed and built in the 1970s and 1980s, and their designs addressed specific Cold War problems from the 1960s. In the time of high stockpile numbers, U.S. nuclear tactics emphasized overwhelming adversary defenses using many weapons to defeat a single target and using as much yield as possible given space and weight constraints.

For deterrence purposes, the current composition of the stockpile must contain the attributes required to maintain sufficient diversity and flexibility, to include:

- *Survivable* – the force and nuclear command, control, and communications (NC3) resilience needed to survive any potential adversary attack and endure throughout crises and conflict;
- *Forward Deployable* – the mobility and range needed to temporarily or permanently relocate some U.S. nuclear capabilities to allied or partner territory for needed political or military effect;
- *Diverse and Graduated Options* – the availability of forces with the spectrum of yield options, weapon types, and delivery options necessary to support the most effective tailoring of strategies across a range of adversaries and contingencies;
- *Accurate Delivery* – the precision needed to hold adversary assets at risk while minimizing unintended effects;
- *Penetrating* – the capacity to counter active and passive defenses, including hardened and buried facilities, to pose credible deterrent threats, and achieve military objectives with high confidence;
- *Responsive* – the capacity to deploy and employ forces as promptly as is necessary to pose credible threats;
- *Diversity of Ranges* – the availability of forces with a spectrum of range options necessary to support the most effective tailoring of strategies;
- *Diversity of Trajectories* – the capacity to locate forces at multiple geographical locations and with multiple flight profiles to complicate adversary active and passive defense planning;

- *Visible* – the capacity to display national will and capabilities as desired for signaling purposes throughout crisis and conflict; and
- *Weapon Reallocation* – the capacity to change target information quickly to enable adaptive planning and effective employment.[2]

Nuclear deterrence is the number one priority mission of DoD and its highest investment priority. DoD expects nuclear modernization, including strategic delivery platforms and nuclear command and control systems, to cost approximately 3.7% of the DoD budget during the peak of the 23-year modernization period (this does not include the costs for NNSA). Total projected costs for sustainment plus modernization of U.S. nuclear forces is approximately 6.4% of the DoD budget in the same time period (see Figure 1.8). By these measures, these efforts are notably more cost effective than in the past—the previous two large nuclear recapitalization efforts required 10.6% of the defense budget in the early 1980s and 17.1% of the defense budget in the early 1960s. As former Secretary of Defense James Mattis affirmed, "America can afford survival."



REPLACING THE TRIAD WILL COST 3.7% OF THE DOD BUDGET AT ITS PEAK

Figure 1.8 DoD Nuclear Enterprise Funding
(Source: 2018 NPR)

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[2] U.S. Department of Defense, "Nuclear Posture Review," (Arlington, VA: U.S. Department of Defense, February 2018), 43–44, https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF.

FUTURE OF THE NUCLEAR DETERRENT

While some may characterize the past three decades as the United States doing nothing while U.S. adversaries continued to advance their offensive and defensive forces, the United States has not been idle. The U.S. military has operated the nuclear force so that the deterrent has done its job, as evidenced by the fact that no nuclear weapons have been employed in combat since 1945. In addition, U.S. scientists, engineers, designers, and production workers have maintained the stockpile and successfully extended the lives of U.S. weapons without the need to resume nuclear explosive testing.

However, Cold War legacy delivery systems and their associated weapons cannot be sustained indefinitely. It is necessary to modernize the nuclear deterrent to avoid "rusting to zero" (performance degradation due to weapons aging). A modern U.S. deterrent must also be threat responsive, and able to take advantage of technological advances, as adversary technologies also advance. Replacement programs are underway to ensure there are no capability gaps when these legacy systems age out, or become obsolete due to advances in adversary capabilities.

Nuclear deterrence will continue to be vital to U.S. national security strategy and be underpinned by nuclear forces and effective nuclear command, control, and communications. The nuclear deterrent will provide survivable, responsive capabilities to ensure adversaries do not attempt a disarming first strike; demonstrate resolve through the positioning of forces, messaging, and flexible response options; ensure the United States can respond to a broad range of contingencies with tailored options; and mitigate the risk of a technological failure or adversary breakthrough while providing adaptability to changes in the security environment.


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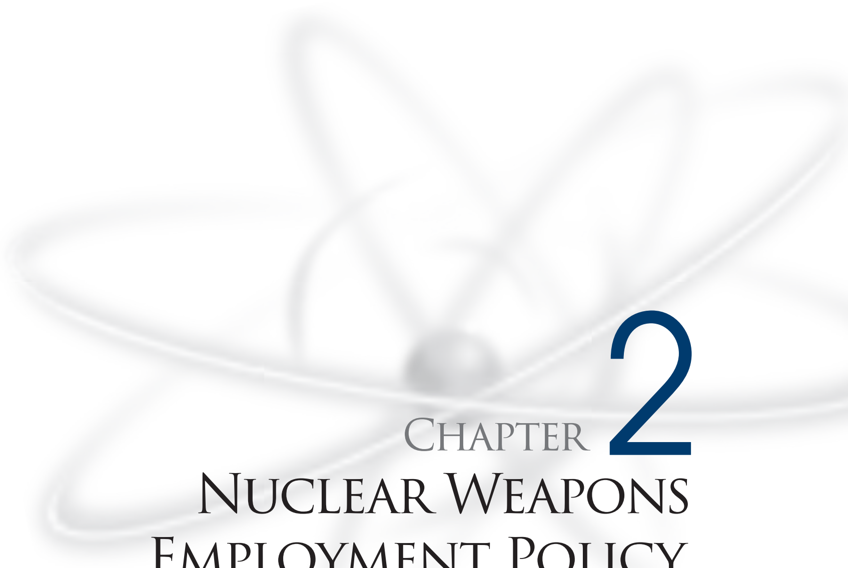

CHAPTER 2

NUCLEAR WEAPONS EMPLOYMENT POLICY, PLANNING, AND NC3

OVERVIEW

Planning for the potential employment of U.S. nuclear forces goes through a deliberate and meticulous process. This process includes elements such as identification of objectives and guidance, target development, weaponeering, force planning, force execution, and battle damage assessment (BDA). In order to meet policy and planning objectives, U.S. Strategic Command (USSTRATCOM) and geographic combatant commands nominate, vet, and select adversary strategic facilities and capabilities as targets. This process cannot succeed without command and control, and U.S. policy states that the nuclear deterrent is only as effective as the command and control network that enables it to function. The United States ensures this effectiveness through the Nuclear Command and Control System (NCCS), a combination of capabilities necessary to: ensure the authorized employment and termination of nuclear weapon operations under all threats and scenarios; secure against the accidental, inadvertent, or unauthorized access to U.S. nuclear weapons; and prevent the loss of control, theft, or unauthorized use of U.S. nuclear weapons. The NCCS is broken into two main components: nuclear command, control, and communications (NC3) and nuclear weapons safety, security, and incident response. NC3 is the focus of this chapter.

NUCLEAR WEAPONS EMPLOYMENT POLICY AND PLANNING

OBJECTIVES AND GUIDANCE

Planning for the potential employment of U.S. nuclear forces goes through a deliberate and methodical process, as depicted in Figure 2.1. The first step in the planning process is the issuance of nuclear employment policy and planning guidance to meet national security objectives. Planning for the employment of nuclear systems is consistent with national policy and strategic guidance, which is articulated in a number of documents. These include:

- *Presidential guidance*, issued through directives and memoranda, addresses planning, posture, and strategic objectives regarding nuclear employment.
- *Departmental guidance*, issued by the Secretary of Defense, implements the President's guidance and contains amplifying planning and policy guidance consistent with Presidential direction.
- *Military guidance*, from the Chairman of the Joint Chiefs of Staff (CJCS) to Combatant Commanders (CCDRs), provides guidance on the development and coordination of nuclear operations plans.
- *Other strategy and posture documents*, such as the *National Security Strategy*, the *National Defense Strategy*, and the *Nuclear Posture Review*, which together describe U.S. nuclear policy, strategy, capabilities, and force posture.

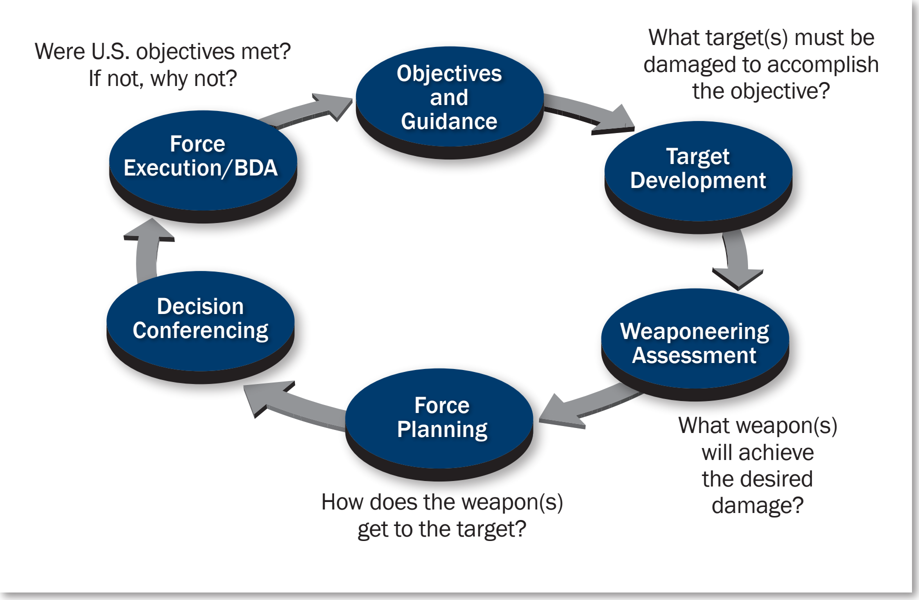

Figure 2.1 Nuclear Planning Process

TARGET DEVELOPMENT

In order to meet policy and planning objectives, USSTRATCOM and geographic combatant commands nominate, vet, and select adversary strategic assets, facilities, and capabilities as targets. This process is based on analysis of the strategic environment as well as the identification of adversary weaknesses that, if exploited, would help achieve U.S. military goals and objectives. Facilities and capabilities can be nominated as they are discovered or in response to changing priorities, guidance, or objectives. Once selected, the Defense Intelligence Agency (DIA) performs a physical vulnerability assessment to evaluate a target's susceptibility to the effects of a nuclear weapon.

Using engineering best practices and target intelligence information, structural engineers develop detailed models of targets with an emphasis on design aspects, and the construction practice and materials relevant to a comprehensive vulnerability analysis. Simplifying assumptions are made about the behavior of a structure and a numerical engineering model is developed to evaluate the target's response to nuclear weapon effects. The applied modeling techniques span the spectrum of numerical methods, from simple single-degree of freedom models to high fidelity codes. Factors determining the type of method used include required structural details, damage mechanism, and strategic importance of the target. Whether very simple or very complex, the model must allow an estimate of the actual behavior of the structure with reasonable accuracy.

A target's response to a nuclear detonation is determined for a wide range of weapon yields and results in a vulnerability number. Vulnerability numbers for targets are stored in the DIA target database, the national-level repository for the general military intelligence available to the entire DoD intelligence information system community.

WEAPONEERING ASSESSMENT

Nuclear planning or "weaponeering" is the process of delivering and applying weapons to targets in order to meet national and military objectives. Nuclear weaponeering assessments consider the characteristics of nuclear systems (e.g., yield and accuracy) against the characteristics of targets (e.g., vulnerability, size, defenses) and seek to identify applications of weapons on targets that would succeed in delaying, disrupting, disabling, or destroying critical enemy forces or resources. Other considerations include the adversary ability to reconstitute or regenerate, avoidance of collateral damage, and environmental conditions in the target vicinity.

Another aspect of nuclear planning is the construction of the intended location of a weapon detonation, known as the Desired Ground Zero (DGZ). The goal of DGZ construction is to identify weapon aim points to achieve the stated damage criteria. Whenever possible, a single weapon may be planned for use to cause damage to multiple targets.

Force Planning

Force planning brings together target development and weaponeering analysis with available forces. It marks a shift in the overall process from analysis to operational planning. Planning for the employment of nuclear weapons is based on a number of factors, to include: the number, yields, and types of nuclear weapons available; the operational availability of weapon delivery platforms; the characteristics and limitations of the forces available; and the status and disposition of friendly forces at the time nuclear weapons are to be employed.

Each nuclear delivery system and weapon has unique planning and employment considerations, including alert levels and generation times (time required for the weapon or system to become available for employment), overflight considerations, and flight times. As such, there may be adjustments to targeting recommendations as planners develop force packages, assign primary and supporting assets to carry out the mission, and deconflict other operational considerations (e.g., timing, sequencing). This is a dynamic stage in the overall process, whereby operations and intelligence staffs work closely together to determine the optimal execution of nuclear-capable forces and supporting assets to engage a target and achieve a particular objective.

Decision Conferencing

The decision to employ nuclear weapons requires the explicit authorization of the President of the United States. In a crisis, the President will be briefed on the likelihood of achieving national or military objectives using nuclear weapons as well as the diplomatic, strategic, operational, and legal implications of such use. The President bases this decision on many factors and will consider the advice and recommendations of senior advisors, to include the Secretary of Defense, the Chairman of the Joint Chiefs of Staff, and CCDRs. Depending on the crisis situation, the President may consult with U.S. allies during the decision-making process. The Nuclear Command and Control System plays a critical role in enabling decision-making conferencing and, if determined, receiving presidential orders to conduct a nuclear strike.

Force Execution/Battle Damage Assessment

The execution of nuclear operations must seek to optimize both the survivability and combat effectiveness of the forces, while mitigating casualties to the extent possible while still achieving objectives. As a whole, U.S. nuclear forces are diverse, flexible, effective, survivable, enduring, and responsive in order to prevail against a range of threats and across a spectrum of environmental conditions.

During the pre- and post-employment of nuclear forces, planners, operators, and intelligence staffs will conduct a battle damage assessment. This entails measuring the physical and functional effects of target engagement, assessing the extent of collateral damage, and examining the overall impact on adversary military activities. This includes examining direct, indirect, cumulative, cascading, and unintended effects of nuclear weapon use, which are further described in *Chapter 13: Basic Nuclear Physics and Weapons Effects*.

NUCLEAR WEAPONS TARGETING TERMINOLOGY

Damage Criteria

Damage criteria are standards identifying specific levels of destruction or material damage required for a particular target category. These criteria vary by the intensity of the damage and by the particular target category, class, or type, and are based on the nature of the target, including its size, hardness, and mobility, as well as the target proximity to military or non-military assets. These criteria provide a means by which to determine how best to strike particular targets and, following the attack, evaluate whether the target or target sets were sufficiently damaged to meet operational objectives.

Radius of Damage

Radius of damage (RD) is the distance from the nuclear weapon burst at which the target elements have a 50 percent probability of receiving at least the specified (severe or moderate) degree of damage. In strategic targeting, this has been called the weapon radius. Because some target elements inside the RD will escape the specified degree of damage while some outside the RD are damaged, response variability results. The RD depends on the type of target, the yield of the weapon, the damage criteria, and height of burst (HOB) of the nuclear weapon.

Circular Error Probable

Circular error probable (CEP) is a measurement of the delivery accuracy of a weapon system and is used as a factor in determining probable damage to a target. The CEP is the radius of a circle within which half of the weapons are expected to fall. A weapon has a 50 percent probability of landing within one CEP of an aimpoint.

Probability of Damage

Probability of damage (PD) is the prospect of achieving at least the specified level of damage, assuming the weapon arrives and detonates on target. It is expressed as fractional coverage for an area target and probability of damage for a point target. The PD is a function of nuclear weapons effects and weapons system delivery data including yield, RD, CEP, and HOB.

Probability of Arrival

Probability of arrival (PA) is the likelihood the weapon arrives and detonates in the target area, calculated as a product of weapon system reliability (WSR), prelaunch survivability (PLS), and probability to penetrate (PTP). The equation for planners is WSR x PLS x PTP = PA.

- *WSR* – compounded reliability based on test data for each warhead-type and each delivery system type.
- *PLS* – probability the weapon system will survive a strike by the enemy.
- *PTP* – probability the weapon system survives enemy air-defense measures and reaches the target.

Damage Expectancy

Damage expectancy (DE) is calculated as the product of the PD and the PA, shown in the formula PA x PD = DE. DE accounts for both weapons effects and the probability of arrival in determining the probability of achieving at least the specified level of damage.

Nuclear Collateral Damage

Nuclear collateral damage is undesired damage or casualties produced by the effects of nuclear weapons. Such damage includes danger to friendly forces, civilians, and non-military-related facilities as well as the creation of obstacles and residual nuclear radiation contamination. Because the avoidance of casualties among friendly forces and non-combatants is a prime consideration when planning either strategic or theater nuclear operations, preclusion analyses must be performed to identify and limit the proximity of a nuclear strike to civilians and friendly forces. Specific techniques for reducing collateral damage include:

- *Reducing weapon yield* – the yield of the weapon needed to achieve the desired damage is weighed against the associated risks in the target area;
- *Improving accuracy* – accurate delivery systems are more likely to strike closer to the aimpoint, reducing the required yield and the potential collateral damage;
- *Employing multiple weapons* – collateral damage can be reduced by dividing one large target into two or more smaller targets and by using more than one lower-yield weapon rather than one high-yield weapon;
- *Adjusting the height of burst* – HOB adjustments, including the use of air bursts to preclude any significant fallout, can help to minimize collateral damage; and
- *Offsetting the desired ground zero* – moving the DGZ away from target center may achieve the desired effects while avoiding or minimizing collateral damage.

Counterforce Targeting

Counterforce targeting plans to destroy the military capabilities of an enemy force. Typical counterforce targets include bomber bases, ballistic missile submarine bases, intercontinental ballistic missiles (ICBM) silos, air-defense installations, command and control centers, and weapons of mass destruction storage facilities. Because these types of targets may be hardened, buried, masked, mobile, and defended, the forces required to implement this strategy need to be diverse, numerous, and accurate.

Countervalue Targeting

Countervalue targeting plans the destruction or neutralization of selected enemy military and military-related targets such as industries, resources, and/or institutions contributing to the enemy's war effort. As these targets tend to be softer and less protected, weapons required for this strategy need not be as numerous or accurate as those required to implement a counterforce targeting strategy.

Layering

Layering is a technique that plans to use more than one weapon against a target. This method is used to either increase the probability of target destruction or improve the probability a weapon arrives and detonates on target to achieve a specific level of damage, particularly against defended targets.

Cross-Targeting

Cross-targeting incorporates the concept of "layering" and uses different delivery platforms for employment against one target to increase the probability of at least one weapon arriving at that target. Using different delivery platforms, such as ICBMs, SLBMs, or aircraft-delivered weapons, increases the probability of achieving the desired damage or target coverage, particularly against hardened, buried, masked, mobile, and defended targets.

NUCLEAR COMMAND, CONTROL, AND COMMUNICATIONS

The U.S. command and control is necessary to ensure the authorized employment and termination of nuclear weapons operations, to secure against accidental, inadvertent, or unauthorized access, and to prevent the loss of control, theft, or unauthorized use of U.S. nuclear weapons. The President's ability to exercise authorities is ensured by NC3.

NUCLEAR COMMAND AND CONTROL

In order to understand NC3, it is important to define nuclear command and control (NC2). NC2 is the exercise of authority and direction, through established command lines, over nuclear weapon operations by the President as the chief executive and head of state. NC2 is supported by a survivable network of communications and warning systems that ensure dedicated connectivity from the President to all nuclear-capable forces. The fundamental requirements of NC2 are that it must be assured, timely, secure, survivable, and enduring in providing the information and communications for the President to make and communicate critical decisions throughout the crisis spectrum.

EXERCISING PRESIDENTIAL AUTHORITY

NC3 assures the integrity of transmitted information and must be survivable to reliably overcome the effects of a nuclear attack. NC3 performs five critical functions:

- detection, warning, and attack characterization;
- nuclear planning;
- decision-making conferencing;
- receiving presidential orders; and
- enabling the management and direction of forces.

The elements detailed below comprise the NC3 infrastructure that supports the President, through his military commanders, in exercising presidential authority over U.S. nuclear weapons operations, all of which need to function before and during a nuclear attack or nuclear war.

Personnel

Because of the policy implications, military importance, destructive power, and the political consequences of an accident or an unauthorized act, it is DoD policy that only those individuals who are appropriately trained, cleared, experienced, and demonstrate reliability are authorized to perform NC3 duties. NC3 personnel include operators, security personnel, and those who maintain facilities, equipment, communications, weapons, and delivery systems.

Procedures and Processes

NC3 requires rigorous procedures and processes to support the President and the Secretary of Defense in exercising command authorities in the areas of situation monitoring, decision-making, force direction, force management, and planning to direct the actions of the people who operate nuclear systems.

Facilities

Facilities include the National Military Command Center (NMCC), the Global Operations Center (GOC), the E-4B National Airborne Operations Center (NAOC), and the E-6B Take Charge and Move Out (TACAMO)/Airborne Command Post.

The primary facility is the NMCC located within the Pentagon. The NMCC provides daily support to the President, the Secretary of Defense, and the CJCS, allowing for the monitoring of nuclear forces and ongoing conventional military operations.

Another command center resides with USSTRATCOM Headquarters at Offutt Air Force Base in Nebraska. The USSTRATCOM GOC enables the Commander of USSTRATCOM to conduct command and control while also enabling the day-to-day management of forces and the monitoring of world events.

If fixed command centers are destroyed or incapacitated, several survivable alternatives exist to which NC2 operations can transfer, including the E-4B NAOC and the E-6B TACAMO/Airborne Command Post (Figures 2.2 and 2.3). A NAOC aircraft is continuously ready to launch within minutes from random basing locations, thus enhancing the survivability of the aircraft and the mission.

Figure 2.2 E-4B NAOC

Figure 2.3 E-6B TACAMO/Airborne Command Post

NC3, managed by the Military Departments, nuclear force commanders, and the defense agencies, provides the President with the means to authorize the use of nuclear weapons in a crisis.[1]

The E-6B serves as an airborne command post. In this capacity, the E-6B is an airborne backup of the GOC. As a result of this role, the E-6B performs two additional key missions. First, as the Airborne Launch Control System, the aircraft has the ability to launch Minuteman III ICBMs as backup to the land-based launch control facilities. Second, in its TACAMO role, it can relay presidential nuclear control orders to Navy nuclear submarines and Air Force nuclear missile control centers and bombers.

Equipment

Equipment includes information protection (cryptological) devices, and the sensors (radars and infrared satellites, fixed, mobile and processing systems) of the Integrated Tactical Warning/Attack Assessment (ITW/AA) System.

The ITW/AA includes rigorously tested and certified systems that provide unambiguous, reliable, accurate, timely, survivable, and enduring warning information of ballistic missile, space, and air attacks on North America. In general, the ITW/AA process includes four steps to support the decision-making process:

1. *Surveillance* – detection, collection, identification, processing, and reporting of ballistic missile, atmospheric, and space events by means of a worldwide network of ground- and space-based sensors.
2. *Correlation* – collection, integration, analysis, and interpretation of surveillance data along with intelligence information on all potentially hostile events.
3. *Warning* – process that uses automated displays of missile, atmospheric, and space events, confirmed by voice conferences to sensor sites, to assess the validity of warning information. Intelligence information can further corroborate sensor data.
4. *Assessment* – evaluates the likelihood that an air, missile, and/or space attack is in progress against North America or an ally. Missile or air attack assessment is based on a combination of sensor information and the judgment of the Commander, North American Aerospace Defense Command (NORAD) of its validity. The Commander,

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[1] NC3 can also prove critical for U.S. response to other significant national events, such as a terrorist attack or natural disaster, where there is a need for continuity and the means to ensure the performance of essential government functions during a wide range of emergencies. Nuclear crisis is the worst-case scenario.

> USSTRATCOM validates missile and space warning information for areas outside North America and provides an assessment of potential attacks on U.S. and allied space assets.

To assist in ITW/AA decisions, two independent information sources using different physical principles, such as radar and infrared satellite sensors associated with the same event, help clarify the operational situation and ensure the highest possible assessment credibility. Regardless of the type of event, assessments are passed over an emergency communications conference to the President, the Secretary of Defense, and the CJCS. The assessment details whether an attack is occurring against North America or U.S. assets or allies.

Communications

NC3 relies on terrestrial (e.g., land-based secure and non-secure phone lines and undersea cables), airborne relay (e.g., E-4B and E-6B), and satellite (military and commercial) sensors to transmit and receive voice, video, or data. The ability to move trusted data and advice from sensors to correlation centers, from presidential advisors to the President, from the President to the NMCC, and from the NMCC to the nuclear weapons delivery platforms depends on NC3 (Figure 2.4). These encompass a myriad of terrestrial, airborne, and satellite-based systems ranging in sophistication from the simple telephone, to radio frequency systems, to government and non-government satellites. Some of these systems are expected to be able to operate through nuclear effects, while others are expected to be subject to nuclear effect disruption for periods ranging from minutes to hours.[2]

NC3 REQUIREMENTS

NC3, managed by the Military Departments, nuclear force commanders, and the defense agencies, provides the President with the means to authorize the use of nuclear weapons in a crisis. Presidential guidance, via presidential policy directives, is the authoritative source for NC3 requirements. The requirements support nuclear force planning, situation monitoring including an ITW/AA of bomber threats and missile launches, senior leader decision-making, dissemination of presidential force-direction orders, and management of geographically dispersed forces.

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[2] As with other critical elements of NC3, even communications systems whose frequency spectrum is expected to be available in a nuclear-affected environment are susceptible to physical effects. This includes burnout or temporary disruption due to the effects of a nuclear detonation on their electronic components if these components are not hardened against such effects.

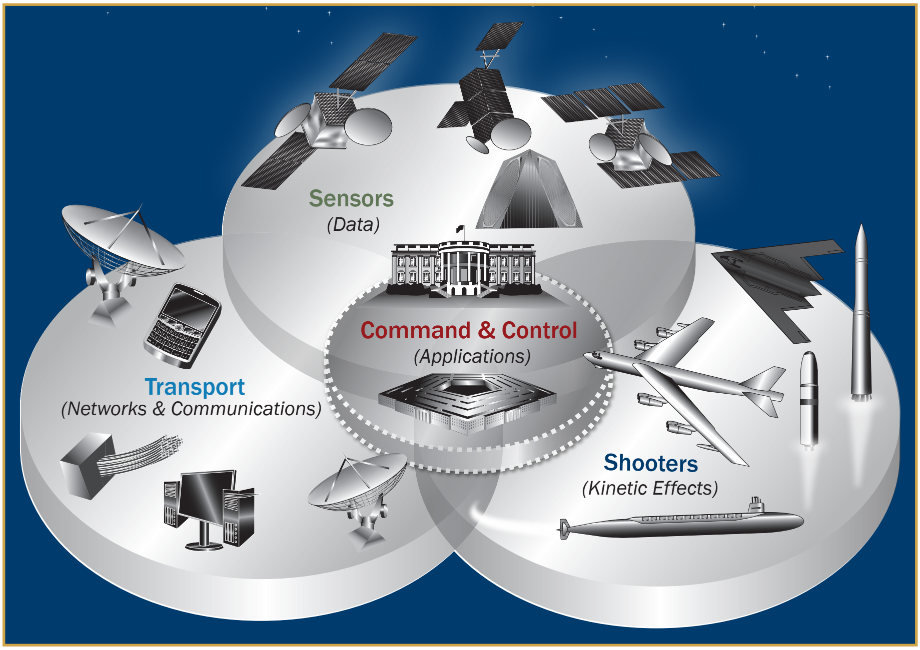

Figure 2.4 Nuclear Command, Control, and Communications

Many NC3 requirements are set forth in national and DoD policy; among these are the requirements that NC3 must be assured, reliable, and resilient. These requirements have been translated into specific, measurable, and testable criteria to evaluate the performance of NC3 elements through exercise, testing, and analysis.

Mission-critical facilities and equipment must be built to resist the effects of a nuclear explosion, especially electromagnetic pulse (EMP), which can interrupt or destroy sensitive electronics. See *Chapter 9: Nuclear Survivability and Effects Testing* and *Chapter 13: Basic Nuclear Physics and Weapons Effects* for more information about nuclear effects.

Additionally, modern systems must be capable of operating on internet-like networks to provide survivable, reliable support for senior U.S. government officials, the U.S. military, and U.S. allies, as appropriate. While the implications and applicability of this policy can introduce increased vulnerability, it is still necessary to protect critical information and information systems against cyber-attack or network intrusion.

CURRENT NC3 ARCHITECTURE

The present U.S. NC3 architecture is described in two layers. The first layer is the day-to-day architecture which includes a variety of facilities and communications to provide robust command and control over nuclear and supporting government operations.

The second layer provides the survivable, secure, and enduring architecture known as the "thin-line." The thin-line responds to policy that requires assured, unbroken, redundant, survivable, secure, and enduring connectivity to and among the President, the Secretary of Defense, the CJCS, and designated commanders through all threat environments to perform all necessary command and control functions. The thin-line NC3 architecture must be sustained and supported during any modernization effort to ensure presidential requirements can be met.

EVOLVING THREATS

The threat to NC3 is evolving as more nations and non-state actors recognize the benefits and seek their own space or counterspace capabilities as well as cyber, electronic warfare, and advanced conventional capabilities. As the modernization of NC3 evolves, the United States is faced with new opportunities and new challenges in the NC3 domain. Space, cyber, the changing nuclear environment, and modernization are a few examples of these opportunities and challenges.

Space

Current policy states, "Space is no longer a sanctuary and orbital space is increasingly congested, competitive, and contested."[3] Strategic competitors, such as Russia and China, have developed counterspace capabilities to provide a military advantage. These capabilities threaten critical U.S. NC3 assets. Next-generation NC3 will have to mitigate or "fight through" a degraded environment.

Cyber

Legacy NC3 had minimal vulnerability to cyber effects due to its isolation from the global internet network. As NC3 modernization occurs and continues to integrate nuclear and non-nuclear command and control, new cyber vulnerabilities will be identified and must be mitigated.

Cyber risks will accelerate as nuclear modernization proceeds and systems are migrated to internet protocols. The new generation of nuclear forces, the Columbia-class SSBNs, ground-based strategic deterrent (GBSD), ICBMs, B-21, long-range standoff (LRSO) cruise missiles, and F-35 will be designed to modern cyber standards. It will be critical for designers of future NC3 to adopt cyber defense to mitigate threats from adversary offensive cyber action against these systems. Cyber threat mitigation will address the network vulnerabilities to ensure U.S. NC3 remains an assured, effective, and resilient network.

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[3] 2018 Nuclear Posture Review.

Nuclear Environment

Original NC3 was designed to counter a massive nuclear attack from Russia. As the nuclear environment changed through the addition of nuclear capable adversaries, NC3 has also been modified to meet this change. In the future, with potential new adversaries with new nuclear weapons tactics, the U.S. NC3 must be able to counter an adversary's limited nuclear strike. Additionally, U.S. leadership must be able to communicate across nuclear and non-nuclear command and control.

MODERNIZING NC3

Current national policy outlines a series of initiatives to ensure NC3 remains survivable and effective in crisis and conflict, and is strengthened to address future needs and challenges. The United States will:

- strengthen protection against space-based threats;
- strengthen protection against cyber threats;
- enhance integrated tactical warning and attack assessment;
- improve command posts and communications links;
- advance decision support technology;
- integrate planning and operations; and
- reform governance of overall NC3.

In July 2018, the Secretary of Defense and the Chairman of the Joint Chiefs of Staff formally appointed the USSTRATCOM Commander to be "the NC3 enterprise lead, with increased responsibilities for operations, requirements, and systems engineering and integration." USSTRATCOM has created an NC3 Enterprise Center inside the command's headquarters at Offutt Air Force Base, Nebraska. On November 5, 2018, Commander, USSTRATCOM stated, "It is imperative that the U.S. government modernize its three-decade old NC3 in a manner that accounts for current and future threats to its functionality and vulnerabilities." The NC3 Enterprise Center is developing and evaluating NC3 architectures and approaches for modernization.

The Under Secretary of Defense for Aquisition and Sustainment (USD(A&S)) created an NC3 Enterprise Capability Portfolio Manager organization to: provide NC3 policy guidance to the heads of other DoD components; conduct analyses (including but not limited to NC3 planning, programming, budgeting, and execution activities); make recommendations; and monitor the implementation and performance of approved NC3 programs.

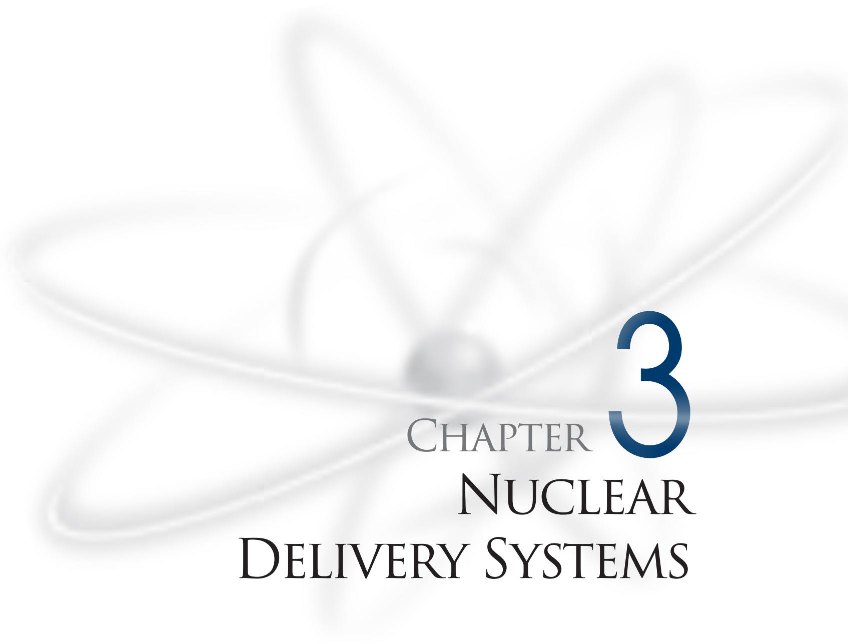
To meet NC3 modernization initiatives, specific activities include:

- *Survivable airborne operations center (SAOC)* – A new aircraft(s) will replace the E-4B Boeing 747-model national airborne operations center (NAOC) and the new Boeing 707-model E-6B Mercury;
- *Very low frequency receivers (VLF)* – The common VLF receiver program will provide new terminals to command and control aircraft, bombers, tankers (to refuel bombers), ICBM launch control centers, and other command posts. These receivers will allow the reliable and secure transmission of emergency action messages on the VLF band over very long distances and through nuclear detonation interference; and
- *Satellite terminals* – The Advanced Extremely High Frequency (AEHF) satellite constellation is designed to operate through EMP and nuclear scintillation. It is jam resistant. Satellite replacement receive-transmit terminals include the Family of Advanced Beyond Line-of-Sight Terminals (FAB-T), Global Aircrew Strategic Network Terminal (Global ASNT), the Minuteman Minimum Essential Emergency Communications Network Program Uupgrade (MMPU), and Presidential and National Voice Conferencing (PNVC).

LAND

AIR

SEA



Chapter 3

Nuclear Delivery Systems

Overview

For more than six decades, the United States has emphasized the need for a nuclear force that credibly deters adversaries, assures allies and partners, and would achieve U.S. objectives should deterrence fail. Since the 1960s, these objectives have been met by the U.S. nuclear triad through forces operating at sea, on land, and in the air. Today's nuclear triad consists of: 14 ballistic missile submarines (SSBNs) armed with 240 submarine-launched ballistic missiles (SLBMs); 400 land-based intercontinental ballistic missiles (ICBMs); and 60 nuclear-capable heavy bomber aircraft capable of delivering gravity bombs and cruise missiles.

These strategic forces are enabled by secure nuclear command, control, and communications (see *Chapter 2: Nuclear Weapons Employment Policy, Planning, and NC3*) and supplemented by a small number of non-strategic nuclear forces that provide an ability to forward deploy weapons in Europe and globally.

This chapter provides an overview of current and planned U.S. nuclear delivery systems and platforms. Figure 3.1 offers an overview of current nuclear weapons and delivery systems.

SEA-LAUNCHED

Description: SLBM
Mission: Underwater-to-Surface
Platform: Ohio-class SSBN
Vehicle: Trident II D5 LE Missile
Weapon: W76-0/1/2, W88
Military Department: USN

GROUND-LAUNCHED

Description: ICBM
Mission: Surface-to-Surface
Platform: Minuteman III
Weapon: W78, W87
Military Department: USAF

AIR-LAUNCHED

Description: Heavy Bomber
Mission: Air-to-Surface
Platform: B-52H
Vehicle: ALCM
Weapon: W80-1
Military Department: USAF

Description: Heavy Bomber
Mission: Air-to-Surface
Platform: B-2A
Weapon: B61-7/11, B83-1
Military Department: USAF

Description: DCA
Mission: Air-to-Surface
Platform: F-15E, F-16, NATO aircraft
Weapon: B61-3/4/10
Military Department: USAF & select NATO Allies

Note: B = Bomb W = Warhead

Figure 3.1
Current U.S. Nuclear Deterrent
(Delivery systems and associated nuclear weapons)

COMPLEMENTARY ATTRIBUTES OF THE U.S. NUCLEAR TRIAD

Each leg of the triad provides unique and complementary attributes. Collectively, the triad seeks to ensure that no adversary believes it could launch a strategic attack that eliminates the ability of the United States to respond and inflict unacceptable damage—for any reason, under any circumstances.

SSBNs are survivable. A portion of the SSBN fleet is always on patrol, making it very difficult to track U.S. ballistic missile submarines, which means they are highly survivable. ICBMs are responsive. ICBMs are deployed in hundreds of nuclear-hardened silos and can be launched to reach targets within minutes, creating a complex targeting problem for adversaries. U.S. strategic bombers are a "show of force." Bombers are a clear and visible signal of U.S. intent and resolve during a crisis and provide a variety of deployment and yield options. Bombers may also be recalled.

Eliminating a leg of the triad would weaken the combined strength of the force and simplify adversary attack planning. Also, the diversity of the triad enables risk mitigation if a particular leg of the triad is degraded or unavailable.

Currently, all three legs of the nuclear triad will undergo modernization at roughly the same time. Because of the tight schedule between the expected retirement of the legacy systems and the fielding of the replacement systems, the DoD, as a top priority, is committed to keeping these programs on track.

The combination of the advanced age of U.S. weapon delivery systems and current efforts to revitalize all three legs of the nuclear triad present challenges to the future U.S. nuclear deterrent. Every U.S. delivery system has had to remain in service far beyond its expected lifespan—by several decades, in some cases.

As many of these platforms reach an age at which their lives cannot be further extended, the United States is working to field new platforms and delivery vehicles on all three legs of the triad simultaneously. These replacement projects are time-sensitive; their current schedule has been described by senior DoD leaders as "just-in-time" delivery. Figure 3.2 illustrates the aging legacy delivery systems and the current plan for initial replacement (first unit deployed).

System	Year First Deployed	Original Design Life	Projected First Replacement Year	System Age at Initial Retirement
Ohio-class SSBN	1981	30 years	2031	~42 years*
Minuteman III ICBM	1970	10 years	2029	~60 years
B-2A Bomber	1993	No set life; dependent on flight hours/ airframe viability	TBD (replaced as B-21 comes online)	~35 years
AGM-86 ALCM	1982	10 years	Early 2030s	~50 years
F-15E DCA	1988	No set life; dependent on flight hours/ airframe viability	TBD (F-35A DCA available in 2024)	~40 years

** Each Ohio-class SSBN is being evaluated on a case-by-case basis and will be retired at end of life.*

Figure 3.2 Legacy Delivery Systems Aging and Replacement

NUCLEAR WEAPON DELIVERY SYSTEMS

A nuclear weapon delivery system is the military platform and delivery vehicle[1] by which a nuclear weapon is delivered to its intended target in the event of authorized use (by the President of the United States, who retains sole authority to employ nuclear weapons). Most nuclear weapons have been designed for a specific delivery system, making interoperability potentially challenging.

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[1] The terms nuclear weapon delivery system, nuclear delivery vehicle, and nuclear weapon platform or nuclear platform are often used interchangeably. For the purposes of this handbook: (a) a nuclear weapon delivery system is the mating of the military platform and the delivery vehicle to form the system (e.g., Trident II D5 LE on Ohio-class SSBN); (b) a delivery vehicle is the portion of the weapons system which provides the means of delivery of a nuclear weapon to its intended target (e.g., nuclear cruise missile, Trident II D5 LE missile); and (c) a nuclear platform is any structure or system on which a weapon can be mounted/loaded (e.g., ballistic missile submarine). ICBMs are both a delivery platform and a delivery vehicle.

In addition to the U.S. mix of silo-based Minuteman III (MMIII) ICBMs, Trident II D5 Life Extension (LE) SLBMs carried on Ohio-class SSBNs,[2] and B-2A and B-52H nuclear-capable heavy bombers, the U.S. nuclear force includes dual-capable aircraft (DCA), that can carry conventional or nuclear weapons.

SEA-LAUNCHED

Nuclear-powered Ohio-class SSBNs (Figure 3.3) carry Trident II D5 LE missiles armed with W76-0/1/2 and W88 warheads. SSBNs are considered the most survivable leg of the nuclear triad because of their ability to transit and hide in the ocean depths, coupled with the long range of the missiles. Continuously on patrol, SSBNs provide a worldwide launch capability, with each patrol covering a target area of more than one million square miles. The intercontinental range of the SLBM and constant readiness allow U.S. SSBNs to hold targets at risk from their launch areas in the Atlantic and Pacific oceans.

Figure 3.3 Ohio-class SSBN USS Rhode Island

As the virtually undetectable undersea launch platforms for intercontinental missiles, Ohio-class SSBNs were built by the Electric Boat Division of General Dynamics, based at Groton, Connecticut. Eighteen Ohio-class submarines were built and commissioned between 1981 and 1997; thus, the average age is currently over 30 years old, and there are plans to extend the submarines up to 42 years of age.

The SSBNs of the Pacific Fleet are based at Naval Base Kitsap in Washington, and those of the Atlantic Fleet at Naval Submarine Base Kings Bay in Georgia. On average, submarines spend 70 days at sea, followed by 25 days in dock for overhaul.

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[2] The SSBN acronym stands for "Ship, Submersible, Ballistic, Nuclear." However, the SSBN is more commonly referred to as ballistic missile submarine or fleet ballistic missile submarine.

The U.S. Navy operates a total of 18 Ohio-class submarines which consist of 14 ballistic missile submarines and four cruise missile submarines (SSGNs) that no longer carry nuclear weapons. The United States continues to take the necessary steps to ensure that Ohio-class SSBNs remain operationally effective and survivable until their replacement.

The *Columbia-class SSBN* is the replacement for the Ohio-class SSBN. The first Columbia-class submarine is scheduled to begin construction in 2021 and enter service in 2031. The Navy is planning to build 12 SSBNs, which are scheduled to remain in service until the 2080s. Each Columbia-class SSBN will be equipped with 16 missile tubes.

Current U.S. planning is for the number of SSBNs available for deployment to be reduced by two during the 2030s as the Ohio-class SSBN retires and the Columbia-class SSBN completes production.

Submarine-launched ballistic missiles have been an integral part of the strategic deterrent for six generations, starting in 1956 with the U.S. Navy Fleet Ballistic Missile (FBM) Polaris (A1) program. Since then, the SLBM has evolved through Polaris (A2), Polaris (A3), Poseidon (C3), Trident I (C4), and today's force of Trident II (D5). In 2017, the Trident II force began deploying the Trident II life extension (LE). This SLBM will be deployed on both Ohio- and Columbia-class SSBNs. Each SLBM program has been continuously deployed as a survivable force and has been routinely operationally tested and evaluated to maintain confidence and credibility in the deterrent.

Each Ohio-class SSBN carries 24 Trident II D5 LE missiles. The Trident II D5 LE missile is a three-stage, solid-propellant, inertially guided ballistic missile with a range of more than 4,000 nautical miles, or 4,600 statute miles. Trident II D5 LE is launched by the pressure of expanding gas within the launch tube. When the missile attains sufficient distance from the submarine, the first stage motor ignites, the aerospike extends, and the boost stage begins. Within about two minutes, after the third stage motor kicks in, the missile is traveling in excess of 20,000 feet (6,096 meters) per second.

Trident II was first deployed in 1990 and is planned to be in the inventory beyond 2020. The Trident II missile is also provided to the United Kingdom (UK), which equips the missile with UK nuclear warheads and deploys the missile on four UK nuclear-armed submarines that provide the UK Continuous-At-Sea-Deterrent (CAS-D).

Additionally, the United States has modified a small number of existing SLBM warheads to provide a low-yield option. The United States is also planning to pursue a modern nuclear-armed sea-launched cruise missile (SLCM). This will provide additional diversity in platforms, range, survivability, and assurance to allies.

Trident II has been deployed for more than 30 years. It is currently in the early stages of a life extension which will extend its deployment until 2042. This life extension will match the Ohio-class submarine service life and serve as the initial baseline SLBM through the introduction of the Columbia-class. The U.S. Navy will begin studies in 2020 to define requirements for the future SLBM (D5 LE2) planned to be deployed through the service life of the Columbia-class (through 2080).

GROUND-LAUNCHED

Intercontinental ballistic missiles, which are launched from hardened silos buried in the ground, are high-yield, accurate, on continuous alert, provide immediate reaction if necessary, and can strike their intended targets within 30 minutes or less of launch (see Figure 3.4).

Figure 3.4 Unarmed MMIII ICBM Launch during an Operational Test at Vandenberg AFB, CA

ICBMs are the most responsive leg of the triad because they are always ready and can be launched within minutes on Presidential authority. U.S. ICBMs provide deterrence against a first strike by an adversary because no adversary can be confident in its ability to destroy all U.S. ICBMs prior to their being launched.

Starting in January 1951, when the Air Force directed a $500,000 study for the development of an ICBM capable of delivering an atomic bomb, known as "Project Atlas," ICBMs have underpinned the U.S. nuclear deterrent. From

1959–1965, the Atlas was deployed at different Air Force bases stretching from upper New York State all the way to New Mexico. The majority of the Atlas ICBMs were stored vertically in aboveground launchers. From 1962–1987, two versions of the Titan, I and II, were deployed. The Titan was the largest ICBM ever deployed and held a nine megaton nuclear warhead, making it one of the most powerful nuclear weapons in U.S. history.

When Minuteman became operational in 1962 and began to replace Titan, it was the first solid-fueled ICBM ever deployed, and this technology brought about a revolution in missile development. There have been four versions of the Minuteman, the IA, IB, II and III. Additionally, the Peacekeeper ICBM was deployed from 1987 until 2005 and held up to ten nuclear warheads each. Although the START II arms control agreement never entered into force, Peacekeeper was removed from the ICBM force in anticipation of the treaty's ratification.

The Minuteman III ICBM was first deployed in 1970, with a planned ten-year service life. A series of life extension programs have kept MMIII viable. For the ten-year period between 2002–2012, MMIII underwent a life extension program intended to keep the system fielded until 2030. By 2030, and after 60 years of operation, MMIII will be the oldest deployed strategic ballistic missile in the world as it begins to be replaced by the ground-based strategic deterrent (GBSD) ICBM.

Today, the U.S. ICBM force consists of 400 single-warhead MMIII missiles, armed with W78 and W87-0 warheads. If authorized by the President, MMIII could carry up to two additional warheads. MMIII missile bases are located at F.E. Warren Air Force Base (AFB) in Wyoming, Malmstrom AFB in Montana, and Minot AFB in North Dakota. The United States has initiated the GBSD program to begin the replacement of MMIII in 2029. The GBSD program will also modernize the 450 ICBM launch facilities that will support the fielding of 400 modern ICBMs, to be armed with W87-0 and W87-1 nuclear warheads.

The GBSD program will replace the MMIII with a modern ICBM, revitalize the command and control architecture, and recapitalize the associated infrastructure. The GBSD program is currently in the technology maturation phase. GBSD is scheduled to enter service by the early 2030s and will be deployed until the 2070s.

AIR-LAUNCHED

The *U.S. bomber force* serves as a visible, flexible, and recallable national strategic asset. Bombers provide a rapid and effective hedge against technical challenges that might affect another leg of the triad and offset the risks of geopolitical uncertainties. Furthermore, nuclear-capable bombers are important to maintain extended deterrence against potential attacks on U.S. allies. The ability to forward deploy heavy bombers, especially in Europe, signals U.S. resolve and commitment in a crisis and enhances the reassurance of U.S. allies, strengthening regional security architectures. The bombers also play a critical role in the U.S. hedging strategy, given their ability to upload additional weapons, bombs, and nuclear air-launched cruise missiles (ALCMs) in response to possible geopolitical surprises. The upload potential of the U.S. bomber force also provides an important hedge against programmatic risk in the strategic replacement programs (i.e., if any of the nuclear delivery system replacement programs are late).

The nuclear B-52H force is located at Barksdale AFB in Louisiana and Minot AFB in North Dakota. The B-52H fleet has been the backbone of the strategic bomber force for more than 50 years. The B-52H *Stratofortress* (Figure 3.5) is a heavy, long-range bomber that can perform a variety of missions. It is capable of flying at subsonic speeds at altitudes of up to 50,000 feet and can carry precision-guided conventional ordnance in addition to ALCMs armed with W80-1 warheads. B-52H bombers carry six AGM-86B/C/D ALCM missiles on each of two externally mounted pylons and eight internally on a rotary launcher, giving the B-52H a maximum capacity of 20 missiles per aircraft. Beginning in 1982, B-52H bombers were equipped with ALCMs in response to steady advances in adversary air defense systems. This way, the B-52 can launch its nuclear weapons without having to penetrate adversary defenses, as it would have to do in order to deliver nuclear gravity bombs.

Figure 3.5 B-52H Stratofortress

The *Long Range Stand Off (LRSO) cruise missile* will replace the aging ALCM with a modern cruise missile capable of holding targets at risk, even in heavily defended airspace. The LRSO is currently in the development phase and scheduled to be fielded in 2030. The LRSO, armed with W80-4 nuclear warheads, will enable the B-52H to remain an effective part of the nuclear-capable bomber force and preserve its upload potential as a key hedge against unforeseen technical and geopolitical challenges. Also critical to the heavy bomber force is a viable aerial refueling capability, which is undergoing recapitalization now, with the KC-46 *Pegasus* currently being produced.

The Air Force is modernizing the B-52 bomber to remain a viable long-range strike platform for its extended life. These upgrades include replacement of the current engines, integration with modern digital munitions, and replacement of various avionics systems.

The B-2 *Spirit* stealth bomber (Figure 3.6) entered the force in 1997, enhancing U.S. deterrent forces with its ability to penetrate adversary air defenses. The B-2A bomber is now the only long-range, nuclear-capable U.S. aircraft that can penetrate advanced air defenses. The B-2 is a multi-role bomber capable of delivering both conventional and nuclear munitions, including B61-7/11 and B83-1 nuclear bombs until their planned retirement in the mid-2020s, after which, the B-2 will carry the B61-12. The B-2 force is located at Whiteman AFB in Missouri.

Figure 3.6 B-2 Spirit

The United States will sustain and modernize the B-52H and B-2A to ensure they remain effective into the future. Given the continuing proliferation and improvement of adversary air defense capabilities and the continued aging of the B-52H, ALCM, and B-2A, the United States has initiated a program to develop and deploy the next-generation bomber, the B-21 *Raider*. The B-21 will be a long-range, stealth strategic bomber with the ability to deliver conventional and nuclear weapons, to include the B61-12 bomb and the W80-4 nuclear warhead on the LRSO. The plan is for a 100-aircraft fleet to begin entering service in the mid-2020s. For its nuclear mission, the B-21 will be capable of delivering both gravity bombs and the new LRSO cruise missile.

In addition to the nuclear strategic triad, the United States maintains a fleet of F-15E *Strike Eagle* dual-capable aircraft (DCA) (Figure 3.7). These DCA are based in the continental United States (CONUS) and also forward deployed in Europe. DCA are able to deliver conventional munitions or B61-3/4/10 nuclear bombs. The forthcoming B61-12 gravity bomb will replace earlier versions of the B61 and will be available in the early to mid-2020s. DCA are available to support the North Atlantic Treaty Organization (NATO) in combined-theater nuclear operations.

Figure 3.7 F-15E Strike Eagle

The United States is incorporating a nuclear capability into the F-35 as a replacement for the current aging DCA force. Plans for initial fielding of the nuclear-capable F-35 is 2025. Several NATO allies also provide DCA capable of delivering U.S. forward-deployed nuclear weapons.

The forward presence of dual-capable aircraft contributes to the deterrence of potential adversaries and the assurance of allies. If necessary, the United States has the ability to deploy DCA and nuclear weapons to other regions, such as Northeast Asia.

Figure 3.8 shows U.S. current and planned near-future delivery systems and associated platforms and nuclear weapons.

CURRENT			NEAR FUTURE		
Delivery System		Nuclear Weapon (Bomb or Warhead)	Delivery System		Nuclear Weapon (Bomb or Warhead)
Platform	Vehicle		Platform	Vehicle	
SEA					
Ohio-class SSBN	Trident II D5 LE1 SLBM	W76-0, W76-1, W76-2, W88	Columbia-class SSBN	Trident II D5 LE2 SLBM	W76-1, W76-2, W88
			TBD	SLCM	TBD
LAND					
MMIII ICBM		W78, W87-0	GBSD		W87-0, W87-1
AIR					
B-2A Bomber		B83, B61-7/11	B-21 Bomber	LRSO	B61-12, W80-4
B-52H Bomber	AGM-86 ALCM	W80-1	B-52H Bomber	LRSO	W80-4
DUAL-CAPABLE AIRCRAFT					
F-15E DCA		B61-3/4	F-35A DCA		B61-12

Figure 3.8 Current and Near-Future Nuclear Deterrent

Comprehensive List of Warhead-Types and Descriptions

FATMAN	Strategic Bomb
LITTLEBOY	Strategic Bomb
B3/MKIII	Strategic Bomb
B4/MKIV	Strategic Bomb
T-4	ADM
B5	Strategic Bomb
W5	Matador/Regulus Missiles
B6	Bomb
B7	Tactical Bomb/Depth Charge
W7	Corporal SSM/Honest John/ BOAR ASM/Betty NDB/ Nike-Hercules SAM/ADM
B8	Penetrator Bomb
W9	280mm AFAP
B10	Strategic Bomb*
B11	Hard Target Penetrator Bomb
B12	Tactical Bomb
B13	Strategic Bomb*
B14	Strategic Bomb
B15	Strategic Bomb
B16	Strategic Bomb*
B17	Strategic Bomb
B18	Strategic Bomb
B19	280mm AFAP
B20	Strategic Bomb*
B21	Strategic Bomb
W23	16 in. AFAP
B24	Strategic Bomb
W25	Genie AAM*/Little John Missile/ADM
B26	Strategic Bomb*
B27	Strategic Bomb
W27	Regulus SLCM
B28	Strategic/Tactical Bomb
W28	Hound Dog ASM/Mace GLCM
W29	Redstone SSM*
W30	Talos AAW/TADM
W31	Nike-Hercules SAM/ Honest John SSM/ADM
W32	240mm AFAP*
W33	8 inch AFAP
W34	Astor ASW/ Hotpoint Tactical Bomb/ Lulu DB
W35	Atlas ICBM/Titan ICBM/ Thor IRBM/Jupiter IRBM*
B36	Strategic Bomb
W37	Nike-Hercules SAM*
W38	Atlas ICBM/Titan ICBM
B39	Strategic Bomb
W39	Redstone Tactical Missile
W40	Bomarc Strategic SAM/ Lacrosse Tactical Missile/ Corvus Antiship Missile*
B41	Strategic Bomb
W42	Hawk/Falcon/Sparrow*
B43	Strategic/Tactical Bomb
W44	ASROC Missile
W45	MADM/Little John SSM/ Terrier SAM/Bullpup ASM
W46	Redstone Snark Missile*
W47	Polaris A1/A2 SLBM
W48	155mm AFAP
W49	Atlas/Thor ICBMs, Jupiter/ Titan IRBMs
W50	Pershing 1a SSM
W51	Falcon/Davy Crockett/ Reevitess Rifle
W52	Sergeant SSM
B53	Strategic Bomb
W53	TITAN II ICBM
B54	SADM
W54	Falcon AAM/Davy Crockett
W55	SUBROC
W56	Minuteman II ICBM
B57	Tactical Depth Charge/ Strike Bomb
W58	Polaris A3 SLBM
W59	Minuteman Y1 ICBM
W60	Typhoon*
B61	**Strategic/Tactical Bomb**
W62	Minuteman III ICBM
W63	Lance SSM
W64	Lance SSM*
W65	Sprint SAM
W66	Sprint SAM
W67	Minuteman III/Poseidon SLBM*
W68	Poseidon C3 SLBM
W69	SRAM ASM
W70	Lance SSM
W71	Spartan SSM
W72	Walleye Tactical Bomb
W73	Condor*
W74	155mm AFAP*
W75	8 inch AFAP*
W76	**Trident II SLBM**
B77	Strategic Bomb*
W78	**Minuteman III ICBM**
W79	8 inch AFAP
W80	**ALCM/SLCM**
W81	Standard Missile-2*
W82	155mm AFAP*
B83	**Strategic Bomb**
W84	GLCM SSM
W85	Pershing II SSM
W86	Pershing II SSM*
W87	**Minuteman III ICBM**
W88	**Trident II SLBM**
W89	SRAM II*
B90	NDSB*
W91	SRAM-T*
W92	Sealance *(proposed)*

This list is in chronological order according to entry into Phase 2A (when a warhead receives its designated name)

* *Never Deployed*

■ *Currently in the U.S. force structure*

Chapter 4

Nuclear Weapons

Overview

To maintain a safe, secure, and effective U.S. nuclear stockpile, DoD works with the National Nuclear Security Administration (NNSA), through the Nuclear Weapons Council (NWC), to maintain the quantity and quality of weapons necessary for U.S. national security, as determined by policy and presidential direction. In the post–Cold War era, the United States terminated its production of new weapons and stopped underground nuclear explosive testing. As a result, the NNSA today maintains the stockpile through the application of science, technology, engineering, high-speed computing, and manufacturing efforts within its Stockpile Stewardship Program. The United States, however, is entering into an era of both nuclear delivery system and nuclear weapons modernization. The Departments will partner in these modernization activities and must align their efforts in a way that has not been achieved in many decades.

Nuclear Weapons Stockpile

All nuclear weapons in the U.S. stockpile are designated as either a warhead (W) or a bomb (B).[1] Weapons that have different engineering requirements because they must interface with a launch platform or delivery vehicle are called warheads. Weapons that do not have these interface requirements, such as gravity bombs and retired atomic demolition munitions (ADM), are called

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[1] The earliest U.S. nuclear weapons were distinguished by Mark (MK) numbers, derived from the British system for designating aircraft. In 1949, the MK5 nuclear weapon, intended for the Air Force surface-to-surface *Matador* cruise missile and the Navy *Regulus I* cruise missile, had delivery system interface engineering considerations that were not common to gravity bombs. A decision was made to designate the weapon as a warhead, using the term W5. At the programmatic level, the joint DoD-NNSA Project Officers Group (POG) distinguishes between warheads and bombs and weapons are designated accordingly.

bombs. Using these definitions, the total number of U.S. nuclear weapons equals the sum of warheads plus bombs. In this handbook, the term "warhead" is used to mean both warheads and bombs, and the terms "weapon" and "warhead" are used interchangeably. The term "warhead-type" is used to denote a population of weapons with the same design. Weapons in the current force structure include B61, W76, W78, W80, B83, W87, and W88.

Throughout the history of nuclear weapons development, the United States has produced families of warheads based on a single-warhead design. Thus, some weapons in the stockpile were developed as modifications (Mods) to an existing design. For example, the B61 bomb has had 12 variations over time. Each variation was designated as a different Mod. Each Mod used the basic design of the B61, but incorporated different components that changed the operational characteristics of the weapon in a significant way. Four of these Mods are still in the current stockpile: B61-3, B61-4, B61-7, and B61-11. The B61-12, which will replace all current variants of the B61, is currently in production. This is an efficient approach when conducting quality assurance testing and evaluation because warhead Mods that have common components can be tested and maintained as a family of warheads.

All nuclear weapons in the stockpile are designated as strategic or non-strategic. Strategic weapons are those delivered by intercontinental ballistic missiles (ICBM), submarine-launched ballistic missiles (SLBM), or heavy bombers. All other nuclear weapons are considered non-strategic. Non-strategic nuclear weapons, which are sometimes called "tactical" or "theater" nuclear weapons, have historically included bombs delivered by dual-capable aircraft (DCA), which can be used for both nuclear and conventional missions; warheads in cruise missiles delivered by non-strategic aircraft; warheads on sea-launched cruise missiles (SLCM); warheads on ground-launched cruise missiles (GLCM); warheads on ground-launched ballistic missiles (GLBM) with a maximum range that does not exceed 5,500 kilometers, including air-defense missiles; warheads fired from cannon artillery; ADMs; and anti-submarine warfare nuclear depth bombs. Today, only air-launched cruise missiles (ALCMs) and gravity bombs delivered by DCA are in the non-strategic category. Future planning calls for sea-launched nuclear cruise missiles to once again be introduced into the stockpile.

Figure 4.1 illustrates U.S. nuclear weapons and associated delivery systems, both current and future. All U.S. nuclear weapons in the current stockpile were designed and produced in the 1970s and 1980s, with an original design life of 20 years. Since the end of U.S. nuclear production in 1991, the United States has developed and executed life extension programs (LEPs) for weapon-types in the legacy Cold War stockpile. For example, the W76 entered the stockpile in 1978 and the first life-extended warhead re-entered the stockpile in 2008. LEPs address only non-nuclear components and do not replace nuclear components. Non-nuclear component categories include explosive materials, arming devices, fuzing devices, casings, detonators, firing devices, safing devices, security devices,

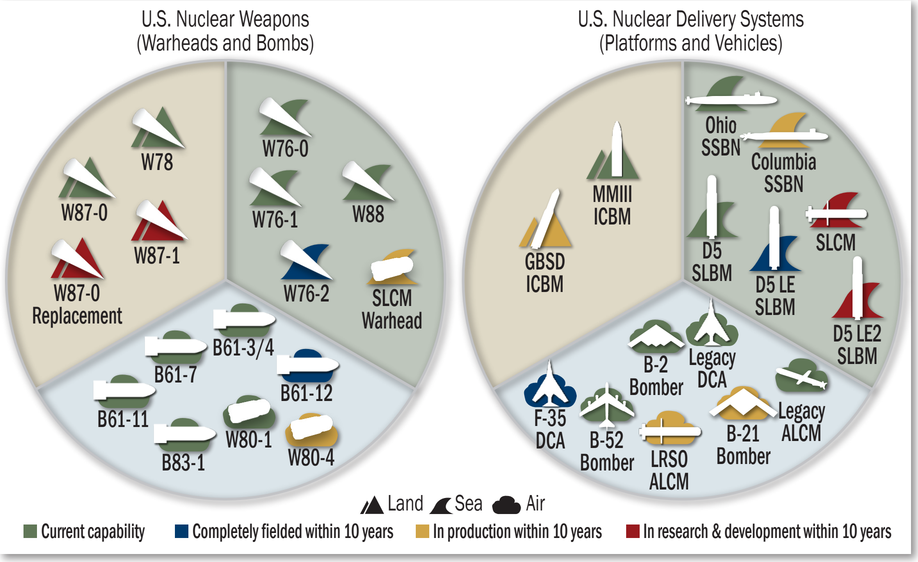

Figure 4.1 U.S. Nuclear Weapons and Associated Delivery Systems

neutron generators, power sources, interface systems, and electronics. Eventually, all nuclear weapons in the stockpile will need to be replaced using newly manufactured nuclear components. Currently, the United States cannot produce these new components. There is some debate surrounding how long nuclear components will continue to perform as required. Figure 4.2 delineates the ages of the weapons in the current stockpile.

Warhead Type	Date of Entry into Stockpile	Planned LEP[1]	First Prod. LEP	Planned Repl.[2]	Projected FPU[5] for Replacement	Nuclear Component Age at Initial Replacement[6]
B61-3/4*	1979	B61-12 LEP	2020	FAW[3]	~2040–2050	~60–70 yrs
B61-7/11**	1985/1997	B61-12 LEP	2020	FAW	~2040–2050	~60–70 yrs
B83-1**	1983	Retired by 2025	n/a	n/a	n/a	n/a
Cruise Missile W80-1	1982	W80-4 LEP	2025	FAW	~2040–2055	~60–75 yrs
SLBM W76	1978	W76-1 LEP	2008	FBW[4]	~2045–2047	~65–70 yrs
ICBM W78	1979	n/a	n/a	W87-1	~2030	~50 yrs
ICBM W87	1986	Partial LEP	1999	FBW	~2035–2040	~50–55 yrs
SLBM W88	1989	Alt 370 Refresh	2022	FBW	~2035–2040	~45–50 yrs

* Non-strategic bomb ** Strategic Bomb [1] Life extension programs (LEP) reuse nuclear components
[2] Replacement requires nuclear component production [3] Future Air-Delivered Warhead (FAW) timeframe identified; characteristics to be determined [4] Future Ballistic Missile Warheads (FBW) initial studies planned; diversity and characteristics to be determined [5] First Production Unit [6] Replacement dates are notional

Figure 4.2 Aging of the Legacy Stockpile

Figure 4.3 correlates delivery platforms and vehicles to current and near-future weapons in the U.S. stockpile.

Delivery Platform	Delivery Vehicle	Current Weapon(s)	Near-Future Weapon(s)
SSBN	SLBM	W76-0 W76-1 W76-2 W88	W76-1 W76-2 W88
ICBM (Platform/Vehicle)		W78 W87-0	W87-0 W87-1
DCA	Gravity Bombs	B61-3/4	B61-12
Bombers		B61-7/11 B83	B61-12
DCA or Bomber	ALCM	W80-1	W80-4
TBD	SLCM		TBD

Figure 4.3 Current and Near-Future Nuclear Delivery Systems and Associated Weapons

STOCKPILE QUANTITIES

While the United States has continued to reduce the number and salience of nuclear weapons, other nations, including Russia and China, have moved in the opposite direction. They have added new types of nuclear capabilities to their arsenals and increased the role of nuclear forces in their strategies and plans.

Stockpile quantities are authorized annually by presidential directive that specifies quantities of warheads, by type and by year, for a multi-year period. Figure 4.4 illustrates U.S. warhead production from the 1940s through the 2020s.

The United States has led the world in decreasing nuclear weapons quantities consistent with U.S. national security objectives. As of September 2017, the stockpile consisted of 3,822 warheads. Figure 4.5 shows stockpile quantities between 1962 and 2017. Since 2018 the U.S. government has not declassified stockpile quantities. Classification in future years will be decided on a case-by-case basis.

NUCLEAR WEAPONS STOCKPILE HEDGE

The stockpile is subject to many uncertainties and associated risks. These include the possibility of an unforeseen catastrophic failure of a class of delivery platform/vehicle, warhead-type/family, an unexpected change in the geopolitical situation, or advances in adversary capabilities and defenses, which could require an increase in the number of weapons available for use. It is vital for DoD and NNSA to have procedures in place to mitigate these and other risks with a strategy that accounts for threats to the stability of the nuclear deterrent at lower stockpile levels.

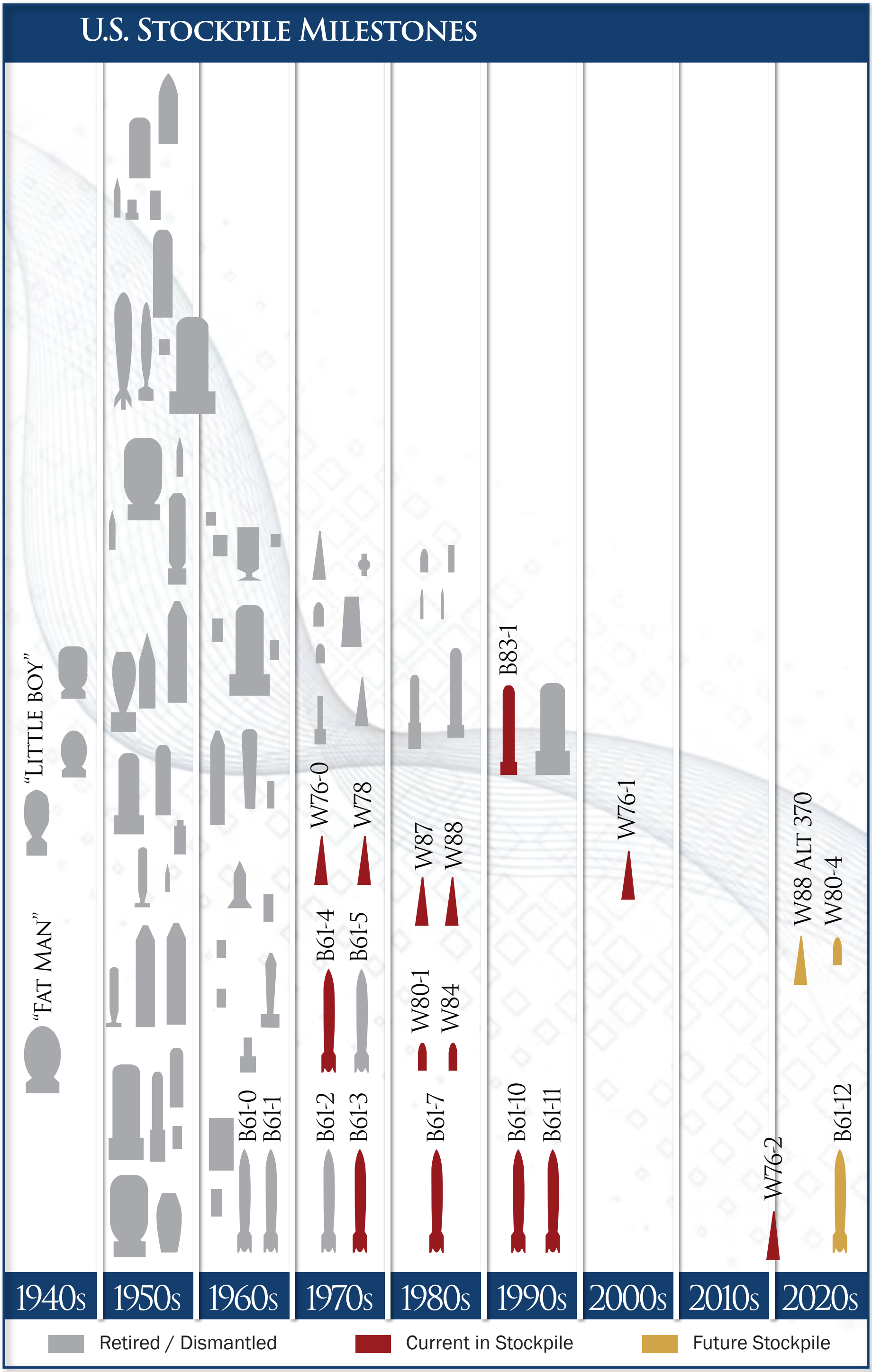

Figure 4.4 U.S. Warhead Production from the 1940s through the 2020s
(There have been no new warhead-types produced since the 1980s.)

1962	25,540
1963	28,133
1964	29,463
1965	31,139
1966	31,175
1967	31,255
1968	29,561
1969	27,552
1970	26,008
1971	25,830
1972	26,516
1973	27,835
1974	28,537
1975	27,519
1976	25,914
1977	25,542
1978	24,418
1979	24,138
1980	24,104
1981	23,208
1982	22,886
1983	23,305
1984	23,459
1985	23,368
1986	23,317
1987	23,575
1988	23,205
1989	22,217
1990	21,392
1991	19,008
1992	13,708
1993	11,511
1994	10,979
1995	10,904
1996	11,011
1997	10,903
1998	10,732
1999	10,685
2000	10,577
2001	10,526
2002	10,457
2003	10,027
2004	8,570
2005	8,360
2006	7,853
2007	5,709
2008	5,273
2009	5,113
2010	5,066
2011	4,897
2012	4,881
2013	4,804
2014	4,717
2015	4,571
2016	4,018
2017	3,822

Figure 4.5 Stockpile Numbers End of Fiscal Years 1962–2017
(does not include weapons retired and awaiting dismantlement)

Basic approaches to stockpile risk mitigation include: the existence of a significant warhead production capability, which existed prior to 1991; maintenance of warheads designated to counter significant unforeseen events, which have been maintained since 1991; or some combination of the two, which is the plan as the United States transitions to limited nuclear weapon production over time. Maintaining warheads to counter unforeseen events is referred to as a "hedge." During the Cold War, the United States maintained a robust production capability to augment stockpile quantities as required. Today, the United States does not have an active, effective nuclear weapons production capability and relies on maintaining warheads as a hedge to reduce risks.

In the absence of a modernized nuclear infrastructure and the reestablishment of a fissile component production capability with sufficient capacity, the decision to reduce the quantity of warheads designated to mitigate unforeseen events and to dismantle additional weapons is not taken lightly. Hedging strategies and the size and composition of the warhead hedge are complex issues that are considered by policy and military decision makers at the highest levels.

STOCKPILE CONFIGURATION

The current stockpile is composed of weapons developed and produced during the Cold War and maintained well beyond their original planned lives for roles and missions that have evolved significantly since their original production. Modern stockpile configuration involves maintaining aging weapons in an environment where they cannot be replaced once dismantled or they become irreparable. Stockpile composition refers not only to the differences among bombs and warheads or strategic and non-strategic weapons, but also to the various stockpile categories into which the weapons are divided. This enables the United States to maintain the required numbers of deployed weapons together with those that could be deployed if they were ever needed.[2]

It is necessary for the government to identify the numbers, types, and configurations of nuclear warheads required to support an array of employment options and address possible contingencies. The United States must maintain the required number of operationally ready weapons to ensure confidence in the credibility of the nuclear deterrent, maintain strategic stability with Russia and China, and assure U.S. allies of the credibility of the U.S. nuclear umbrella. Because some contingencies are based on strategic warning, meaning the United States would know in advance of the need to employ its nuclear weapons to respond to emerging circumstances, not all nuclear weapons must be maintained in an operationally responsive mode. To save resources and preserve limited facilities and capabilities, some weapons are maintained in less-ready modes, requiring maintenance action or component replacement or production to become operationally ready.

Because all U.S. nuclear weapons are not ready for immediate use all of the time, balancing the various operational requirements against physical, logistical, and fiscal realities is challenging. Considering the United States has no current capability to mass produce fissile components for nuclear weapons, stockpile composition must retain some flexibility to allow for options in the event of a technological failure or to augment U.S. nuclear forces in response to geopolitical reversals. Stockpile composition is a function of configuration management (the categorization of warheads by function and readiness state) and the associated logistical planning.

Configuration management requires warheads in different status to be designated in different categories. For example, operational warheads are called the *active stockpile*. An operational weapon is maintained with functioning limited life components (LLCs), such as power sources (batteries) and tritium gas bottles, in place. Nonoperational warheads are called the *inactive stockpile* and do not maintain LLCs. Based on employment plans, strategic requirements, and logistical requirements, the NWSP specifies the number of warheads required to be operational in a given year.

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[2] U.S. Strategic Command, the Military Departments, and other Combatant Commanders recommend the numbers and types of operational nuclear weapons required to satisfy national security policy objectives. These numbers, combined with the NNSA capability and capacity to support surveillance, maintenance, and life extension, result in stockpile projections over time. These projections are codified in the annual NWSP issued by the President. See *Chapter 6: Nuclear Weapons Council* for more information.

Active Stockpile

Active stockpile warheads are maintained in an operational status and undergo regular replacement of LLCs (e.g., tritium components, neutron generators, and power-source batteries), usually at intervals of a few years. Active stockpile warheads are also refurbished with all required life extension program (LEP) upgrades, evaluated for reliability estimates, usually every six months, and validated for safety, usually every year. These warheads may be stored at a depot, operational base, or uploaded on a delivery vehicle (e.g., a reentry body (Navy) on an SLBM, a reentry vehicle (Air Force) on an ICBM, an air-launched cruise missile, or a delivery aircraft).

Active stockpile warheads include: *active ready (AR)* warheads that are operational and ready for wartime employment; *active hedge* warheads that serve as part of the technical or geopolitical hedge and can serve as active ready warheads within prescribed activation timelines; and *active logistics* warheads to facilitate workflow and sustain operational status.

Inactive Stockpile

Inactive stockpile warheads are maintained in a nonoperational status. Inactive stockpile warheads have their tritium components removed as soon as logistically practical, and the tritium is returned to the national repository.[3] Other LLCs are not replaced until the warheads are reactivated and moved from the inactive to the active stockpile. Some inactive stockpile warheads are refurbished with all required LEP upgrades, while others are not upgraded until the refurbishment is required for reactivation. Some inactive stockpile warheads are evaluated for reliability estimates, while others may not require this. All inactive stockpile warheads are validated for safety, usually every year, and are normally stored at a depot rather than an operational base.

Inactive stockpile warheads include: *inactive hedge* warheads that are a part of the technical or geopolitical hedge and can serve as active ready warheads within prescribed activation timelines; *inactive logistics* warheads that serve logistical and surveillance[4] purposes; and *inactive reserve* warheads retained as a long-term response to risk mitigation for technical failures in the stockpile.

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[3] Tritium is a radioactive gas used in U.S. warheads as a boosting gas to achieve required yields. Because tritium is in limited supply and very expensive, special procedures are used to ensure none is wasted in the process of storing, moving, and maintaining warheads. The national repository for tritium is at the Savannah River Site, located near Aiken, South Carolina.

[4] Surveillance is the term used to describe the activities to ensure weapons continue to meet established safety, security, and reliability standards. Surveillance involves system and component testing and is conducted with the goal of validating safety, estimating reliability, and identifying and correcting existing or potential problems with the weapons. As the stockpile continues to age well beyond its original planned life, the quality assurance approach has been expanded to include planned replacement for many key components before they begin to degrade in performance.

Warhead Readiness States

A warhead readiness state (RS) refers to the configuration of the weapons in the active and inactive stockpiles. Figure 4.6 depicts the readiness states and categorizes them as part of the active or inactive stockpile. Because not all weapons are maintained in an AR configuration, there are lead times associated with reactivating weapons not in the active stockpile or designated as augmentation warheads.[5] However, the RS of any particular warhead should be transparent to the force provider (DoD) insofar as NNSA is able to meet requirements for maintenance and reactivation on schedules previously agreed to by both Departments. The RS is determined by stockpile category, location, and maintenance requirements. Currently there are six different readiness states, divided into active and inactive stockpiles, defined below.

Figure 4.6
Warhead Readiness States

Active Stockpile. Strategic and non-strategic warheads maintained to ensure Combatant Command (CCMD) requirements for operational warheads are met and are updated to incorporate the latest warhead refurbishment—Mods or alterations (Alts). CCMD orders specify the allocation of operational warheads and readiness timelines. Operational warheads are fully assembled warheads with a tritium gas transfer system and other LLCs installed.

- *Active Ready (RS 1)* – Warheads designated available for wartime employment planning. AR warheads are loaded onto missiles or available for generation on aircraft within required timelines.
- *Active Hedge (RS 2)* – Warheads retained for deployment to manage technological risks in the AR stockpile or to augment the AR stockpile in response to geopolitical developments. These warheads are not loaded onto missiles or aircraft. Warheads are available to deploy or upload per prescribed U.S. Strategic Command (USSTRATCOM) activation timelines.

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[5] Hedge or contingency weapons available for redeployment over time.

- *Active Logistics (RS 3)* – Warheads used to facilitate workflow and sustain the operational status of AR or Active Hedge quantities. These warheads may be in various stages of assembly in preparation for deployment. However, gas transfer systems are installed or co-located on the operational base in sufficient quantities to meet the readiness timelines specified in CCMD operational orders. Ballistic missile submarine surveillance warheads are currently allowed to remain in this category.

Inactive Stockpile. Warheads retained in a nonoperational status for augmentation or replacement of warheads in the active stockpile. Tritium gas transfer systems, if installed, are removed and returned to NNSA prior to their projected limited life expiration. Hedge and logistics warheads are updated to incorporate the latest warhead Mods or Alts.

- *Inactive Hedge (RS 4)* – Warheads retained for deployment to manage technological risks in the AR stockpile or to augment the AR stockpile in response to geopolitical developments. These warheads are available to deploy or upload per prescribed USSTRATCOM activation timelines.
- *Inactive Logistics (RS 5)* – Warheads used for logistical and surveillance purposes. Warheads may be in various stages of disassembly.
- *Inactive Reserve (RS 6)* – Warheads retained to provide a long-term response for risk mitigation of technical failings in current and future LEPs. Warheads in this category are exempt from future LEPs including Mods and Alts.

Figure 4.7 depicts the characteristics of each readiness state.

Readiness State	Deployed	LLCs Installed	LEP (as required)	Reliability Assessed	Safety Assessed	AS or IS
RS 1: Active Ready	✓	✓	✓	✓	✓	AS
RS 2: Active Hedge		✓	✓	✓	✓	AS
RS 3: Active Logistics		✓	✓	✓	✓	AS
RS 4: Inactive Hedge			✓	✓	✓	IS
RS 5: Inactive Logistics			✓	✓	✓	IS
RS 6: Inactive Reserve					✓	IS

Figure 4.7 Stockpile Readiness States

Logistical Planning

Logistical planning for configuration management ensures components, weapons movements, and locations are synchronized, as appropriate. Logistical planning includes plans for storing, staging, maintaining, moving, testing, and refurbishing weapons. Nuclear weapons logisticians must comply with requirements and restrictions from several sources, including joint DoD-NNSA agreements and memoranda of understanding, Joint Publications (JP) published by the Joint Chiefs of Staff, the Joint Nuclear Weapons Publications System (JNWPS),[6] and regulations of the Military Departments. Logistical planning ensures weapons are handled, stored, and transported in ways that are safe, secure, and maintained so as to be reliable, with appropriate controls in place to preclude unauthorized acts or events.

Storage

Figure 4.8 Munitions Storage Igloo

Storage is the placement of weapons in a holding facility for an indefinite period of time. Nuclear weapons are amassed in secure weapons storage areas, most in munitions storage igloos (Figure 4.8). Logistical planning for nuclear weapons storage includes several critical considerations: the number of square feet required to store the designated warheads in each igloo so as to avoid nuclear criticality concerns; special barriers needed for safe separation of certain types of nuclear warheads; inside traffic flow for access to warheads by serial number for maintenance or movement of a surveillance sample; and procedures for allowing access and security, both within the exclusion area and at greater distances from the storage facility. Currently, storage of nuclear weapons occurs only at DoD facilities operated by the Navy and the Air Force. Storage is also a consideration for retired nuclear weapons awaiting dismantlement.

Staging

Staging refers to the placement of warheads awaiting some specific function (e.g., transportation, disassembly, or dismantlement) in a holding facility for a limited period of time. Nuclear weapons staging includes the logistical planning elements and the planned flow of warheads in the disassembly or dismantlement queue. Nuclear weapons are usually staged in secure areas awaiting disassembly or dismantlement at the Pantex Plant near Amarillo, Texas. Many current U.S. nuclear weapons have been staged in the disassembly queue at least once as

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[6] JNWPS is a system of technical manuals on nuclear weapons, associated materiel, and related components. It includes general and materiel manuals developed by DoD and NNSA to provide authoritative nuclear weapons instructions and data.

surveillance samples, where they were disassembled, their components were tested and evaluated, and they were reassembled for return to the stockpile. Some warheads have been through this process several times.

Maintenance

Nuclear weapons maintenance includes the technical operations necessary to disassemble and reassemble a warhead to whatever extent is required for the replacement of one or more components. Maintenance operations require highly specialized training to qualify maintenance technicians as well as special ordnance tools, technical manuals, and secure and effective maintenance facilities. Most maintenance operations, including limited-life component exchanges (LLCEs), are performed by Navy or Air Force technicians and maintainers at an appropriate military nuclear weapons maintenance facility. Some maintenance operations require the warhead to be disassembled to a greater extent than military technicians are authorized; in this case, the warhead must be sent back to the Pantex Plant for maintenance.

NNSA establishes an LLCE schedule for each type of warhead. This schedule is managed by individual warhead and serial number and is coordinated between the appropriate Military Department and NNSA.

Movement

Nuclear weapons are moved for several reasons. Warheads may be moved for maintenance activities, or they may be moved within an operational base area. Warheads can be moved from an operational base to a depot upon retirement as part of the dismantlement queue, and they can be moved again to Pantex for actual dismantlement. Warheads may also be moved to the Pantex Plant for disassembly or returned from Pantex after re-assembly. On occasion, a warhead will be returned from DoD to Pantex because of a special maintenance problem. Normally, all warhead movements from one installation to another within the continental United States are accomplished using NNSA secure safeguards ground transport vehicles. The Air Force uses its own certified ground vehicles and security for moves within an operational base area. Movements of weapons to and from Europe are accomplished by the Air Force using certified cargo aircraft. LLCs may be transported by special NNSA contract courier aircraft or by NNSA secure safeguards transport vehicles. Representatives from agencies with nuclear weapons movement responsibilities meet frequently to coordinate the movement schedule.

Surveillance

The logistical aspect of the surveillance program include downloading, uploading, reactivating, and transporting warheads. For example, an active ready warhead selected at random to be a surveillance sample is downloaded from an ICBM. A logistics warhead is uploaded to replace the active ready warhead, with minimal loss of operational readiness. NNSA produces LLCs which are sent to the depot, and a replacement warhead is reactivated and transported by a secure safeguards transport vehicle to the operational base to replace the logistics warhead. The secure safeguards vehicle transports the surveillance sample warhead to Pantex for disassembly. After the surveillance testing is complete, the warhead may be reassembled and returned to the depot as an inactive warhead. Logisticians plan and coordinate the dates and required transport movements for each upload and download operation.

Forward Deployment

The United States remains committed to supporting NATO forces with nuclear weapons that are forward deployed in Europe. Recommendations for forward deployment are sent to the President as a Nuclear Weapons Deployment Plan. The President then issues a classified Nuclear Weapons Deployment Authorization (NWDA) as a directive, specifying the quantities and locations of U.S. forward-deployed weapons.

Life Extension Program

Weapon systems are being maintained well beyond their original design lifetimes. As these systems age, NNSA continues to detect anomalies that may ultimately degrade performance of some nuclear weapons to unacceptable levels. Life extension activities address these aging and performance issues, enhancing safety features and improving security, while meeting strategic deterrence requirements. Additional LEP goals are to reduce, to the extent possible, materials that are hazardous, costly to manufacture, degrade prematurely, or react with other materials in a manner that affects performance, safety, or security. A well-planned and well-executed stockpile life extension strategy improves safety and security while enabling DoD to implement a deployment and hedge strategy consistent with national security guidance. In addition, because of production constraints, NNSA uses both refurbished and reused components from legacy systems as well as newly manufactured parts. Changing materials, using components from legacy systems in new LEPs, and remanufacturing legacy component designs present significant challenges to today's stockpile stewards.

Retired Warheads

Warheads are retired from the stockpile in accordance with presidential guidance in the NWSP. Retired warheads that are released for disassembly are scheduled for disassembly consistent with the throughput available in NNSA facilities so as not to impact support for DoD requirements. Currently, there is a backlog of weapons awaiting disassembly. Most of these warheads remain stored at DoD facilities because of limited staging capacity at NNSA facilities.

NNSA validates the safety of all retired warheads and reports annually to the Nuclear Weapons Council Standing and Safety Committee (NWCSSC) until the weapons are dismantled. These annual reports specify the basis for safety validation and may require additional sampling from the population of retired warheads. See *Chapter 6: Nuclear Weapons Council* for more information on the NWCSSC and NWC reports.

STOCKPILE STEWARDSHIP PROGRAM

The NNSA Stockpile Stewardship Program (SSP) was established by *Presidential Directive 28* as a response to the *National Defense Authorization Act for Fiscal Year 1994* (Public Law 103-160) which requires, in the absence of nuclear explosive testing, a program to:

- support a focused, multifaceted program to increase the understanding of the enduring stockpile;
- predict, detect, and evaluate potential problems of the aging stockpile;
- refurbish and remanufacture weapons and components, as required; and
- maintain the science and engineering institutions needed to support the U.S. nuclear deterrent, now and in the future.

In the past, underground nuclear testing and the continuous development and production of new nuclear weapons were essential to preserve high confidence in the stockpile. The United States has not manufactured a new weapon for over 30 years. The challenge for NNSA has been to maintain confidence in the nuclear weapons in the stockpile without producing new weapons or conducting nuclear explosive tests. The solution has been to field a suite of innovative experimental platforms, diagnostic equipment, and high-performance computers that build on past test data to simulate the internal dynamics of nuclear weapons. Armed with this understanding, the effects of changes to the current stockpile through either aging or component replacement may be understood through non-nuclear testing as well as modeling and simulation.

The SSP exercises the NNSA Nuclear Security Enterprise capabilities across the entire nuclear weapon life cycle that are critical for sustaining the deterrent into the future. The program also ensures proficiency of the NNSA workforce for the future and helps maintain the readiness of its infrastructure to support near-term and future workloads. Finally, it provides foundational science, technology, and engineering (ST&E) and computational capabilities that serve as a hedge against prospective and unanticipated risks and technological surprise. Key activities include advanced modeling and simulation capabilities, subcritical and hydrodynamic experiments, high-energy-density physics experiments, and test flights in high-fidelity simulators, which provide the capabilities to underwrite the present day and future nuclear stockpiles.

STOCKPILE MANAGEMENT

Stockpile management refers to the cradle-to-grave activities related to all U.S. nuclear weapons. All stockpile management activities are coordinated by DoD and NNSA through the NWC. Stockpile management is the sum of the activities, processes, and procedures for the concept development, design engineering, production, quality assurance, fielding, maintenance, repair, storage, transportation, physical security, employment (if directed by the President), dismantlement, and disposal of U.S. nuclear weapons and associated components and materials. Stockpile management ensures the nuclear deterrent is safe, secure, reliable, and effective.

STOCKPILE MANAGEMENT EVOLUTION

The U.S. approach to stockpile management has evolved over time to reflect the military and political realities of the international security environment as well as U.S. national security priorities and objectives. From 1945 to 1991, U.S. nuclear warheads were designed, developed, produced, deployed to the stockpile (usually for a period up to 15 to 20 years), and retired and dismantled, to be replaced by new, more modern weapons that generally offered unique military capabilities and better safety and security features. Figure 4.9 illustrates U.S. nuclear stockpile management during the Cold War. This continuous replacement cycle ensured U.S. nuclear weapons incorporated evolving technological advances and achieved the best military performance to counter the specific threats of the day.

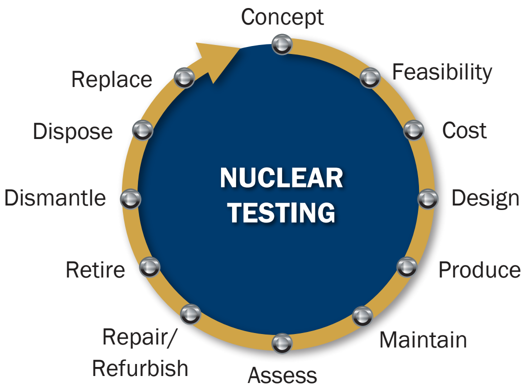

Figure 4.9 U.S. Nuclear Stockpile Management During the Cold War

STRATEGIC, OFFENSIVE
- **Intercontinental Ballistic Missiles***
- **Strategic Heavy Bombers***
- **Submarine-Launched Ballistic Missiles***
- **Air-Delivered Bombs***
- **Air-Launched Cruise Missiles***

STRATEGIC, DEFENSIVE
- Air Defense Missiles
- Anti-Ballistic Missiles

TACTICAL, OFFENSIVE
- **Dual-Capable Aircraft (DCA)***
- **Air-Delivered Bombs***
- Free-Flight Rockets
- Surface-Launched Ballistic Missiles
- Surface-Launched Cruise Missiles
- Artillery-Fired Atomic Projectiles

TACTICAL, DEFENSIVE
- Air Defense Missiles
- Atomic Demolition Munitions

TACTICAL, SEA
- Carrier-Based DCA
- Anti-Submarine Depth Bombs
- Air-Delivered Bombs
- Sea-Launched Cruise Missiles
- Torpedoes
- 16-inch Battleship Guns

*** indicates current U.S. nuclear delivery system**

Figure 4.10 Cold War Nuclear Weapon Delivery System Categories

During the Cold War, a primary objective of U.S. nuclear weapons design and development became maximizing the yield of the weapon in the smallest possible package, resulting in a maximum yield-to-weight ratio. Warheads built to achieve this goal were produced with cutting edge technology and manufactured with very tight tolerances. Warheads were designed to be carried by increasingly more sophisticated and capable delivery systems.[7] A second objective was to incorporate modern safety and security features in the warheads, which added to the design complexity and level of production sophistication. A third objective was to achieve operational flexibility in the stockpile. At the height of the Cold War, the United States had more than 50 different types of nuclear weapons in five delivery categories (see Figure 4.10). This offered the President a wide range of options in the event nuclear weapons were needed.

The current stockpile is composed of a subset of these weapons. All of the weapons in the current stockpile were developed and produced during the Cold War and have exceeded the end of their originally planned life cycle.

Between the mid-1980s and the early 1990s, U.S. stockpile management strategies shifted significantly. The end of the Cold War in the late 1980s

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[7] The first nuclear delivery system, the *Enola Gay*, was a specially modified long-range bomber. Since 1945, the United States has added ICBMs and SLBMs to its nuclear triad. For additional information on nuclear delivery systems, see *Chapter 3: Nuclear Delivery Systems*.

coincided with the closure of the Rocky Flats production facility.[8] At that time, the United States adjusted its national security priorities and reconsidered the appropriate role of nuclear weapons in light of a desire to realize the benefits of the "peace dividend." There was also an increasing awareness that nuclear proliferation and the possibility of a nuclear accident or nuclear terrorism were becoming the most urgent threats facing the United States and its allies.

In response to these changing geopolitical circumstances, President George H. W. Bush announced the immediate termination of additional nuclear weapons production in 1991 and a moratorium on underground nuclear explosive testing, which began in 1992 and has continued ever since. As a result, the nuclear weapons modernization and replacement model was abruptly terminated and supplanted by a mandate for the indefinite retention of the weapons in the legacy stockpile. To fulfill this mandate, stockpile management strategies evolved toward maintaining the legacy stockpile indefinitely.

Stockpile Life Extension from 1992–Present

By 1992, when warhead production and underground nuclear explosive testing ended, the designs of each type of weapon in the stockpile had been confirmed with nuclear testing, and U.S. nuclear scientists and engineers were confident in both the designs and manufacturing processes that produced the weapons. Because of this confidence, the primary stockpile management strategy to ensure the continued safety, security, and reliability of U.S. nuclear weapons was to maintain the weapons in the stockpile as closely as possible to their original designs and specifications. This has been achieved through stockpile life extension programs. During this period, each weapon-type in the enduring stockpile had LEPs planned as far into the future as practicable, in many cases up to two decades. LEP planning and the reductions in stockpile quantities associated with various arms control treaties led to a revised life cycle for nuclear weapons, as illustrated in Figure 4.11.

LEPs, which have been conducted since the 1990s, involve the use of existing or newly manufactured non-nuclear components that are based on the original designs specific to that weapon. Non-nuclear components are produced or refurbished as closely as possible to the original designs for a specific warhead. Deviations from original designs are often the result of "sunset" technologies

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[8] The Rocky Flats Plant in Colorado was the only U.S. facility that mass-produced plutonium pits. It was closed as a result of violating environmental protection laws. Reestablishing a pit production capability (including plutonium processing) and building a modern secondary production facility are necessary steps for NNSA to achieve a modern and responsive capacity to produce nuclear components. This will mark the beginning of a new stockpile support paradigm whereby NNSA can meet stockpile requirements through its production infrastructure, rather than through the retention of inactive stockpile weapons to serve as a hedge and support Military requirements.

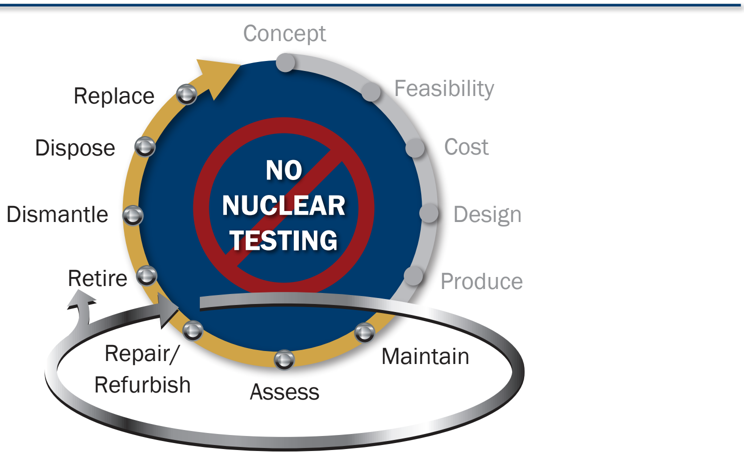

Figure 4.11 U.S. Approach to Stockpile Management, 1992–Present

(where there are no longer technologies in existence to produce items) or manufacturing processes and the use of alternate materials that cannot be replicated because of environmental or health hazards.

There are two increasingly challenging issues with a life extension-only stockpile maintenance strategy. First, as a growing number of incremental changes are made to nuclear weapons through the life extension process, the further away from their original underground nuclear test (UGT)-validated specifications the weapons become. Because these legacy weapons were built to push the envelope of what was technologically possible in terms of achieving yield-to-weight ratios, very little margin for error exists; any deviations from very exact specifications could negatively impact confidence in the performance of the weapon. As confidence degrades and uncertainty is introduced, it becomes increasingly difficult to certify that these weapons continue to meet safety, security, and yield requirements. In light of the underground explosive testing moratorium, the LEP process by itself limits the U.S. ability to understand how new technologies would interact with the existing safety, security, and yield characteristics of the legacy weapons.

The second issue is that life extension offers little opportunity to enhance safety, security, or military performance through the introduction of modern technological improvements. Currently fielded stockpile weapons have features that were developed in the 1970s and 1980s. Today, the United States has the technical capability to enhance safety, security, and military performance relative to current weapons. For example, increasing the accuracy of warheads could result in the need for lower yields to achieve similar military effects.

ADVANCEMENT OF STOCKPILE LIFE EXTENSION

The United States has understood the value of flexibility for nuclear deterrence for six decades, but its importance is now magnified by the emerging diversity of nuclear and non-nuclear strategic threats and the dynamism and uncertainties of the security environment.

The United States has a two-pronged approach to maintaining the stockpile: first, the operational lives of legacy weapons are being extended to the extent practicable; second, the United States is planning to begin to replace warheads in the existing stockpile by the early 2030s.

STOCKPILE EVALUATION AND QUALITY ASSURANCE

As part of the nuclear weapons life cycle, weapons in the U.S. stockpile are surveilled for the purpose of evaluation and quality assurance. Issues with a nuclear weapon-type or nuclear weapon family have occurred in the past as a result of design and/or production problems, but each of the weapon-types in the current U.S. stockpile have undergone underground nuclear explosive testing during their original production runs. As a result, there is high confidence that all of the legacy Cold War weapons in the current U.S. stockpile were designed and produced to be safe and reliable.

Today, however, the aging of components—both nuclear and non-nuclear—cause the majority of the problems and concerns that lead to requirements for warhead Alts and Mods. These problems may be detected as a result of evaluations during stockpile surveillance that includes non-nuclear flight and laboratory testing and/or observations made by field maintenance technicians. A weapon may also undergo an Alt or a Mod because of changes in the mechanical or electrical interface between a warhead and its delivery system, rather than as a result of a problem or issue affecting safety or reliability.

In order to detect problems or issues in a timely manner, and to ensure that they are resolved as quickly and efficiently as possible, NNSA has a formal stockpile evaluation program for quality assurance. The NNSA surveillance program has evolved over the years, but has so far been successful in identifying and resolving issues affecting the overall credibility of the U.S. nuclear deterrent.

HISTORY OF STOCKPILE EVALUATION

The Manhattan Project, which produced one test device and two war reserve (WR) weapons, *Little Boy* and *Fat Man*, employed to end World War II, had no formal, structured Quality Assurance (QA) program and no safety standards or reliability requirements to be met. Rather, quality was assured through the knowledge and expertise of weapons scientists and engineers. History proves the Manhattan Project approach to quality was successful in that it accomplished an extremely difficult task without a catastrophic accident.

The first nuclear weapons required in-flight insertion (IFI) of essential nuclear components, until which time the weapons were unusable, making them inherently safe. Once assembled in flight, the weapons had none of the modern safety features that preclude an accidental detonation. The early focus was on ensuring the reliability of the weapons given that they would not be assembled until they were near the target. In the early 1950s, as the U.S. nuclear weapons capability expanded into a wider variety of delivery systems and, because of an emphasis on more rapid response times for employment, IFI became impractical. The development of sealed-pit weapons to replace IFI weapons led to requirements for nuclear detonation safety features to be built into the warheads.[9] See *Chapter 8: Nuclear Surety* for a detailed discussion of nuclear detonation safety and security standards.

During this time, the concern for safety and reliability caused the expansion of QA activities into a program that included random sampling of approximately 100 warheads of each type, each year. Tests were conducted to detect and repair problems related to design and/or production processes. The warheads that were randomly sampled were used for both laboratory and flight testing and provided a sample size to calculate reliability and stress-test the performance of key components in various extreme environments. This sample size was unsustainable for the long term, and, within a year or two of entering full production, the sample size was reduced to a random sampling of 44 warheads. This sample size was adequate to calculate reliability for each warhead-type. Within a few more years, the number was reduced to 22 per year. Eventually, the sample number was reduced to 11 per year to reflect fiscal and logistical realities. Each weapon system was re-evaluated on a case-by-case basis with respect to the approach to its sampling, accounting for the specific technical needs of each system and new approaches to evaluation tests that were being developed and implemented. As a result, some system samples were reduced from 11 per year to lower numbers.

SURVEILLANCE PROGRAM

In the mid-1980s, DOE strengthened the significant finding investigation (SFI) process, which was the method by which anomalous findings were identified and reported. Since then, any anomalous finding or suspected defect that might

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[9] Sealed-pit warheads are the opposite of IFI; they are stored and transported with the nuclear components assembled into the warhead and require no assembly or insertion by the military operational delivery unit prior to employment.

negatively impact weapon safety or reliability is documented as an SFI. Weapon system engineers and surveillance engineers investigate, evaluate, and resolve SFIs.

At the national level, warheads drawn from the fielded stockpile as random samples are considered part of the NNSA surveillance program. Under this program, additional efficiencies are gained by sampling and evaluating several warhead-types as a warhead "family" if there are enough identical key components. Now as a rule, each warhead family has 11 random samples evaluated each year under what used to be called the Quality Assurance and Reliability Testing (QART) program. This sample size enables the quality assurance program to provide an annual safety validation, supply a reliability estimate semi-annually, and identify any randomly occurring problem present in 10 percent or more of that warhead-type with a 90 percent assurance, within two years of occurrence.

Weapons drawn for surveillance sampling are returned to the Pantex Facility for disassembly. Generally, of the samples selected randomly by serial number, two to three are used for flight testing and the remainder are used for laboratory testing and/or component and material evaluation. Surveillance testing and evaluation may be conducted at Pantex or at other NNSA facilities. Certain components are physically removed from the weapon, assembled into test configurations, and subjected to electrical, explosive, or other types of performance or stress testing. The condition of the weapon and its components is carefully maintained during the evaluation process. The integrity of electrical connections remains undisturbed whenever possible. Typically, one sample per warhead family per year is subjected to non-nuclear destructive testing of its nuclear components and cannot be rebuilt. This is called a destructive test or "D-test" and the specific warhead is called a "D-test unit." Depending on the availability of non-nuclear components and the military requirement to maintain stockpile quantities, the remaining samples may be rebuilt and returned to the stockpile.

Today, the goals of the U.S. nuclear weapons quality assurance programs are to validate safety, ensure required reliability, and detect or, if possible, prevent problems from developing for each warhead-type in the stockpile. Without nuclear explosive testing, the current stockpile of nuclear weapons must be evaluated for QA only through the use of non-nuclear testing, surveillance, and, to the extent applicable, modeling and simulation efforts. NNSA surveillance activities provide data to evaluate the condition of the stockpile in support of annual assessments of safety, security, reliability, and performance. In addition, the cumulative body of surveillance data supports decisions regarding weapon life extensions, Mods, Alts, repairs, and rebuilds.

As warheads in the stockpile age, stockpile evaluation has detected a number of problems and areas of potential future concern that so far have been managed.

These problems, together with national security policy decisions, have led to expanded life extension programs and planned replacement programs while surveillance continues to assess the quality of products during life extension. During life-extension production, the surveillance activity is robust in order to detect design, material, production, and other assurance related issues.

Surveillance requirements, as determined by the national security laboratories for the weapon systems, in conjunction with NNSA, Air Force, and Navy for joint testing, result in defined experiments to acquire the data that support the NNSA surveillance program. The national security laboratories, in conjunction with NNSA and the nuclear weapons production facilities, continually refine these requirements based on new surveillance information, annual assessment findings, and analysis of historical information using modern assessment methodologies and computational tools.

The current NNSA surveillance program has four primary goals:

1. Understand the state of weapons in the U.S. stockpile today (core surveillance activities).
2. Predict the state of weapons in the future (enhanced surveillance activities).
3. Maintain the capabilities to surveil the stockpile.
4. Enhance the capabilities to surveil the stockpile.

Each weapon-type and/or family is considered on a case-by-case basis, so that highly reliable systems might be subject to fewer tests, while weapon-types that have begun to display age-related issues might be given increased scrutiny. The objective is to ensure that surveillance resources are allocated appropriately and that a compelling sampling rationale is developed for each weapon-type or family.

This risk-based approach to surveillance ensures that issues will continue to be identified and resolved as quickly and effectively as possible as the weapons in the U.S. nuclear deterrent age well beyond their original design lives and beyond the data obtained from underground nuclear explosive testing and the experience of U.S. scientists and engineers.

The current NNSA stockpile surveillance program is comprised of two major elements that work closely together: the New Material and Stockpile Evaluation (NMSE) program, whose goal is to understand the current state of the stockpile; and the Aging and Lifetimes (A&L) program, whose goal is to predict the future state of the aging stockpile. Both programs are located within the Office of Engineering and Technology Maturation. The NMSE program conducts surveillance evaluations of both the existing stockpile (i.e., stockpile returns) and newly refurbished LEP weapons. The mission of the A&L program, formerly known as the enhanced surveillance program, is to detect the onset of deleterious aging phenomena in weapon materials, components, or subsystems in time to execute corrective actions before they degrade the nuclear deterrent. The A&L program contributes to weapon safety, performance, and reliability by providing the tools needed to predict material, component, and subsystem lifetimes and detect the precursors of potential age-induced defects. These two programs work closely together to execute the surveillance program and are constantly striving to develop new and better surveillance capabilities and techniques.

NEW MATERIAL AND STOCKPILE EVALUATION PROGRAM

The NMSE program has the following four goals:

1. Identify defects that affect safety, security, performance, and reliability.
2. Establish margins between design requirements and performance at the component and material level.
3. Identify changes and aging trends at a component and material level.
4. Develop the capability for predictive assessments of stockpile components and materials.

The NMSE program consists of planning for and conducting tests of WR hardware, or hardware considered to be representative of WR products. The NMSE program provides critical data to evaluate the safety, security, performance, and reliability of the current condition of the active and inactive stockpiles and to inform decisions about the stockpile.

The evaluations conducted as part of the NMSE program are either system-level tests or laboratory tests. System-level testing can be high-fidelity joint test assemblies (JTAs), instrumented JTAs, Weapons Evaluation Test Laboratory (WETL) testbeds, or joint integrated laboratory test (JILT) units. System-level tests may occur jointly with the Air Force or the Navy and use combinations of existing weapons and/or new production units, which are modified into JTAs. Some JTAs contain extensive telemetry instrumentation, while others contain high-fidelity mock nuclear assemblies to recreate, as closely as possible, the mass properties of WR weapons. Stockpile laboratory tests conducted at the component level assess major assemblies and components and, ultimately, the materials that make up the components (e.g., metals, plastics, ceramics, foams, and explosives). This surveillance process enables detection and evaluation of aging trends and anomalous changes at the component or material level. The NMSE program consists of four elements:

1. *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 during dismantlement can also provide "state-of-health" information.

2. *Flight Testing* – After disassembly and inspection, selected weapons are reconfigured into JTAs and rebuilt to represent the original build to the extent possible. However, all special nuclear material (SNM) components are replaced with either surrogate materials or instrumentation. The JTA units are flown by the DoD operational command responsible for the system. JTA configurations vary from high-fidelity units, which essentially have no onboard diagnostics, to fully instrumented units, which provide detailed information on component and subsystem performance.
3. *Stockpile Laboratory Testing* – Test bed configurations are built to enable prescribed function testing of single parts or subsystems using parent unit hardware from stockpile weapon returns. The majority of this testing occurs at the WETL, which is operated by Sandia National Laboratories at Pantex and involves electrical and mechanical testing of the systems. The JILT facility, located at Hill Air Force Base in Utah, and WETL also conduct evaluations of joint test beds to obtain information regarding delivery system-weapon interfaces.
4. *Component Testing and Material Evaluation* – Components and materials from the disassembly and inspection process, or Shelf Life Program, undergo further evaluations to assess component functionality, performance margins and trends, material behavior, and aging characteristics. This testing can involve both non-destructive evaluation techniques (e.g., radiography, ultrasonic testing, and dimensional measurements) and destructive evaluation techniques (e.g., tests of material strength and explosive performance as well as chemical assessments).

AGING AND LIFETIMES PROGRAM

The A&L program pursues three principal goals:

1. Provide timely warning of aging phenomena that threaten the effectiveness of the nuclear stockpile.
2. Provide diagnostic tools and methods for improving effective and efficient stockpile evaluation of the enduring and future stockpiles.
3. Inform and enable age-aware design, manufacture, and surveillance decisions for stockpile modernization.

A desired outcome of this new process is to make surveillance (a) more predictive (i.e., using reliable predictive modeling and performance codes), (b) use less invasive/destructive testing, and (c) more cost effective by preserving precious overall subsystems and components from the weapons. A&L personnel at the national security laboratories and nuclear weapons production facilities collaborate and partner with NMSE personnel as many A&L diagnostic development activities lead to capabilities (i.e., test equipment, analysis techniques, and computational simulations) that are ultimately deployed in the NMSE program.

DUAL-AGENCY RESPONSIBILITY FOR STOCKPILE MANAGEMENT

The responsibilities for nuclear weapons management and development were originally codified in the *Atomic Energy Act of 1946*, which reflected congressional desire for civilian control over the uses of atomic (nuclear) energy and established the Atomic Energy Commission (AEC) to manage the U.S. nuclear weapons program. Basic departmental responsibilities and the development process were specified in the *1953 Agreement Between the AEC and the DoD for the Development, Production, and Standardization of Atomic Weapons*, commonly known as the "1953 Agreement."

In 1974, an administrative reorganization transformed the AEC into the Energy Research and Development Agency (ERDA). A subsequent reorganization in 1977 created the Department of Energy. At the time, the Defense Programs (DP) portion of DOE assumed the responsibilities of AEC/ERDA. In 1983, DoD and DOE signed a Memorandum of Understanding (MOU), *Objectives and Responsibilities for Joint Nuclear Weapon Activities*, providing greater detail for the interagency division of responsibilities. In 2000, the NNSA was established as a semi-autonomous agency within DOE responsible for the U.S. nuclear weapons complex and associated nonproliferation activities. Figure 4.12 illustrates the evolution of the AEC to NNSA. Figure 4.13 illustrates the timeline of basic DoD-DOE nuclear weapons laws and agreements.

While the fundamental dual-agency division of responsibilities for nuclear weapons has not changed significantly, the 1953 Agreement was supplemented in 1977 to change the AEC to the ERDA, again in 1984 to incorporate the details of the 1983 MOU, and most recently in 1988 to incorporate the then newly established NWC.

The NWC serves as the focal point for inter-agency analyses and decisions to sustain and modernize the U.S. nuclear deterrent, maintain and manage the

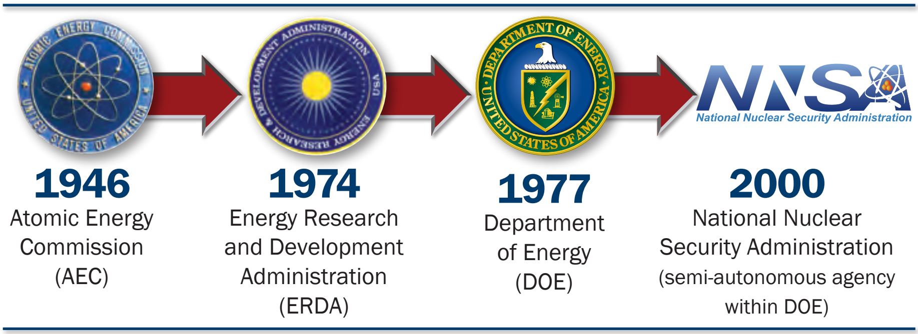


Figure 4.12 AEC to NNSA

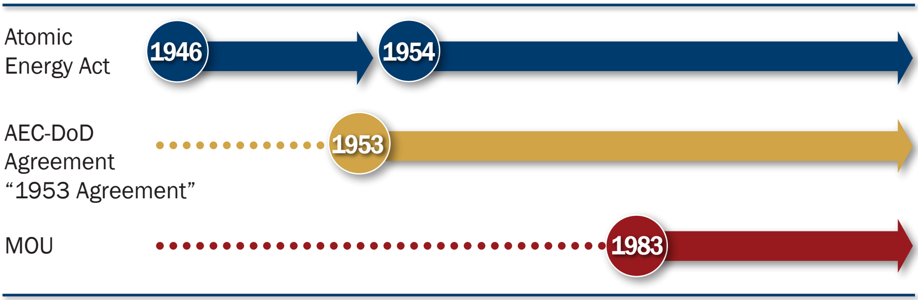


Figure 4.13 Timeline of DoD-DOE Nuclear-Related Agreements

stockpile, and ensure alignment between DoD delivery system programs and NNSA weapons programs. See *Chapter 6: Nuclear Weapons Council* for additional information.

DEPARTMENTAL RESPONSIBILITIES

DoD is responsible for the acquisition of delivery platforms and vehicles. DoD is also responsible for identifying the requirements that drive the retention of existing weapons associated with these systems and the need for modifications or new weapons. DoD is responsible for operational employment preparedness, security, accountability, and logistical maintenance of weapons in DoD custody. Overall, NNSA is responsible for developing, producing, certifying, and maintaining nuclear weapons.

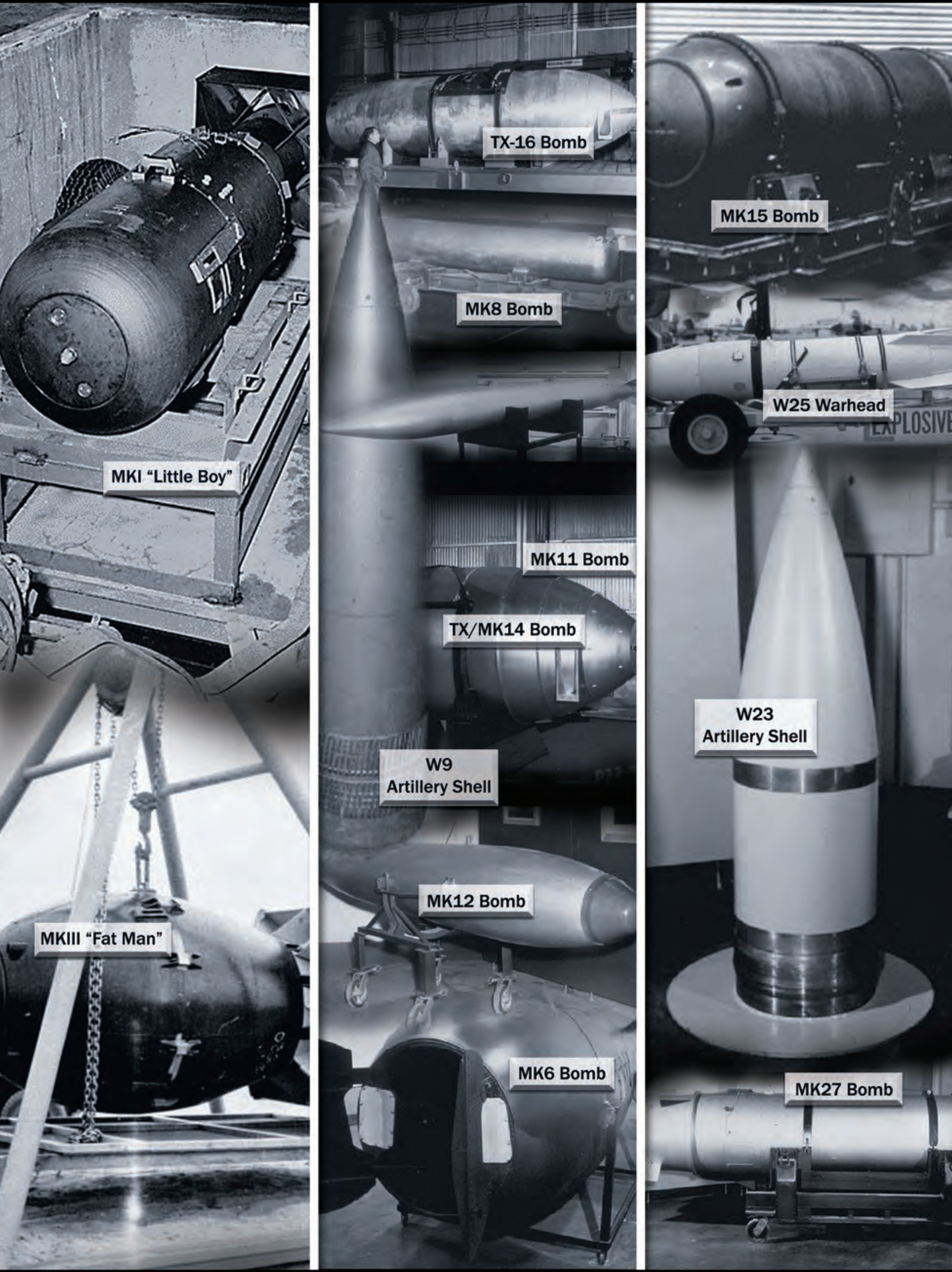
Specifically, DoD is responsible for:

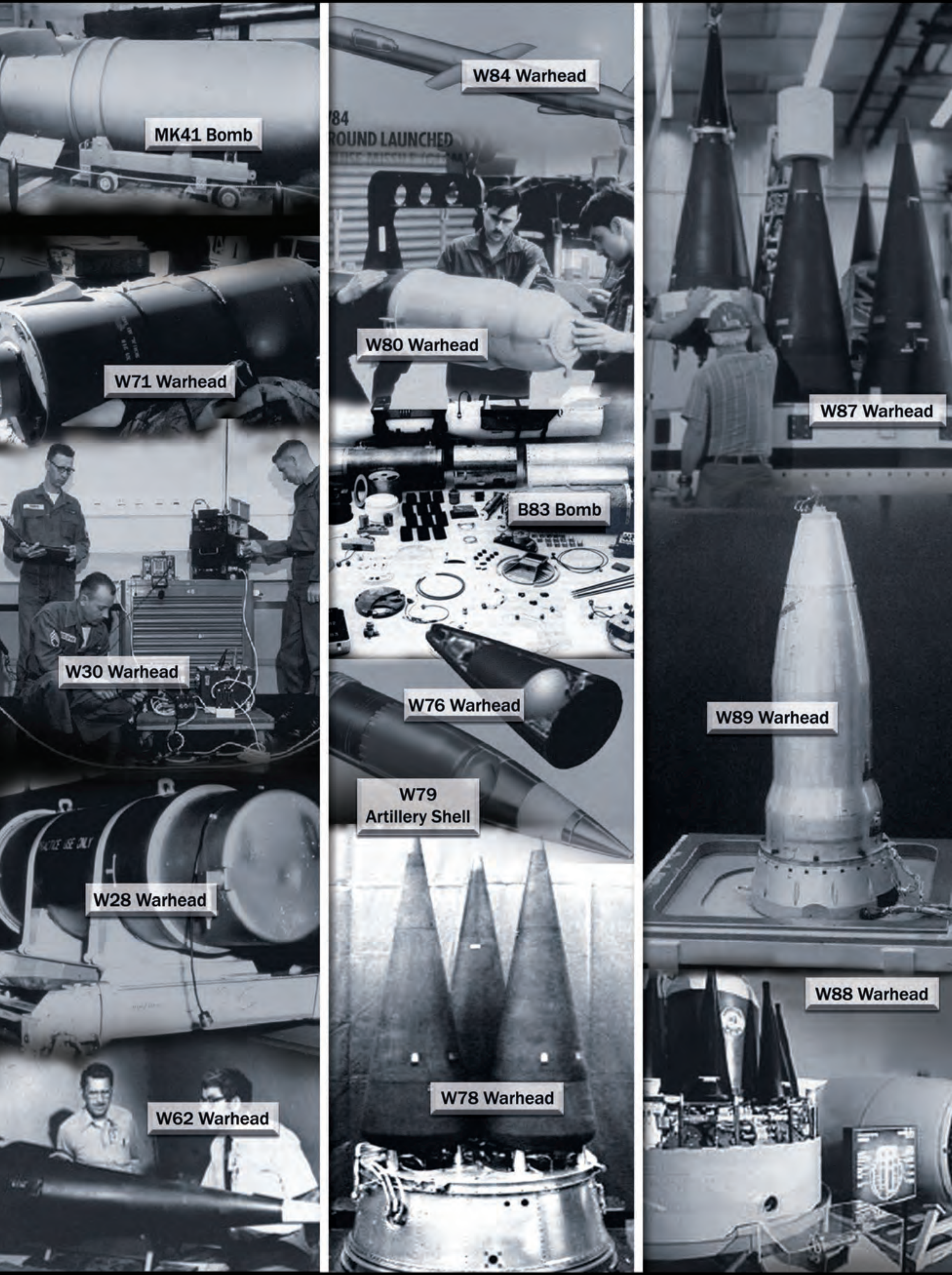
- participating in authorized concept and feasibility studies;
- developing requirements documents that specify operational characteristics for each warhead-type and the environments in which the warhead must perform or remain safe;
- participating in the coordination of the engineering interface requirements between the warhead and the delivery system;

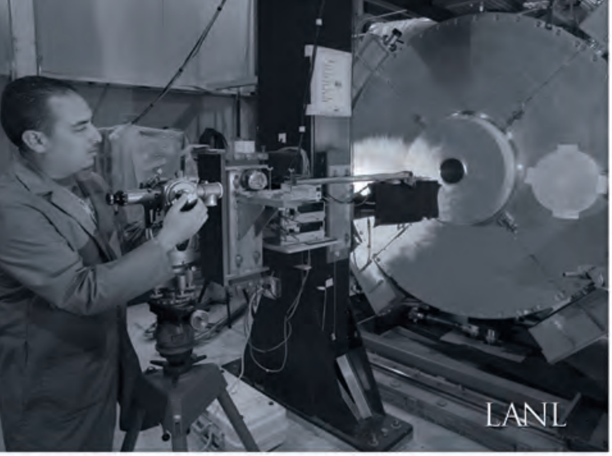
- determining design acceptability;
- specifying military/national security requirements for specific types and quantities of warheads;
- receiving, transporting, storing, securing, maintaining, and, if directed by the President, employing fielded warheads;
- accounting for individual warheads in DoD custody;
- participating in the joint nuclear weapons decision process (including the NWC, the NWCSSC, working groups, and the warhead joint DoD-NNSA POG);
- developing and acquiring the delivery vehicle and launch platform for a warhead; and
- storing retired warheads awaiting dismantlement in accordance with jointly approved plans.

NNSA is responsible for:

- participating in authorized concept and feasibility studies;
- evaluating and selecting the baseline warhead design approach;
- determining the resources (e.g., funding, nuclear and non-nuclear materials, human capital, facilities) required for the program;
- performing development engineering to establish and refine the warhead design;
- engineering and establishing the required production lines;
- producing or acquiring required materials and components;
- assembling components and sub-assemblies into stockpile warheads (if approved by the President);
- providing secure transport within the United States;
- developing maintenance procedures and producing replacement LLCs and replacement components;
- conducting a jointly approved quality assurance program;
- developing LEPs, when required, for sustaining the stockpile;
- securing warheads, components, and materials while at NNSA facilities;
- accounting for individual warheads in NNSA custody;
- participating in the joint nuclear weapons decision process;
- receiving and dismantling retired warheads; and
- disposing of components and materials from retired warheads.


MKI "Little Boy"
MKIII "Fat Man"
TX-16 Bomb
MK8 Bomb
MK11 Bomb
TX/MK14 Bomb
W9
Artillery Shell
MK12 Bomb
MK6 Bomb
MK15 Bomb
W25 Warhead
EXPLOSIVE
W23
Artillery Shell
MK27 Bomb


MK41 Bomb
W84 Warhead
84
ROUND LAUNCHED
W80 Warhead
W71 Warhead
W87 Warhead
B83 Bomb
W30 Warhead
W76 Warhead
W89 Warhead
W79
Artillery Shell
W28 Warhead
W88 Warhead
W62 Warhead
W78 Warhead


LANL


PANTEX


LLNL


SRS


SNL


Y-12


DISPLZ
4.000e-01
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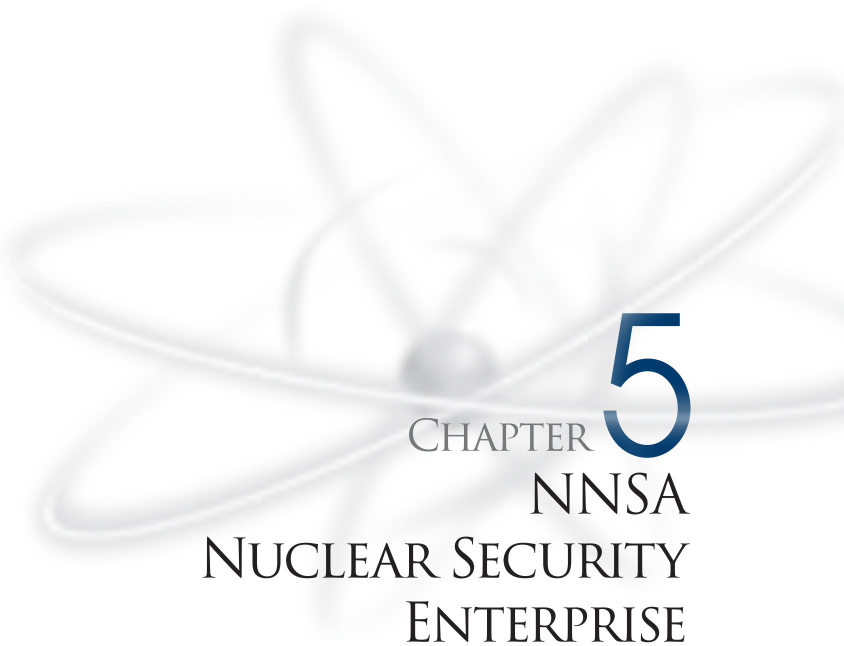
KCNSC


NNSS



CHAPTER 5

NNSA NUCLEAR SECURITY ENTERPRISE

OVERVIEW

The National Nuclear Security Administration (NNSA) is responsible for ensuring U.S. nuclear weapons meet mission requirements and remain safe, secure, and effective. NNSA maintains the nuclear stockpile through the application of science, technology, engineering, and manufacturing exercised throughout the nuclear weapons complex. Additionally, NNSA is responsible for detecting and preventing the proliferation of weapons of mass destruction (WMD), securing nuclear and radiological materials, providing the Navy with fuel for safe and effective nuclear propulsion, and providing the United States with state-of-the-art nuclear counterterrorism and emergency response capabilities.

To ensure U.S. nuclear weapons capabilities meet mission requirements, new capacity demands require reinstating production of components and materials within the NNSA nuclear security enterprise (NSE). Specifically, the United States plans to restore a plutonium pit production capability, increase tritium production, restart lithium processing capabilities, and reestablish several uranium production capabilities (to include developing a domestic uranium enrichment capability).

NNSA Nuclear Security Enterprise

To provide the research, development, production, dismantlement, and surveillance capabilities necessary to support the nuclear weapons stockpile, NNSA manages a complex of manufacturing, laboratory, and testing facilities.[1] The NSE (Figure 5.1) spans eight sites with headquarters elements in Washington, D.C., including:

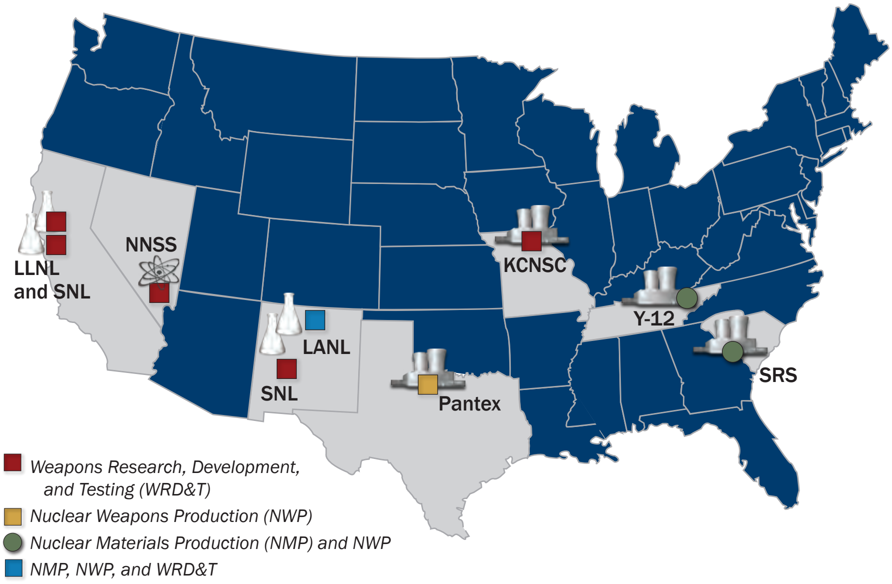


Figure 5.1 NNSA Nuclear Security Enterprise

- **National Security Laboratories:** Los Alamos National Laboratory in Los Alamos, New Mexico; Lawrence Livermore National Laboratory in Livermore, California; and Sandia National Laboratories in both Albuquerque, New Mexico, and Livermore, California.
- **Manufacturing Sites:** Kansas City National Security Campus in Kansas City, Missouri; Pantex Plant in Amarillo, Texas; Savannah River Site in Aiken, South Carolina; and Y-12 National Security Complex in Oak Ridge, Tennessee.
- **Test Site:** Nevada National Security Site in Nye County, Nevada.

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[1] There are several facilities that were once part of the NSE and have since been transitioned away from nuclear weapons-related activities. Among the largest of these were the Rocky Flats Plant in Colorado, the Mound Site in Ohio, the Pinellas Plant in Florida, and the Hanford Site in Washington.

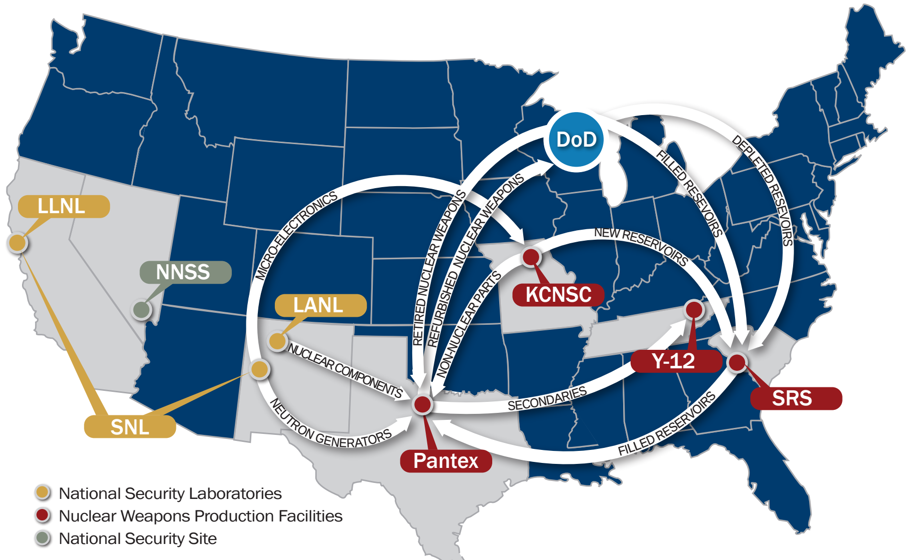

Figure derived from NNSA 2020 SSMP

Figure 5.2 NNSA Nuclear Weapon Product Flow

Each laboratory, plant, and site within the NSE provides a critical contribution to ensure the safety, security, and effectiveness of the U.S. nuclear deterrent. These sites work interdependently to deliver the end result—certified nuclear weapons. Figure 5.2 depicts the continuous nuclear and non-nuclear component production transactions among the NSE locations.

Figure 5.3 describes the contribution of the NSE sites to the key strategic components/materials necessary for weapons performance.

Strategic Material	Site
Plutonium Pits	**LANL, SRS (future capability)**
Plutonium is a radioactive chemical element with fissile isotopes that can sustain a nuclear chain reaction necessary for nuclear weapons. Processing and handling plutonium is essential to assess and maintain nuclear weapons and requires proper storage facilities, safe and secure disposal pathways, and unique equipment and facilities for R&D activities. The largest portion of the U.S. weapons-usable plutonium inventory is in the form of retired pits. NNSA is currently pursuing a two-site strategy to meet the military requirement of producing at least 80 pits per year by 2030.	
Uranium	**Y-12**
Uranium is a chemical element used in fission weapons and processes and can include low-enriched uranium (LEU), high-assay LEU, and highly enriched uranium (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.	

Strategic Material	Site
Lithium	**Y-12**
Lithium is a soft, silver-white metal used as a target element in nuclear weapons. Lithium reacts with a neutron to produce tritium.	
Tritium	**SRS**
Tritium is a beta-emitting radioactive isotope of hydrogen. It is used to enhance the efficiency and yield of nuclear weapons in a process known as "boosting." Tritium enables weapons to meet system military characteristics, increase system margins, and ensure weapon system reliability.	
Radiation-Hardened (Rad-Hard) Microelectronics	**SNL**
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 functions to meet current program requirements, and supports R&D in the nuclear weapons realm.	
Energetic Materials	**Pantex**
Energetic materials are materials with high amounts of stored chemical energy that can be released. Energetic materials are required for a nuclear weapon to detonate as designed—e.g., high explosives, pyrotechnics, and propellants.	

Figure 5.3 NSE Contributions to Key Strategic Components and Materials

The NSE sites are government owned but managed by a mix of management and operating (M&O) and federally funded research and development centers (FFRDC). This status indicates that the facility is managed and operated through a contract between NNSA and a contractor or contractor team selected by NNSA.

Los Alamos National Laboratory

Established in 1943 as part of the Manhattan Project, Los Alamos National Laboratory (LANL) is a nuclear weapon design laboratory responsible for providing research, development, and manufacturing guidance authority for nuclear explosive packages and other nuclear weapon components. LANL, as part of the annual stockpile assessment process, has responsibilities to ensure the performance, safety, and reliability of nuclear warheads; support surveillance, assessments, refurbishments, and future production of stockpile weapons; and provide unique capabilities in high-performance scientific computing, dynamic and energetic materials science, neutron scattering, enhanced surveillance, radiography, plutonium science and engineering, actinide chemistry, and beryllium technology. LANL is the associated physics laboratory and design agency for the W76-0/1/2, W78, and W88 warheads and B61 family of gravity bombs. LANL operates unique facilities that support both NNSA stockpile and non-stockpile missions, including the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility (X-ray imaging for non-nuclear testing), the Los Alamos Neutron Science Center (LANSCE) (hydrodynamics, weapons nuclear science, and materials science), and TA-55 (plutonium science and manufacturing). LANL is on track to produce at least 30 plutonium pits a year by 2030 at its plutonium fabrication facility at PF4.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL), established in 1952, is a nuclear weapon design laboratory responsible for providing research, development, and manufacturing guidance authority for nuclear explosive packages and other nuclear weapon components. The laboratory, as part of the annual stockpile assessment process, has responsibilities to ensure the performance, safety, and reliability of nuclear warheads; support surveillance, assessments, refurbishments, and future production of stockpile weapons; and possess and employ important stewardship capabilities that include high-energy-density physics and unique performance scientific computing assets. For today's stockpile, LLNL is the physics laboratory and design agency for the B83-1, W80-1/4, and W87-0/1 warheads. LLNL will be the physics laboratory and design agency for the W87-1, which is the replacement warhead for the W78. The W87-1 will be the first warhead in 30+ years to utilize newly manufactured plutonium pits. LLNL operates facilities that support both NNSA stockpile and non-stockpile missions, including the High Explosives Application Facility (HEAF) (study of chemical high explosives), Site 300 Experimental Test Site (assessment of nonnuclear components through hydrodynamic testing using high explosives), and the National Ignition Facility (NIF) (high-energy-density weapons physics and fusion ignition research).

Sandia National Laboratories

Established as Sandia Laboratory in 1948, Sandia National Laboratories (SNL), the engineering arm of the U.S. nuclear weapons enterprise, is responsible for non-nuclear components of U.S. nuclear weapons. It designs, develops, qualifies, tests, certifies, and serves as the system integrator of all components required to safe, arm, fuze, and fire a weapon to military specifications. Sandia's mission encompasses production agency responsibilities for weapon components, including neutron generators and trusted radiation-hardened integrated circuits. Like LANL and LLNL, Sandia plays an important role in providing annual safety, security, and reliability assessments in the annual stockpile assessment process. Sandia's mission-essential facilities include specialized test facilities and manufacturing space for microelectronics, neutron generators, and unique power sources. Scientific facilities include reactors, pulsed-power devices, material characterization, and computational modeling and simulation capabilities housed in specialized facilities that provide an unprecedented understanding of nuclear weapons performance, safety, and security without underground nuclear explosive testing.

Figure 5.4 provides an overview of the nuclear weapons stockpile and the specific physics laboratory associated with each weapon type (with SNL as the engineering laboratory for each).

Kansas City National Security Campus

In 1949, Kansas City was selected by the Atomic Energy Commission (AEC) to produce certain components for the nuclear weapons program. Today, Kansas City National Security Campus (KCNSC) is responsible for the procurement and manufacturing of non-nuclear components for nuclear weapons such as radar systems, mechanisms, programmers, reservoirs, joint test assemblies, engineered materials, and mechanical components. KCNSC is also responsible for evaluating and testing non-nuclear weapons components.

Specific mission areas of KCNSC include:

- additive manufacturing;
- analytical chemistries;
- training equipment/tools used by the military;
- design/development/manufacture of production and surveillance testers;
- surety activities (Nuclear Enterprise Assurance, Production Security Verification, Human Reliability Program, etc.); and
- generic production and fabrication capabilities (circuit boards, precision machining, minature mechanisms, plastics, polymers, cables, electromechanical assemblies, etc.).

Pantex Plant

In 1951, the Pantex Plant (PX) was established to focus on high explosive and non-nuclear component assembly operations. Today, PX is charged with supporting three key missions: stockpile stewardship, nonproliferation, and safeguards and security. In support of the stockpile stewardship mission, Pantex is responsible for the evaluation, retrofit, and repair of weapons, and weapon safety certification and reliability

WARHEADS
(Strategic Ballistic Missile Platforms)

Type: W78 ***(Lab: LANL/SNL)***
Description: Reentry vehice warhead
Delivery System: MMIII ICBM
Mission: Surface-to-Surface
Military Dept: USAF

Type: W87***(Lab: LLNL/SNL)***
Description: Reentry vehice warhead
Delivery System: MMIII ICBM
Mission: Surface-to-Surface
Military Dept: USAF

Type: W76-0/1/2 ***(Lab: LANL/SNL)***
Description: Reentry body warhead
Delivery System: Trident II D5 SLBM
Mission: Underwater-to-Surface
Military Dept: USN

Type: W88 ***(Lab: LANL/SNL)***
Description: Reentry body warhead
Delivery System: Trident II D5 SLBM
Mission: Underwater to Surface
Military Dept: USN

BOMBS
(Aircraft Platforms)

Type: B61-3/4 ***(Lab: LANL/SNL)***
Description: Non-strategic bomb
Delivery System: F-15-E, F-16, certified NATO aircraft
Mission: Air-to-Surface
Military Dept: USAF/Select NATO forces

Type: B61-7 ***(Lab: LANL/SNL)***
Description: Strategic bomb
Delivery System: B-52 and B-2
Mission: Air-to-Surface
Military Dept: USAF

Type: B61-11 ***(Lab: LANL/SNL)***
Description: Strategic bomb
Delivery System: B-2
Mission: Air-to-Surface
Military Dept: USAF

Type: B83-1 ***(Lab: LLNL/SNL)***
Description: Strategic bomb
Delivery System: B-52 and B-2
Mission: Air-to-Surface
Military Dept: USAF

WARHEADS (Cruise Missile Delivery Vehicle)

Type: W80-1 ***(Lab: LLNL/SNL)***
Description: Air-launched cruise missile strategic weapon
Delivery System: B-52 bomber
Mission: Air-to-Surface **Military Dept:** USAF

Figure derived from NNSA 2020 SSMP

Figure 5.4 NSE Responsible Laboratories for the Current Nuclear Stockpile

assessments. Pantex is also responsible for the development, testing, and fabrication of high explosive components. In support of the nonproliferation mission, PX is responsible for dismantling surplus strategic stockpile weapons, providing interim storage and surveillance of plutonium pits, and sanitizing dismantled weapons components. In support of the safeguards and security mission, Pantex is responsible for the protection of plant personnel, facilities, materials, and information.

Nuclear Knowledge for the Nation
enterprise·srs

SAVANNAH RIVER SITE

The Savannah River Site (SRS) was established in the 1950 and is primarily responsible for the management of tritium inventories and facilities. As part of this responsibility, SRS personnel load tritium and non-tritium reservoirs to meet U.S. requirements. SRS is also responsible for the conduct of tritium reservoir surveillance operations, the testing of tritium gas transfer systems, and research and development on tritium operations.

In addition to its tritium-related responsibilities, SRS will be responsible (together with LANL) for the production of plutonium pits after the new Savannah River Plutonium Processing Facility is completed. SRS will plan to produce a minimum of 50 plutonium pits per year while LANL will plan to produce at least 30, meeting the minimum national requirement for at least 80 pits per year by 2030.

Y-12 National Security Complex

In 1943, Y-12 was established to produce enriched uranium. Today, the Y-12 mission is the production or refurbishment of complex nuclear weapon components and secondaries; the receipt, storage, and protection of special nuclear material; and the dismantlement of weapon secondaries and disposition of weapon components. Y-12 is in the process of constructing a Uranium Processing Facility (UPF), which is intended to replace and consolidate approximately 800,000 square feet of existing uranium facilities that are decades old and do not meet modern safety standards. Y-12 also plans to build a new lithium production facility to replace its current Manhattan Project-era facilities.

Nevada National Security Site

In 1950, the AEC designated a portion of the Las Vegas Bombing Range as a nuclear test site responsible for nuclear explosive and effects tests. The 1992 moratorium on U.S. underground nuclear explosive testing and the September 11th attacks were significant events which reshaped the mission of the NNSS (formerly the Nevada Test Site). Today, employees across six government agencies, eleven prime contractors, and three national security laboratories work daily at the NNSS to ensure the security of the U.S. nuclear weapons stockpile with high-tech experimentation and training. The NNSS also provides nuclear and radiological emergency response training and capabilities, support to national security customers, and expertise for non-proliferation and arms control initiatives.

FUTURE ENTERPRISE INFRASTRUCTURE ENHANCEMENTS

Modernization of existing infrastructure and construction of new facilities are underway within the NNSA enterprise. These infrastructure modernization projects will ensure key capabilities, such as uranium enrichment, sufficient plutonium pit production, lithium processing, and tritium processing, are established and remain reliable for the nuclear stockpile of the future. A list of construction projects is listed in Figure 5.5. Figure 5.6 is a list of recapitalization/facility enhancements.

Location/Facility	Description/Completion
LANL: Chemistry and Metallurgy Research Building Replacement (CMRR)	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. [Completion: FY2022]
Y-12: Uranium Processing Facility (UPF)	The UPF project ensures the long-term viability, safety, and security of the NNSA enriched uranium capability. It supports the capability to manufacture weapon sub-assemblies containing enriched uranium components and convert excess enriched uranium into forms suitable for safe, long-term storage and reuse. The new facility replaces the Y-12 enriched uranium processing operations, currently housed in numerous aging, inefficient buildings in poor condition that pose multiple risks to meeting the mission. [Completion: FY2026]
Y-12: Lithium Processing Facility (LPF)	The LPF project replaces lithium component manufacturing capabilities currently located in a 75-plus-year-old building with 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, and other agencies within and beyond DOE. [Completion: FY2027]
SRS: Tritium Finishing Facility (TFF)	The TFF 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 will reduce operational risk and increase facility reliability compared to continuing operation in the current facility for an additional 20 years. [Completion: FY2031]

Location/Facility	Description/Completion
SRS: Savannah River Plutonium Processing Facility (SRPPF)	The SRPPF was formerly designated to be the Mixed Oxide Fuel Fabrication Facility will instead be home to a facility capable of producing at least 50 war reserve plutonium pits per year by 2030. This is part of the NNSA “two-site solution” for pit production. [Completion: FY2027]
Y-12: Domestic Uranium Enrichment (DUE)	The U.S. government currently has no uranium enrichment capability. NNSA is conducting an analysis of alternatives (AoA) for a domestic uranium enrichment capability. In October 2018, NNSA initiated another campaign to downblend excess HEU from its stockpiles to provide unobligated and unencumbered LEU fuel in support of its tritium production mission. This campaign extends the need date for delivery of unobligated and unencumbered LEU fuel for tritium production out until 2041. [Completion: FY2041]
Multiple: Power Sources Capability	Modern infrastructure is required to meet the long-term, full life-cycle requirements for power source capabilities. NNSA has initiated a project to determine mission needs and analyze alternatives to ensure capabilities are sustained. [Completion: FY2030]
Pantex: High Explosives Synthesis, Formulation, and Production Facility	This facility will consolidate limited legacy facilities that are inadequate for the mission 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. [Completion: FY2029]
Y-12: Consolidated Depleted Uranium Manufacturing Capability (CDMC)	NNSA is currently exhausting usable inventories of high-purity depleted uranium metal feedstock used for weapons production. NNSA is planning to reestablish the capability to convert DUF6 to DUF4 at the Portsmouth site in Ohio. Reestablishment efforts will begin in FY2019. [Completion: FY2045]

Figure 5.5 Construction Projects
(derived from NNSA 2020 SSMP)

Location/ Facility	Description/Completion
LANL: Los Alamos Plutonium Pit Production Project (LAP4)	The LANL Plutonium Facility (PF-4) will be recapitalized to produce no fewer than 30 plutonium pits per year by 2026. This is part of the NNSA “two-site solution” for pit production. [Completion: FY2027]
LANL: TA-55 Reinvestment Project Phase 3	The TA-55 project will support design and construction of 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. [Completion: FY2022]

Location/ Facility	Description/Completion
SNL: Neutron Generator Enterprise Consolidation (NGE+)	Neutron generators must meet the highest levels of reliability and survivability and be periodically replaced. In 1995, SNL was designated the production agency for neutron generators and 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 increases 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 improve workflow and efficiency, enabling 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. [Completion: FY2038]
Pantex: Weapon System Assembly and Disassembly Cell Upgrade	This assembly/disassembly cell upgraded project would provide additional production cell capacity to support the forecasted increase in weapon workload and 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. [Completion: FY2042]

Figure 5.6 Recapitalization/Facility Enhancements
(derived from NNSA 2020 SSMP)

Nuclear Weapons Council

Department of Defense

DIRECTIVE

NUMBER 315

August 26, 200

Certified Current as of March 8, 2004

ATSD(NCB)

SUBJECT: Joint DoD-DOE Nuclear Weapon Life-Cycle Activities

References: (a) DoD Directive 3150.1, "Joint Nuclear Weapons Development Studies and Engineering Projects," December 27, 1983 (hereby canceled)
(b) "An Agreement Between the AEC and the DoD for the Development, Production, and Standardization of Atomic Weapons," March 21, 195 as supplemented through 1984[1]
(c) "Nuclear Weapons Council Procedural Guideline for the Phase 6.X Process," April 19, 2000[2]
(d) DoD Instruction 5030.55, "Joint AEC-DoD Nuclear Weapons Development Procedures," January 25, 2001
(e) through (j), see enclosure 1

1. REISSUANCE AND PURPOSE

This Directive:

1.1. Reissues, updates and expands the scope of reference (a) to prescribe policies, responsibilities, and procedures for all joint Department of Defense (DoD) Department of Energy (DOE) nuclear weapon life-cycle activities, consistent with the spirit of reference and with refurbishment guidelines issued by the Nuclear Weapons Council (reference

1.2. Continues to authorize publication of reference (d).

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available from the Deputy Assistant to the Secretary of Defense for Nuclear Matters, Room Pentagon.

available from the Deputy Assistant to the Secretary of Defense for Nuclear Matters, Room Pentagon.

Chapter 6

Nuclear Weapons Council

Overview

The Nuclear Weapons Council (NWC) is the focal point for interagency activities to sustain and modernize the U.S. nuclear deterrent. The Council endorses military requirements, approves trade-offs, and ensures alignment between DoD delivery systems and National Nuclear Security Administration (NNSA) weapons. The NWC is charged with cradle-to-grave management of the existing nuclear weapons stockpile and for planning for the future nuclear deterrent. The NWC develops and promulgates a number of important policy documents and provides significant information on nuclear weapons safety, security, and effectiveness to the President and Congress.

The NWC provides policy guidance and oversight of the nuclear weapons stockpile management process to ensure high confidence in the safety, security, reliability, and performance of U.S. nuclear weapons. The Council meets regularly to discuss status, paths forward, and resolve issues between DoD and NNSA regarding strategies for stockpile sustainment and modernization.

Background

Following World War II, Congress wanted to ensure civilian control over the uses of nuclear energy. Consequently, the *Atomic Energy Act of 1946* created the Atomic Energy Commission (AEC), which evolved into what is now NNSA.

MILITARY LIAISON COMMITTEE

The Atomic Energy Act also established the Military Liaison Committee (MLC), the predecessor of the NWC. The MLC was created to coordinate nuclear defense activities between the War and Navy Departments (hereafter referred to as DoD, the present day organization) and the AEC (hereafter referred to as the Department of Energy (DOE), the present day organization).

The MLC was an executive- or flag-level military organization that served as the authorized channel of communication between DoD and DOE on all atomic energy matters related to the military application of atomic weapons or atomic energy, as determined by DoD. The MLC addressed substantive matters involving policy, programming, and the commitment of significant funds associated with the military application of atomic energy. The MLC formulated the official DoD position on all matters related to joint nuclear weapons issues for transmittal to DOE.

The MLC was composed of seven members and three official observers. The Assistant to the Secretary of Defense for Atomic Energy (ATSD(AE)) served as MLC chairman and members included two flag-level representatives from each of the three Military Departments. The MLC was the DoD forum for the coordination of policy and the development of unified DoD positions on nuclear weapons-related issues. The DOE, Joint Staff (JS), and Defense Nuclear Agency (DNA) participated as observers. An action officers (AO) group, which was composed of AOs representing each of the seven members and each of the three official observers, supported the MLC. Other organizations with a direct interest in nuclear weapons, such as the national security laboratories, frequently participated in AO-level meetings and discussions.

In the early 1980s, some members of Congress expressed concern about the high cost of funding the U.S. nuclear weapons program. In 1984, a majority of the Senate Armed Services Committee members proposed the transfer of funding responsibility for DOE nuclear weapons activities from DOE to DoD. Under this proposal, DOE would then execute its nuclear weapons-related activities using funds provided by DoD. The goal was to encourage DoD nuclear weapons system acquisition decisions to account for total costs.

Other senators, who endorsed the proposal's general purpose, expressed reservations about the proposed transfer of funding responsibility and argued the transfer might undermine the principle of civilian control over nuclear weapons research and development. Although opposed to the proposed transfer, the Secretaries of Defense and Energy supported a study of the issue. As a result of these developments, the *National Defense Authorization Act (NDAA) for Fiscal*

Year 1985, Public Law (Pub. L.) 98-525, directed the President to establish a Blue Ribbon Task Group to examine the issue.

BLUE RIBBON TASK GROUP ON NUCLEAR WEAPONS PROGRAM MANAGEMENT

On January 18, 1985, President Ronald Reagan established the *Blue Ribbon Task Group on Nuclear Weapons Program Management* to examine the procedures used by DoD and DOE to establish requirements and provide resources for the research, development, testing, production, surveillance, and retirement of nuclear weapons. The task group issued its final report in July 1985. While the task group found the relationship between DoD and DOE regarding the management of the nuclear weapons program to be generally sound, it also identified areas for improvement. Specifically, the task group suggested introducing administrative and procedural changes to enhance interdepartmental cooperation and achieve potential cost savings. These changes were intended to result in closer integration between nuclear weapons programs and national security planning without sacrificing the healthy autonomy of the two Departments in the performance of their respective nuclear weapons missions.

The task group noted the absence of a high-level, joint DoD-DOE body charged with coordinating nuclear weapons program activities. The MLC had no such mandate. The original purpose of the MLC was to provide a voice for the military in the atomic energy program, which was controlled by the then-powerful AEC. By the time of this task group, the AEC had evolved into DOE, and the original purpose of the MLC had become obsolete.

The MLC was an intra-agency DoD group, not an interagency organization. Also, the staff and stature of the MLC had diminished to a point at which it could no longer effectively analyze nuclear weapons cost trade-offs, establish program priorities, or address budget and resource allocation issues. Consequently, the task group recommended forming a senior-level, joint DoD-DOE group to coordinate nuclear weapons acquisition issues and related matters and oversee joint nuclear activities. The task group suggested the new group be named the *Nuclear Weapons Council*.

The task group recommended certain responsibilities for this new organization pertaining to U.S. nuclear weapons which included:

- preparing the annual Nuclear Weapons Stockpile Memorandum (NWSM);
- developing stockpile options and their costs;
- coordinating programming and budget matters;

- identifying cost-effective production schedules;
- considering safety, security, and control issues; and
- monitoring the activities of the Project Officers Groups (POGs)[1] to ensure attention to cost as well as performance and scheduling issues.

The task group believed a dedicated staff drawn from both Departments and reporting to a full-time staff director was necessary to fulfill these new responsibilities. The task group also argued that, regardless of how the MLC was altered, it was important for the Secretary of Defense to maintain a high-level office within DoD dedicated primarily to nuclear weapons matters. This office was the ATSD(AE) until 1996 and has since transitioned to the multi-mission office of the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs (ASD(NCB)). The successor position to the ATSD(AE) is the Deputy Assistant Secretary of Defense for Nuclear Matters (DASD(NM)).

Nuclear Weapons Council Today

Acting on the recommendations of President Reagan's Blue Ribbon Task Group, Congress established the NWC in the FY1987 NDAA (Pub. L. 99-661). A letter signed by Secretary of Defense Caspar Weinberger formalized the establishment of the NWC.

Congress established the NWC as a means of enhancing coordination between DoD and DOE with respect to nuclear weapons production. The NWC was created when the U.S. plans for continued nuclear weapons production were indefinite and the U.S. production capability was relatively robust. Congress was concerned about the expense of the U.S. nuclear weapons program and wanted to realize possible cost savings without jeopardizing the safety, security, or reliability of the stockpile.

Shortly after the establishment of the NWC, the Soviet Union ceased to exist, the Cold War ended, and the United States terminated nuclear weapons production and explosive testing. Since the inception of the NWC, the United States has neither produced new weapons with newly manufactured components, nor has it designed weapons that are not based on Cold War legacy warheads. Part of the challenge of moving into the current nuclear era is determining the processes and procedures by which new weapons programs will be initiated, developed, and prioritized.

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[1] The POGs are joint DoD-NNSA groups associated with each warhead-type. POGs are created at the beginning of a weapon development program and charged with the responsibility to coordinate the development and ensure the compatibility of a warhead-type with its designated delivery system(s). The POG remains active throughout the lifetime of the nuclear warhead-type.

NWC ORGANIZATION AND MEMBERS

The *National Defense Authorization Act for Fiscal Year 2017* reorganized the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(ATL)). This resulted in six voting members of the NWC instead of the original five as illustrated in Figure 6.1: Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)); Vice Chairman of the Joint Chiefs of Staff (VCJCS); Under Secretary for Nuclear Security of the DOE and NNSA Administrator; Under Secretary of Defense for Policy (USD(P)); Under Secretary for Research and Engineering (USD(R&E)), and Commander, U.S. Strategic Command (CDRUSSTRATCOM). The law also directs DoD and NNSA to provide personnel to serve as the NWC staff. The ASD(NCB) is designated as the NWC Staff Director.

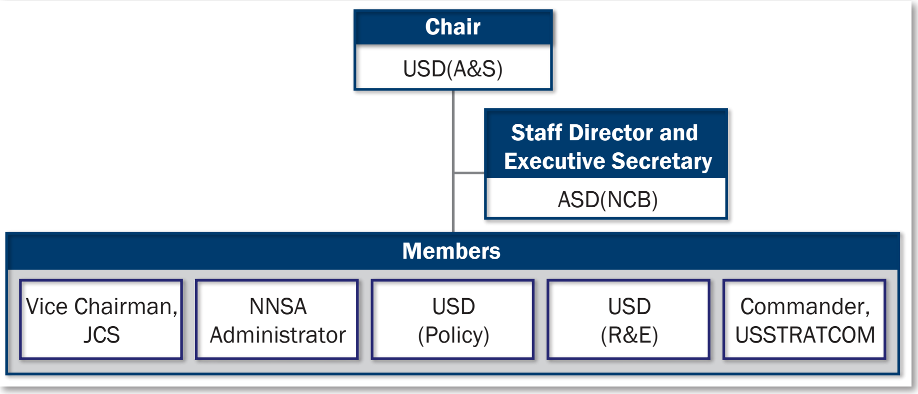


Figure 6.1 NWC Membership

NWC RESPONSIBILITIES AND ACTIVITIES

Title 10 USC §179 gives the NWC specific responsibilities, including evaluating, maintaining, and ensuring the safety, security, and control of the nuclear weapons stockpile as well as developing nuclear weapons stockpile options. Pub. L. 112-239 amended the NWC responsibilities to include an annual certification of the sufficiency of the NNSA budget request to meet the NWC stockpile requirements. The NWC is responsible for a number of annual and biennial reports that garner senior-level attention on important nuclear weapons matters. In addition, through the annual authorization and appropriations processes, Congress typically requires multiple, one-time reports on issues of current congressional interest. The NWC is required to report regularly to the President regarding the safety and reliability of the U.S. stockpile and to provide an annual recommendation on the need to resume underground nuclear explosive testing to preserve the credibility of the U.S. nuclear deterrent. Presidential direction, congressional legislation, and agreements between the Secretaries of Defense and Energy create additional requirements for the NWC. Many of these are coordinated at the subordinate level and then finalized and approved by the NWC.

NWC activities to support its statutory responsibilities were refined in a 1997 joint DoD-DOE memorandum of agreement (MOA) and updated in 2017. These activities include:

- establishing subordinate committees to coordinate senior-level staff support to the NWC and perform such duties as the NWC may assign within the limits of the NWC responsibilities;
- providing guidance to these support committees as well as reviewing and acting on recommendations from the committees relating to the nuclear weapons stockpile;
- providing a senior-level focal point for joint DoD-NNSA consideration of nuclear weapons safety, security, and control;
- authorizing analyses and studies of issues affecting the nuclear weapons stockpile;
- reviewing, approving, and providing recommendations on these analyses and studies to the appropriate authorities within DoD and NNSA;
- receiving information and recommendations from advisory committees on nuclear weapons issues and recommending appropriate actions to DoD and NNSA;
- providing broad guidance to DoD and NNSA on nuclear weapons matters regarding the life cycle of U.S. nuclear weapons;
- reviewing other nuclear weapons program matters as jointly directed by the Secretaries of Defense and Energy; and
- fulfilling annual and other reporting requirements as provided in Title 10 USC §179 and other legislation.

NWC PROCESSES AND PROCEDURES

The statute establishing the NWC did not specify any associated procedures or processes for fulfilling the mandates of the law. As a result, the NWC administrative procedures continue to evolve. These procedures ensure the information and data necessary to make informed decisions and recommendations concerning the nuclear deterrent reach the members of the NWC efficiently and effectively. To achieve this, the NWC has delegated certain responsibilities and authorities to its subordinate organizations. The NWC usually makes decisions or provides final approval only after thorough review and coordination at the subordinate levels. This assures all views are sufficiently considered and reflected.

NWC review and/or approval is usually achieved through an established coordination process in which Principals' positions and views are recorded. The flexibility of NWC administrative processes allows for the chairman and members to determine how they wish to document decisions on a case-by-case basis, which may be time- or situation-driven. This may be a combination of voice vote, memoranda for the record, or documentation in the NWC meeting minutes.

The NWC works to achieve consensus among Principals before it issues official decisions or recommendations, although this is not always possible. Documents reflecting NWC findings and decisions, including NWC reports, memoranda, and letters, are fully coordinated.

NWC administrative processes and procedures are designed to ensure consideration of all relevant factors in making decisions and recommendations. The NWC receives information and data from a variety of sources, including: the POGs associated with each warhead-type in the stockpile; advisory groups; subject matter experts from DoD, NNSA, and the national security laboratories; and programmatic specialists from various government offices. Information and data are communicated to the NWC and its subordinate bodies through correspondence, memoranda, reports, and briefings.

Generally, when a decision is required, representatives from the appropriate organizations brief the NWC (and/or its subordinate groups) to provide an opportunity for members, advisors, and observers to solicit additional information as required for clarity or completeness.

NWC SUBORDINATE ORGANIZATIONS

The NWC conducts day-to-day operations and coordinates issues through its subordinate organizations. NWC subordinate organizations are not codified in Title 10 USC §179. This affords the NWC the necessary flexibility to create, merge, or abolish organizations as needed.

The Nuclear Weapons Council Standing Committee (NWCSC), commonly called the "Standing Committee," and the Nuclear Weapons Council Weapons Safety Committee (NWCWSC), known as the "Safety Committee," were two committees established shortly after the creation of the NWC. The Standing Committee was established in 1987 and served as a joint DoD-DOE senior executive or flag-level committee. The Standing Committee performed the routine activities of the NWC, including coordinating all actions going to the

NWC as well as providing advice and assistance to the NWC. Established in 1989, the Safety Committee was a joint DoD-DOE senior executive or flag-level committee dedicated to nuclear weapons safety issues. The Safety Committee provided advice and assistance to the NWC staff director, the NWCSC, and to the NWC concerning nuclear weapons safety.

In 1994, the Standing and Safety Committees were combined to form the Nuclear Weapons Council Standing and Safety Committee (NWCSSC). Currently, an AO group and a staff team support the NWC and its subordinate bodies.

In 1996, the chairman of the NWC established an additional organization, subordinate to the NWCSSC, called the Nuclear Weapons Requirements Working Group (NWRWG). The NWRWG was created to review and prioritize high-level nuclear weapons requirements and define them more precisely, as necessary. While it was active, several NWRWG functions duplicated those of the NWCSSC. Also, both DoD and DOE developed nuclear weapons requirements processes within their own Departments. For these reasons, the NWRWG members decided to abolish the group and to transfer all NWRWG responsibilities to the NWCSSC in November 2000. The NWC never ratified the decision to disband the NWRWG but the NWRWG has not met since that time.

Also in November 2000, the Compartmented Advisory Committee (CAC) was formed as an additional subordinate body to the NWC, one tier below the NWCSSC. While it was active, the CAC provided information and recommendations to the NWC concerning technical requirements for nuclear weapons surety upgrades. In 2005, the Transformation Coordinating Committee (TCC) was created by the NWC to coordinate the development and execution of a joint strategy for the transformation of the NNSA Nuclear Security Enterprise. Neither the CAC nor the TCC are currently active. New committees are created and disbanded, as needed, by the NWC to respond to issues of the day. Figure 6.2 provides a timeline of their establishment.

NWC STANDING AND SAFETY COMMITTEE

The primary mission of the NWCSSC is to advise and assist the NWC and to provide preliminary approval for many NWC decisions. The NWCSSC conducts transactions between DoD and NNSA on behalf of the NWC.

The NWC uses the NWCSSC to develop, coordinate, and approve most actions before NWC review and final approval, including the annual NWC reports to the President and Congress.

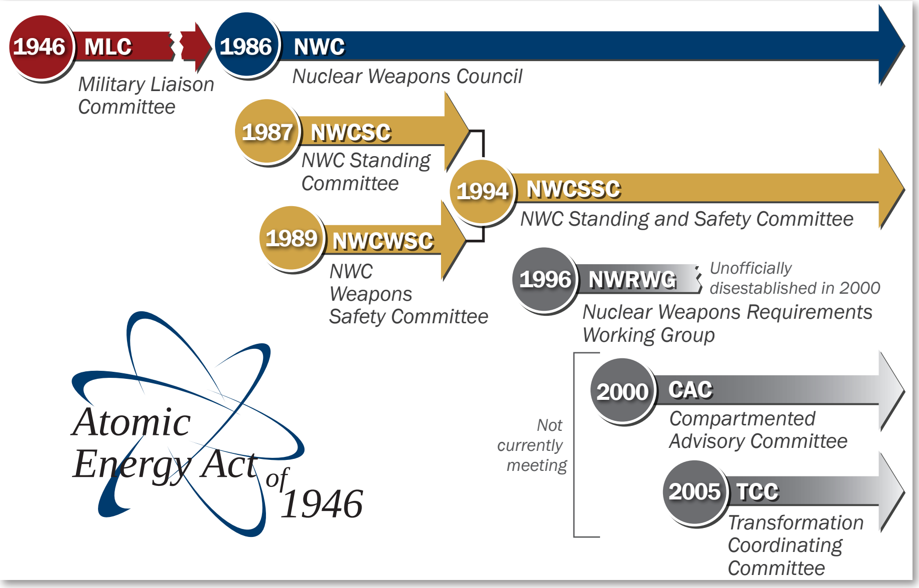


Figure 6.2 Overview of the Establishment of the NWC and Subordinate Bodies

The NWCSSC also actively participates in POG oversight activities. For example, the POGs regularly report to the NWCSSC and seek approval for specific weapons program activities. The NWCSSC can authorize the establishment of POG study groups for activities including NWC-directed studies or reviews, review of Military Department-approved POG charters, and review of POG study proposals and reports.

In addition to its responsibilities relating to POG oversight, the NWCSSC reviews proposed and ongoing life extension programs for existing weapon systems and development and production activities for new systems. As recommended by the POGs, the NWCSSC reviews and provides preliminary approval for the military characteristics (MCs) and stockpile-to-target sequence (STS) for major modifications of existing weapons and for new systems. The NWCSSC is informed on a wide variety of issues related to the nuclear weapons stockpile and associated delivery systems through informational briefings and other channels of communication. Figure 6.3 depicts the summary of NWCSSC responsibilities.

NWC Action Officers Group

The NWCSSC is supported by an AO group, which operates in an open and informal meeting environment to discuss issues, receive pre-briefings in

SUMMARY OF NWCSSC RESPONSIBILITIES

Approve nuclear weapons stockpile quantity adjustments within the authority delegated by the President and NWC.

Review the stockpile, when required, and provide recommended stockpile improvements to the NWC for its endorsement.

Authorize the establishment of POGs for NWC-directed studies or reviews, review Military Department-approved POG charters, provide tasking and guidance to the POGs, review POG study plans and reports, and resolve outstanding issues.

Review and approve the original and/or amended MCs proposed by the Military Departments through their respective POGs. (Safety-related MCs must be approved by the Secretaries of Defense and Energy.)

Review the STS requirements for each nuclear warhead-type and consider proposed changes to the STS that may have a significant impact on cost or weapons performance.

Advise the NWC on weapons safety design criteria, safety standards and processes, safety rules, and the safety aspects of MCs and STSs as well as weapons transportation, storage, and handling.

Review information from the DoD and NNSA on nuclear weapons-related issues under the NWC purview.

Review the status and results of nuclear weapons safety studies performed either by the Military Departments or jointly by the DoD and NNSA.

Request weapon program status information from the DoD and NNSA.

Conduct studies, reviews, and other activities as directed by the NWC, one of its members, or as required by a Joint Memorandum of Understanding (MOU) between the Departments.

Coordinate or take action on other matters, as appropriate.

Figure 6.3 Summary of NWCSSC Responsibilities preparation for NWCSSC or NWC meetings, and coordinate actions for consideration by their Principals at the NWCSSC and NWC levels.

The responsibilities of the AO group have been established through practice as well as direction from the NWC and NWCSSC Principals. The AO group is responsible for reviewing issues, ensuring consistent progress, facilitating information dissemination, and preparing their NWC and NWCSSC Principals. AOs are responsible for keeping their Principals fully informed regarding all NWC-related activities and preparing their Principals for NWC, NWCSSC, or related meetings.

NWC Staff

The NWC staff provides technical, analytical, and administrative support to the NWC and its subordinate organizations. As codified in the 1997 NWC MOA signed by the Secretaries of Defense and Energy, both DoD and NNSA assign personnel to provide necessary support services to the entire NWC organization.

The NWC staff is located within the ODASD(NM) at the Pentagon. The NWC staff is comprised of an NNSA representative, national security laboratory personnel, plant personnel, DoD employees, and government contractors. The NWC staff reports through the DASD(NM) to the NWC Staff Director. The NWC staff is responsible for coordinating meeting times and locations as well as developing meeting agendas. Additionally, the NWC staff serves as the focal point for drafting, tracking, developing, and coordinating NWC reports and provides a status update at each AO meeting.

The NWC staff has a variety of responsibilities to ensure the NWC and its subordinate bodies operate as efficiently and effectively as possible. The primary responsibilities of the NWC staff include meeting preparation and planning as well as responsibility for technical activities for development, drafting, coordination, and execution associated with NWC annual reports and decision memoranda.

The NWC staff plans and schedules all meetings of the NWC, the NWCSSC, and the NWC AO group, which includes preparing meeting agendas, tasking requests for information or briefings from organizations within the nuclear weapons community, and preparing briefings, as needed, for all levels of the NWC structure. The NWC staff works with AOs to develop an annual NWC work plan that identifies the topics for each fiscal year. Agenda items derived from this work plan may include decision and informational briefings as well as issues for group discussion.

The NWC staff is also responsible for technical activities, including preparing technical content for briefings to the NWC and NWCSSC, developing reports and letters, guiding documents through coordination, and resolving issues within the interagency. Additionally, the staff works administrative issues for the NWC, including preparing and coordinating meeting minutes, developing coordination packages for NWC or NWCSSC paper votes, scheduling of supplementary briefings, and developing responses to Principals' questions or requests. The NWC staff maintains the official records of the NWC and NWCSSC proceedings and other official documents.

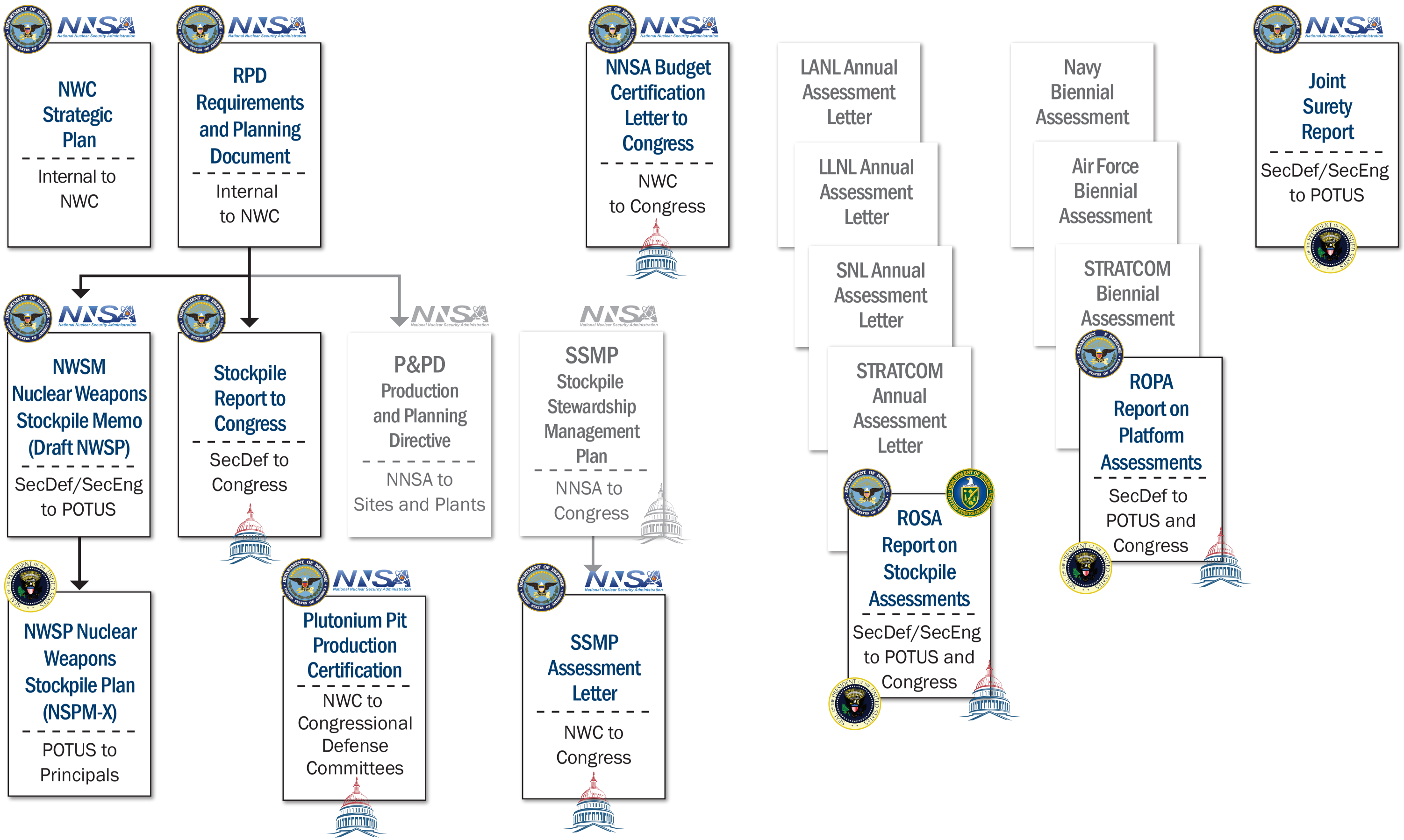
The NWC staff facilitates the timely development of the annual and biennial reports for which the NWC is responsible as well as DoD-only reports. The NWC staff manages the coordination of these reports with the many different representatives from DoD and NNSA. NWC staff activities include publishing report trackers, developing first and subsequent drafts of each annual report, consolidating and reconciling input from various participants, and guiding the reports through the progressive approval channels.

NWC ANNUAL REPORTS

The NWC currently fulfills five annual reporting requirements: the NWSM and Requirements and Planning Document (RPD); the NWC Report on Stockpile Assessments (ROSA); the NWC Joint Surety Report (JSR); the NWC Budget Certification Letter; and, new as of 2019, the NWC Certification of the NNSA Pit Production Strategy. The NWC also has a biennial requirement to assess the NNSA long-range Stockpile Stewardship and Management Plan (SSMP). Additionally, DoD members of the NWC prepare the Annual Report on the Nuclear Weapons Stockpile of the United States and the biennial Report on Platform Assessments (ROPA). These DoD-only requirements fall within the overarching responsibilities of the NWC and the NWC staff coordinates these reports. Figure 6.4 is a visual summary of NWC annual reports.

Each of the NWC reports focuses senior-level attention on important nuclear weapons issues. Each report has a specific purpose and responds to a separate executive or congressional requirement and communicates unique information. NWC reports are a year-round responsibility, with October to April of each year marking the busiest time.

Figure 6.4 Summary of Recurring Nuclear Weapons Council Reports



NUCLEAR WEAPONS STOCKPILE MEMORANDUM AND REQUIREMENTS AND PLANNING DOCUMENT

NWSM/RPD

Requirement:	Title 10 USC §179
Reporting period:	Fiscal Year
Annual due date:	April 1, changed from September 30 by presidential directive
Drafted by:	NWC Staff
Coordinated through:	NWCSSC and NWC
Signed by:	Secretaries of Defense and Energy
Submitted/Transmitted to:	President

The NWSM is an annual memorandum to the President from the Secretaries of Defense and Energy. The NWSM transmits a proposed presidential directive, which includes the proposed Nuclear Weapons Stockpile Plan (NWSP). The NWSP specifies the size and composition of the stockpile for a projected multi-year period, generally the Future Years Defense Program (FYDP) period. The NWSM is the transmittal vehicle for the proposed presidential directive and communicates the positions and recommendations of the two Secretaries. It is the directive signed by the President that guides U.S. nuclear stockpile activities, as mandated by the Atomic Energy Act. For ease of reference, the NWSM (pronounced 'new sum') and the proposed directive containing the recommended NWSP are collectively called the "NWSM package" or "NWSM."

The coordination process for these documents serves as the key forum in which DoD and NNSA resolve issues concerning DoD military requirements for nuclear weapons in relation to NNSA capacity and capability to support these requirements. Resolving these issues is a complex, iterative, and time-consuming endeavor. Once the President signs the directive, the NWC is authorized to approve nuclear weapons stockpile changes within the percentage limits specified by the President, generally 10 percent.

Historically, the NWSM has been the legal vehicle for the President's formal annual approval of the production plans of the U.S. nuclear weapons complex.[2] In the early 1990s, however, the NWSM evolved to reflect the shift away from new warhead production and toward the sustainment of the existing nuclear weapons stockpile. The RPD was developed to facilitate this shift in emphasis and identifies long-term planning considerations that affect the future of the nuclear

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[2] The *Atomic Energy Act of 1954* requires that the President provide annual authorization for all U.S. nuclear weapons production.

weapons stockpile. It provides detailed technical information and analyses that support the development of the NWSM and the proposed presidential directive containing the recommended NWSP.

In 2018, publication of the NWSM/RPD was delayed six months in order to incorporate changes directed by national policy. This change of the annual requirement to deliver a NWSM to the White House from September to April was codified in National Security Presidential Memorandum-12. During this period the focus of the NWSM/RPD was expanded beyond sustaining the existing stockpile to include generating a demand signal to NNSA to build the infrastructure needed to produce the new nuclear weapons directed by national policy and DoD requirements.

NWC Report on Stockpile Assessments

ROSA

Requirement:	FY2003 NDAA, FY2013 NDAA, and FY2015 NDAA
Reporting period:	Fiscal Year
Annual due date:	February 1
Drafted by:	NNSA and NWC Staff
Coordinated through:	NWCSSC and NWC
Signed by:	Secretaries of Defense and Energy
Submitted/Transmitted to:	President and Congress

In August 1995, President Bill Clinton announced the establishment of a "new annual reporting and certification requirement that will ensure that our nuclear weapons remain safe and reliable under a comprehensive test ban." In this speech, the President announced the decision to pursue a "true zero-yield Comprehensive Nuclear-Test-Ban Treaty." As a central part of this decision, President Clinton established a number of safeguards designed to define the conditions under which the United States would enter into such a treaty.

Among these was "Safeguard F," which specified the exact conditions under which the United States would invoke the standard "supreme national interest clause" and withdraw from a comprehensive test ban treaty.[3] The annual assessment process of which the NWC ROSA, formerly the Annual Certification Report, is one element, was originally developed to correspond with

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[3] This clause is written into almost all international treaties. It states the signatory reserves the right to withdraw from the treaty to protect supreme national interests. Most treaties define a specific withdrawal process that normally involves, among other things, advance notification to all states party to the treaty.

Safeguard F, which tasked the director of the U.S. national security laboratories and the CDRUSSTRATCOM to submit a report through the NWC.

Although the United States did not ratify the *Comprehensive Nuclear-Test-Ban Treaty* (CTBT) and the treaty has not entered into force, the United States continues to observe a self-imposed moratorium on underground nuclear explosive testing. The annual assessment process, originally associated with the CTBT, has evolved independently of that treaty. As long as the United States continues to observe a self-imposed underground nuclear testing moratorium, or until the CTBT receives U.S. ratification and enters into force, the annual assessment process serves to ensure the safety and reliability of the stockpile in the absence of nuclear explosive testing.

The annual assessment process itself was originally modeled on the structure of Safeguard F, and the structure remains valid at the present time. Safeguard F specified that if the President were informed by the Secretaries of Defense and Energy that "a high level of confidence in the safety or reliability of a nuclear weapon-type that the two secretaries consider to be critical to the U.S. nuclear deterrent can no longer be certified," the President, in consultation with Congress, would be prepared to conduct whatever nuclear explosive testing might be required.

The FY2003 NDAA legally codified the requirement for an annual stockpile assessment process. Specifically, section 3141 of the FY2003 NDAA required the Secretaries of Defense and Energy submit a package of reports on the results of their annual assessment to the President by March 1 of each year. However, section 3122 of the FY2013 NDAA amended the annual due date to February 1 of each year. This same language requires the individual assessments to be provided to Congress by March 15.

The reports, prepared individually by the directors of the three NNSA national security laboratories (Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and Sandia National Laboratories (SNL)) and by the CDRUSSTRATCOM, provide each official's assessment of the safety, reliability, and performance of each warhead-type in the nuclear stockpile. In particular, the reports include a recommendation on whether there is a need to conduct an underground nuclear test to resolve any identified or emergent issues. In addition, the CDRUSSTRATCOM assesses the military effectiveness of the weapons. The Secretaries of Defense and Energy are required to submit these reports, unaltered, to the President, along with the conclusions the Secretaries have reached as to the safety, reliability, performance, and military effectiveness of the U.S. nuclear deterrent. The NWC supports the two Secretaries in fulfilling their responsibility to inform the President if a return to underground nuclear explosive testing is recommended to address any issues associated with the stockpile.

The principal purpose of the annual assessment is to provide analyses of and judgments about the safety, reliability, performance, and military effectiveness of the nuclear stockpile and the adequacy of the nuclear enterprise to support the stockpile. The process would not be used as a vehicle for notifying decision makers about an immediate need to conduct a nuclear test. If an urgent issue with a weapon were to arise that required a nuclear test, the Secretaries of Defense and Energy, the President, and Congress would be notified outside of the context of the annual assessment process.

JOINT SURETY REPORT

JSR

Requirement:	PPD-35
Reporting period:	Fiscal Year
Annual due date:	March 31
Drafted by:	NNSA and NWC Staff
Coordinated through:	NWC and NWCSSC
Signed by:	Secretaries of Defense and Energy
Submitted/Transmitted to:	President

As reiterated in Presidential Policy Directive 35 (PPD-35), *United States Nuclear Weapons Command and Control, Safety, and Security,* DoD and NNSA are required to prepare and submit to the President the annual JSR that assesses, at a minimum, nuclear weapon safety, security, control, emergency response, inspection and evaluation programs, and the impact of budget constraints on required improvement programs. This report also addresses the current status of each of these subject areas as well as the impact of trends affecting capabilities and the nature of the threat. The security assessment also includes separate DoD and NNSA descriptions of the current state of protection of their respective nuclear weapons facilities in the United States, its territories, and overseas. The report primarily covers activities of the preceding fiscal year. The report is due to the President by March 31 each year.

NWC BUDGET CERTIFICATION LETTER

Section 1039 of the FY2013 NDAA amended Title 10 USC §179 by incorporating a responsibility for the NWC to certify the NNSA funding request for the upcoming fiscal year, and that which is anticipated for the following four fiscal years, is sufficient to meet the NWC stockpile requirements. This

BUDGET CERTIFICATION LETTER

Requirement:	FY2013 NDAA and FY2014 NDAA
Reporting period:	Fiscal Year
Annual due date:	First Tuesday of February (with the President's Budget Request)
Drafted by:	NWC Staff
Coordinated through:	NWC
Signed by:	NWC Chairman
Submitted/Transmitted to:	House and Senate Committees on Armed Services and Appropriations, President of the Senate, and Speaker of the House

certification is sent to Congress in the form of a short letter from the NWC Chairman that represents the position of the NWC.

DoD and NNSA function on different budget request cycles, with NNSA preparing its budget later in the calendar year than DoD. The budget certification is an NWC agenda topic, usually beginning in November, and the members discuss how NNSA is forming its request to meet DoD needs, as laid out in the current endorsed and future stockpile profile. Annually, NNSA provides a line-by-line breakout of its budget for the members to review, while the DoD Cost Assessment and Program Evaluation (CAPE) office typically provides the final review before the draft certification letter is coordinated with the NWC members. While this letter is largely *pro forma*, it is an opportunity to continue a dialogue with Congress on funding the nuclear enterprise.

PLUTONIUM PIT PRODUCTION CERTIFICATION

PLUTONIUM PIT PRODUCTION CERTIFICATION

Requirement:	FY2019 NDAA
Reporting period:	Fiscal Year
Annual due date:	April 1, 2019 through 2025
Drafted by:	NWC Staff
Coordinated through:	NWC
Signed by:	NWC Chairman
Submitted/Transmitted to:	House and Senate Committees on Armed Services and Appropriations

Section 3120 of the FY2019 NDAA stipulates that not later than April 1, 2019, and each year thereafter through 2025, the NWC Chairman shall submit to the Secretary of Defense, the NNSA Administrator, and the Congressional defense committees a written certification that the plutonium pit production plan of NNSA is on track to meet:

- the military requirement of at least 80 pits per year by 2030, or such other military requirement as determined by the Secretary;
- the statutory requirements for pit production timelines under section 4219 of the *Atomic Energy Defense Act* (Title 50 USC §2538a); and
- all milestones and deliverables described in the plans.

If in any year the NWC Chairman is unable to submit the certification, the Chairman shall submit to the congressional defense committees, the Secretary of Defense, and the NNSA Administrator written notification describing why the Chairman is unable to make such certification.

Not later than 180 days after the date on which the Chairman makes a "failure to certify" notification, the Administrator shall submit to the congressional defense committees, the Secretary, and the Chairman a report that:

- addresses the reasons identified in the notification with respect to the failure to make the certification; and
- includes a presentation of either a concurrent backup plan or a recovery plan, and the associated implementation schedules for the plan.

STOCKPILE STEWARDSHIP AND MANAGEMENT PLAN ASSESSMENT

SSMP ASSESSMENT

Requirement:	FY2013 NDAA
Reporting period:	Fiscal Year
Annual due date:	180 days after submission of the SSMP in odd-numbered fiscal years
Drafted by:	NWC Staff
Coordinated through:	NWC and NWCSSC
Signed by:	NWC Chairman
Submitted/Transmitted to:	House and Senate Committees on Armed Services and Appropriations

Each year, the NNSA Administrator submits the SSMP to Congress. In odd-numbered fiscal years, the SSMP is a detailed report on the NNSA plan that covers stockpile stewardship, stockpile management, stockpile surveillance, program direction, infrastructure modernization, human capital, nuclear test readiness, and other areas as necessary. The plan is required to be consistent with the programmatic and technical requirements outlined in the NWSM. In even-numbered fiscal years, NNSA submits a summary of this plan in a much shorter report.

A requirement for the NWC to conduct an assessment on the SSMP in odd-numbered years was codified in section 3133(a)(1) of the FY2013 NDAA. The assessment includes an analysis of whether the SSMP supports the requirements of the national security strategy of the United States; whether the modernization and refurbishment measures and schedules support those requirements; whether the plan adequately addresses the requirements for infrastructure recapitalization of enterprise facilities; the risk to stockpile certification and to maintaining the long-term safety, security, and reliability of the stockpile; and whether the plan adequately meets DoD requirements. The NWC staff reviews the SSMP, then drafts and coordinates the SSMP Assessment in consultation with AOs, representing NWC Principals. The report is coordinated at the NWCSSC level and forwarded to the NWC for final review and approval. After NWC approval, the assessment is signed by the NWC Chairman and transmitted to Congress.

ANNUAL REPORT ON THE NUCLEAR WEAPONS STOCKPILE OF THE UNITED STATES

STOCKPILE REPORT

Requirement:	FY2012 NDAA
Reporting period:	Fiscal Year
Annual due date:	March 1
Drafted by:	NWC Staff
Coordinated through:	DoD
Signed by:	Secretary of Defense
Submitted/Transmitted to:	House and Senate Committees on Armed Services and Appropriations

Section 1045 of the FY2012 NDAA expressed concern from Congress that sustained investments in the nuclear enterprise could allow for greater reductions in the U.S. hedge stockpile. By March 1 of every year, the Secretary of Defense submits to Congress an accounting of the weapons in the stockpile, as of the end of the fiscal year preceding submission of the report, and the planned levels for each nuclear weapon category over the FYDP. The stockpile number projections for this report are derived from the NWSM/RPD.

The Annual Stockpile Report is a DoD-only report, meaning it is not coordinated through the NWC process. However, the ODASD(NM) is the responsible office for DoD and, therefore, the NWC staff assists in drafting and coordinating the report. DoD members of the NWC coordinate on the report as well as the Secretaries of the Navy and the Air Force.

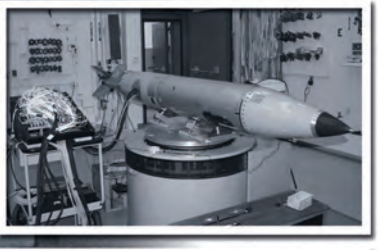
BIENNIAL REPORT ON PLATFORM ASSESSMENTS

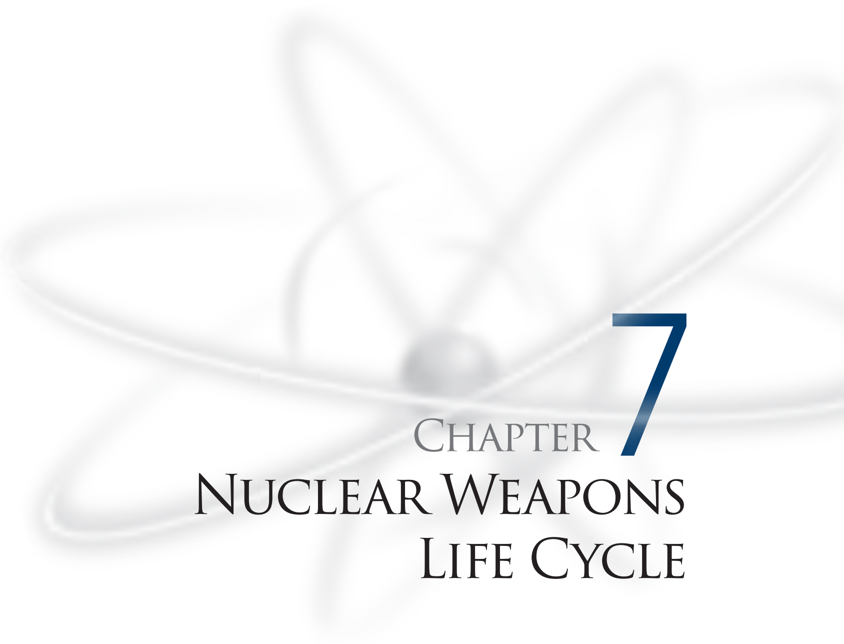
ROPA

Requirement:	FY2012 NDAA and 50 USC 2523
Reporting period:	Two fiscal years
Annual due date:	Biennial (FY); March 1
Drafted by:	Director of the Navy SSP, Commander Air Force Global Strike Command, and CDRUSSTRATCOM
Coordinated through:	ODASD(NM) and NWC
Signed by:	Secretary of Defense
Submitted/Transmitted to:	President and Congress

Section 1041 of the FY2012 NDAA (expanded in Title 50 USC §2523, Chapter 42) created a new DoD-only biennial reporting requirement similar to the construct of the ROSA. The ROPA comprises assessments from the Director of the Navy Strategic Systems Programs (SSP), Commander of the Air Force Global Strike Command, and CDRUSSTRATCOM, also known as the "covered officials." The Navy and Air Force assessments report on the health of their respective nuclear delivery platforms. The CDRUSSTRATCOM assesses whether the platforms meet military requirements and also assesses the health of the Nuclear Command and Control System (NCCS). The "covered officials" coordinate through the ODASD(NM) and submit these assessments to the NWC and the Secretary of Defense by December 1 for the previous even-numbered fiscal year. The NWC staff prepares a cover memorandum from the Secretary of Defense that addresses, at a high level, each platform's sustainment and modernization plans. The Secretary of Defense submits the cover memorandum and the unaltered assessments to the President by March 1 of each odd-numbered fiscal year and the President is required to submit the entire report to Congress by March 15.

The ROPA is a DoD-only report, therefore it is not coordinated through the NWC. However, the ODASD(NM) is the responsible coordinating office for DoD. DoD members of the NWC coordinate on the report as well as the Secretaries of the Navy and the Air Force.





CHAPTER 7

NUCLEAR WEAPONS LIFE CYCLE

OVERVIEW

Nuclear weapons are developed, produced, maintained in the stockpile, and then retired and dismantled. This sequence of events is known as the nuclear weapons life cycle.

In the past, new weapons capabilities were developed in response to requirements for increased military capability as a result of changing geopolitical circumstances, for a nuclear capability in a new delivery system, to attain greater military flexibility, or to incorporate newer and better safety or security features. The United States is currently in the process of restarting the ability to exercise the full nuclear weapons life cycle after a more than 30 year hiatus.

Since the end of the Cold War, U.S. nuclear weapons have not undergone the full life-cycle phase process since the completion of the W88 in 1991 because the United States has not produced new nuclear weapons.

As the United States plans for new warhead production to replace aging legacy systems, it is likely that new weapons will follow the historical life-cycle process. Figure 7.1 depicts the traditional joint DoD-NNSA Nuclear Weapons Life-Cycle process and its associated phases. As the United States prepares to begin producing new designs of nuclear weapons, the traditional Phase Process may be modified or adjusted to reflect the modern development and production

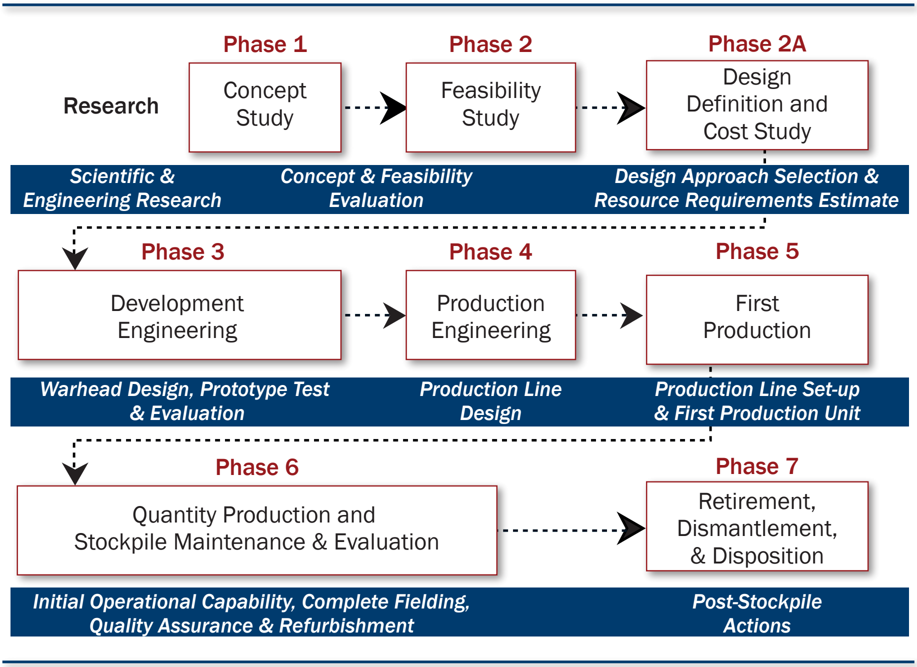


Figure 7.1 Joint Nuclear Weapons Life-Cycle Phases

environment. Until the United States begins new nuclear weapons production only Phase 6 and Phase 7 are executed.

NUCLEAR WEAPONS MANAGEMENT

The responsibilities for nuclear weapons development and management were founded originally in the *Atomic Energy Act of 1946*, which reflected Congressional desire for civilian control over the uses of atomic (nuclear) energy and established the Atomic Energy Commission (AEC) to manage U.S. nuclear weapons programs. Basic departmental responsibilities and the development process were specified in the *1953 Agreement Between the AEC and the Department of Defense (DoD) for the Development, Production, and Standardization of Atomic Weapons*, commonly known as the *1953 Agreement*.

Figure 7.2 illustrates the respective departmental responsibilities of DoD and NNSA throughout the life-cycle process.

While the basic dual agency division of responsibilities for nuclear weapons has not changed significantly, the 1953 Agreement was supplemented in 1977 (to change the AEC to the Energy Research & Development Administration (ERDA)), again in 1984 (to incorporate the details of the 1983 Memorandum of Understanding (MOU)), and, most recently, in 1988 (to incorporate the newly established Nuclear Weapons Council (NWC)).

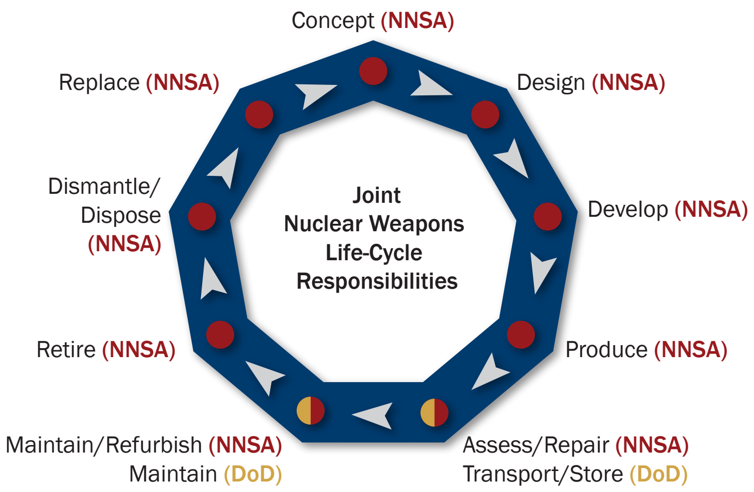


Figure 7.2 Joint Nuclear Weapons Life-Cycle Responsibilities

PHASE 6.X PROCESS

Since 1999, major stockpile sustainment activities have been guided by the Phase 6.X Process. The 6.X Process does not replace Phase 6 activities such as routine maintenance, stockpile evaluation, enhanced surveillance, and annual assessment. Rather, the 6.X Process was developed for non-routine nuclear weapon alterations (Alts) and modifications (Mods) at the system, subsystem, or component level; Life Extension Programs (LEPs); and other warhead modernization activities. For example, Phase 6.X does not apply to limited-life component exchanges (LLCEs) such as tritium gas bottle reservoir replacement, which is managed under normal weapon maintenance programs. Nuclear weapon Alts are assessed on a case-by-case basis to determine applicability of Phase 6.X. Depending on military requirements and the nuclear weapon delivery system, an existing warhead design may be modified through the Phase 6.X Process, or a warhead may be developed through the Phase 1–7 Process, although that has not happened since the late 1980s. For a specific stockpile sustainment activity, some portions of the 6.X Process may be merged, deferred, modified, or omitted, as approved by the NWC. Additionally, the NWC may authorize the weapon project officers group (POG) to coordinate Alts as routine weapon sustainment activities.

Since 1992, the NWC has concentrated its efforts on research related to the maintenance and sustainment of the existing weapons in the legacy stockpile and oversight of the stockpile sustainment activities in the absence of underground nuclear explosive testing. To manage and facilitate the stockpile sustainment process, the NWC approved the *Procedural Guideline for the Phase 6.X Process* in April 2000, with an update in December 2015. Figure 7.3 is an illustration of the Phase 6.X Process.

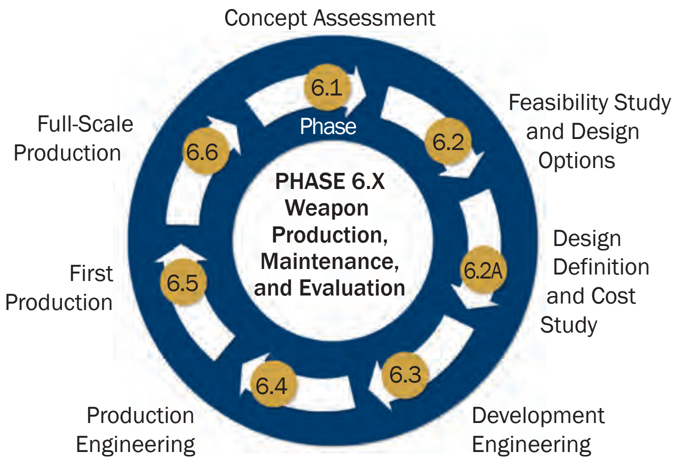


Figure 7.3 Phase 6.X Process

The Phase 6.X Process is based on the original joint DoD-DOE Nuclear Weapons Life-Cycle Process, which includes Phases 1 through 7. The 6.X phases are a "mirror image" of Phases 1 through 6. There is no Phase 6.7, as any weapon slated for retirement, dismantlement, and disposition is covered by the traditional Phase 7 Process. The phased life-cycle process was used to develop a complete warhead, whereas the 6.X Process starts from an existing warhead design or delivery vehicle. Each Phase 6.X program is different; some involve the replacement of only one or two key components, while others may involve the replacement of many key components. If a Phase 6.X program is adapting a warhead to a different delivery system or providing different military characteristics, the warhead design may be significantly modified. As a part of the Phase 6.X Process, the NWC reviews and approves proposed LEPs, Alts, and Mods. The NWC monitors progress throughout the 6.X Process to ensure the stockpile continues to be safe, secure, and reliable, while meeting DoD and NNSA requirements.

PHASE 6.1 – CONCEPT ASSESSMENT

DoD and NNSA are continuously engaged in assessments of nuclear weapons or components as part of normal operations. These activities result in a continuous exchange of information and provide potential concepts for sustainment of systems or components. DoD and NNSA conduct Phase 6.1 studies independently, except when they influence design and operation of the other Department's components.

During Phase 6.1, concepts to meet DoD and NNSA needs are assessed. If the concept is assessed to be valid, the POG determines if a formal program study is warranted or whether the activity should be managed as a POG maintenance action outside the 6.X Process. A formal program study considers program execution, taking into consideration projected technologies, range of costs, and associated technological and program risks.

Prior to commencing a Phase 6.1 study, the POG provides written notification to the Nuclear Weapons Council Standing and Safety Committee (NWCSSC). This notification includes, at minimum, an overview of the study's purpose, scope, objectives, and deliverables.

Key Tasks and Deliverables

At the completion of Phase 6.1, the POG provides:

- a summary of study results to the NWCSSC, including a discussion of all potential concepts and a range of costs and technological risks based on technical boundaries that were considered in the study;
- an initial assessment of supply chain protection considerations;
- proposed potential changes to the military characteristics (MCs), stockpile-to-sequence (STS), or any other requirements drivers; and
- a recommendation to proceed to Phase 6.2, to terminate Phase 6.1 without further action, or to address any issues through normal POG activities.

The POG briefs the NWCSSC on the status of the Phase 6.1 study as requested. Phase 6.1 is complete when the POG submits its reports and deliverables to the NWCSSC.

PHASE 6.2 – FEASIBILITY STUDY AND DESIGN OPTIONS

Once the POG receives approval for entry into Phase 6.2, the POG is authorized to pursue a joint study to further refine potential concepts. During Phase 6.2, the POG develops design options and assesses the feasibility (e.g., cost, schedule, and technical maturity) of these options based on developed criteria, to include tradeoffs and courses of action depending on MCs, STS, timelines, and budgetary and resource constraints to meet the needs for a particular nuclear weapon.

Prior to entering a Phase 6.2 study, the POG acquires written authorization for entry from the NWC or NWCSSC, as appropriate, based on the scope of the effort. In arriving at a decision to authorize entry into Phase 6.2, the NWC factors in the time available for completing activities when establishing the scope of a Phase 6.2 feasibility study of military performance requirements and design options.

Key Tasks and Deliverables

The POG develops a joint, integrated Phase 6.2 study plan outlining the approach, scope, and schedule for the Phase 6.2 analysis activities as early as possible. At a minimum, the Phase 6.2 analysis considers the following programmatic areas during system design:

- range of design options, to include preliminary cost, technological risk, and schedule;
- ability to meet system requirements, to include notional surveillance and logistics components overbuilds;
- evaluation of options to enhance nuclear safety, security, and use control, to include supply chain protection considerations;
- technology readiness levels and associated risk analysis;
- research and development requirements and capabilities;
- qualification and certification requirements;
- production capabilities and capacities;
- research and development, production, life-cycle maintenance, and logistics scope;
- delivery vehicle and platform integration, to include platform nuclear certification considerations;
- preliminary safety study, to include requirements to meet safety environments; and
- rationale for component reuse, remanufacture, or replacement.

The POG updates existing MCs or drafts new MCs to reflect DoD requirements. These updated or new MCs are validated within DoD and analyzed by NNSA to assess the ability to produce, qualify, and certify the design options. Additionally, the POG may evaluate and update existing STS and Interface Control Documents (ICD). If updates are required, the POG coordinates any STS changes, while approval of ICD updates are controlled between NNSA and the appropriate Military Department.

NNSA prepares a Major Impact Report (MIR), identifying those aspects of the program that could significantly affect the schedule or pose a technical risk to the development or production of the nuclear weapon. The POG includes the MIR as an appendix to the Phase 6.2 study report.

The Military Department may decide to conduct a preliminary Pre-Operational Safety Study to begin the process of identifying specific weapon system safety rules. During Phase 6.2 and continuing through to Phase 6.5, the Nuclear Weapon System Safety Group (NWSSG) examines system design features, hardware, procedures, and aspects of the concept of operations that affect safety to determine if DoD nuclear weapon system safety standards can be met. The NWSSG identifies safety-related concerns and deficiencies so corrections may be made in a timely and cost-efficient manner.

The POG briefs the NWCSSC on the status of the Phase 6.2 study at least every six months and delivers a final Phase 6.2 study report to the NWCSSC at the conclusion of the study.

The Phase 6.2 study report summarizes the considered options and associated analyses. It documents criteria used to downselect from the options considered (e.g., the extent to which each concept meets DoD and NNSA requirements) as well as operational risk management plans to ensure U.S. operational commitments are not affected by the stockpile sustainment activity. Draft MC[1] and STS[2] documents are also included in the Phase 6.2 study report.

The POG downselects design options to be analyzed for cost in Phase 6.2A (design definition and cost study). Frequently, the POG makes these downselects early and throughout Phase 6.2 in order to manage costs. These downselect options are presented to the NWC for approval during Phase 6.2 and prior to commencing Phase 6.2A.

Section 3141 of the *National Defense Authorization Act for Fiscal Year 2013* (Pub. L. 112-239) requires the NWC submit a report to Congress assessing the design options considered and the advantages and disadvantages of each option before proceeding beyond Phase 6.2.

PHASE 6.2A – DESIGN DEFINITION AND COST STUDY

Phase 6.2A continues upon successful completion of Phase 6.2 activities. During Phase 6.2A, the POG refines the downselect options by updating the downselect criteria developed in Phase 6.2, developing design and qualification plans, identifying production needs, and creating a preliminary life-cycle plan. The life-cycle plan includes costs to address system stockpile evaluation program requirements and rebuilds, maintenance and logistics, trainer procurement, and handling gear for the protected period. This phase culminates with the release

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[1] The MCs define the operational characteristics of the weapons.

[2] The STS defines the normal peacetime, war employment, and abnormal environments to which the warhead my be exposed during its life cycle.

of the Joint Integrated Project Plan (JIPP) from the POG and the Weapons Development Cost Report (WDCR) from NNSA.

Key Tasks and Deliverables

The POG creates the JIPP based on DoD and NNSA input to implement the proposed downselected set of options. The JIPP serves as the baseline control document for the stockpile sustainment activity. It discusses, as applicable:

- scope (e.g., Mod, Alt, or LEP);
- design definition;
- project schedule (including joint DoD-NNSA milestones, planned management briefings and reviews, first production unit (FPU) milestone, and certification schedules);
- cost analysis;
- configuration management;
- qualification and certification plans;
- supply chain protection program plan;
- military test and evaluation plans;
- MCs, STS, and ICD changes;
- system memoranda of understanding between DoD and NNSA;
- stockpile evaluation planning;
- operational safety implications (integrated safety process);
- proposed changes to technical publications;
- trainers and weapon-type requirements;
- spares, handling gear, use-control equipment, tools, gauges, and field testers;
- development testing and modeling support requirements;
- process development and product qualification;
- archiving and lessons learned;
- component and material characterization for disposition;
- product delivery (components and documents);
- risk management; and
- classification management review.

NNSA develops the WDCR to reflect preliminary cost estimates for design, qualification, production, and life-cycle activities. The JIPP and WDCR are primary inputs to the Phase 6.2A study report.

The POG briefs the NWCSSC on the status of the Phase 6.2A study, as requested. At the conclusion of the study, the POG delivers a final Phase 6.2A study report to the NWCSSC that serves as the basis for a Phase 6.3 entry request, if recommended. The report describes Phase 6.2A activities and includes a recommendation on the design option to carry forward into Phase 6.3, including the applicable Military Department costs. The JIPP and WDCR are included as appendices to the report.

The major deliverables for Phase 6.2A are draft MCs, draft STS, MIR, JIPP, WDCR, and the Phase 6.2A report.

Upon completion of Phase 6.2A, the POG presents a summary of the Phase 6.2A study report to the NWCSSC. At a minimum, this summary includes the following program information:

- scope of stockpile sustainment activity;
- design definition, to include preliminary component reuse forecast;
- preliminary project schedule with major milestones (including FPU);
- military requirements, to include any changes;
- supply chain protection program plan;
- qualification and certification plans, to include updated platform nuclear certification considerations;
- trainer and handling gear forecast;
- proposed Stockpile Evaluation Program plan;
- platform requirements, to include any changes;
- risk management strategy;
- requirements management process;
- configuration management process; and
- cost analysis, to include trade-off decisions.

PHASE 6.3 – DEVELOPMENT ENGINEERING

During Phase 6.3, NNSA, in coordination with DoD, conducts experiments, tests, and analyses to develop and validate the selected design option. The national security laboratories initiate process development activities and produce test hardware, as required.

The POG submits a recommendation to the NWC to proceed to Phase 6.3 with a downselect option. The recommendation for Phase 6.3 entry includes JIPP, MIR, WDCR, and updated MCs and STS documents, as appropriate. Prior to executing Phase 6.3 activities, the POG receives written authorization from the NWC to proceed.

Key Tasks and Deliverables

Following authorization to enter Phase 6.3, the NWC prepares a letter requesting Military Department and NNSA participation in Phase 6.3. The appropriate Military Department would generate and approve interagency agreements, as required, to cover technical and financial responsibilities for product-specific or joint activities. DoD and NNSA forward acceptance letters to the NWC confirming their participation in Phase 6.3. These letters also include comments on the MCs and STS as well as any exceptions or concerns regarding study execution or schedule.

As required, the NWSSG provides a preliminary Pre-Operational Safety Study briefing to the NWCSSC and appropriate Military Departments that includes draft weapon system safety rules.

NNSA formally updates the WDCR and reissues it as the Baseline Cost Report (BCR). NNSA provides the BCR to the NWCSSC to establish a program cost baseline. In coordination with the Defense Threat Reduction Agency (DTRA) and the Military Department, NNSA also prepares a product change proposal identifying stockpile sustainment activity scope, schedule, and specific DoD and NNSA roles and responsibilities.

The national security laboratories prepare a draft addendum to the Final Weapon Development Report (FWDR) or create a new FWDR draft. This draft includes a status of the design as well as an initial discussion of design objectives, descriptions, proposed qualification activities, ancillary equipment requirements, and project schedules.

The Military Department convenes a Design Review and Acceptance Group (DRAAG) to review the draft FWDR. Once the review is complete, the Military Department informs the NWC of the preliminary DRAAG report findings and recommendations.

The POG updates the JIPP based on Military Department and NNSA input. The POG also updates the MC and STS documents, as appropriate, and ensures stakeholder requirements are fully considered.

The POG briefs the NWCSSC on the status of Phase 6.3 at least every six months.

The major deliverables for Phase 6.3 are BCR, draft addendum to the FWDR (or new FWDR draft), preliminary DRAAG report, updated JIPP, and approved MC and STS documents.

Once the national security laboratories finalize the design definition and conduct the Baseline Design Review, NNSA authorizes the national security laboratories and production plants to enter into Phase 6.4.

PHASE 6.4 – PRODUCTION ENGINEERING

During Phase 6.4, NNSA refines the developmental design into a producible design and prepares the production agencies for production. During this phase, the acquisition of capital equipment is completed; tooling, gauges, use control, handling gear, and testers are defined and qualified; process development and process prove-in (PPI) are accomplished; materials are purchased; processes are qualified through production efforts; and trainer components are fabricated. NNSA updates production cost estimates based on preliminary experience gained in PPI and product qualification. Finally, DoD and NNSA define procedures to conduct stockpile sustainment, including supply chain protection considerations and the necessary logistics supporting weapon movements.

Key Tasks and Deliverables

During Phase 6.4, NNSA performs a number of activities to transition to a producible design, including:

- testing developmental prototypes, conducted with the Military Department to ensure operational validation, as appropriate;
- conducting PPI activities leading to a qualified process;
- publishing engineering authorizations to support product and process development; and
- updating production cost estimates.

DoD and NNSA also accomplish a number of joint activities, including:

- provisioning for spare components;
- conducting a laboratory task group and joint task group review to validate proposed procedures;
- updating and finalizing technical publications through a manual files conference; and
- updating the Stockpile Evaluation Plan (SEP).

The POG briefs the NWCSSC on the status of Phase 6.4 at least every six months.

The POG provides an updated JIPP to the NWCSSC and NNSA updates the BCR. Prior to entry into Phase 6.5, the POG provides written notification to the NWC that NNSA is prepared to transition to Phase 6.5.

PHASE 6.5 – FIRST PRODUCTION

During Phase 6.5, NNSA production agencies produce the first warheads. The POG determines if these warheads meet design and military requirements.

Key Tasks and Deliverables

NNSA makes a final weapon evaluation of the design and production processes. The national security laboratories, in coordination with NNSA, prepare the final draft addendum to the FWDR, and then submit it and the draft Major Assembly Release (MAR) to the DRAAG for final review.

The Military Department convenes the DRAAG to review the final draft addendum to the FWDR. Once the review is complete, the Military Department informs the NWC of the final DRAAG report findings and recommendations. The DRAAG, in coordination with the Military Department, informs NNSA whether the weapon meets MCs, STS, and other applicable requirements. DoD acceptance is conveyed in a letter from the Military Department and/or the NWC chair to the NNSA Administrator.

The national security laboratories finalize and release the addendum to the FWDR upon receipt of DRAAG comments, findings, and recommendations and attach a nuclear system certification letter, which serves as the formal recertification for the nuclear system and re-qualification for system deployment.

The FPU milestone occurs when the Military Department and/or the NWC accepts the design and NNSA verifies the first produced weapon(s) meets the design.

The national security laboratories also finalize and transmit the MAR to NNSA following evaluation of production activities and completion of DoD reviews; NNSA formally issues the MAR. The first weapons are released to DoD when the NWC accepts the final DRAAG report and the MAR is issued.

The POG briefs the NWC on readiness to proceed to initial operating capability (IOC) and full deployment. The POG also coordinates specific weapon requirements for test or training purposes.

The Military Department conducts a final Pre-Operational Safety Study in such time that specific weapon system safety rules can be coordinated, approved, promulgated, and implemented, at least 60 days before IOC or first weapon delivery. During this study, the NWSSG examines and finalizes system design features, hardware, procedures, and aspects of the concept of operations that affect safety. The NWSSG also validates that the system meets DoD nuclear weapon system safety standards. The NWSSG recommends final weapon system safety rules to the appropriate Military Departments.

The POG briefs the NWCSSC on the status of Phase 6.5 at least every six months. The POG requests approval from the NWC to proceed into Phase 6.6.

Phase 6.6 – Full-Scale Production

NNSA must have written authorization from the NWC prior to beginning full-scale production and delivery of refurbished weapons for the stockpile.

Key Tasks and Deliverables

NNSA provides a briefing to the NWCSSC outlining the plans and schedule to complete full-scale production.

The POG prepares an End-of-Project Report that serves as the final JIPP and documents the details of each phase of the 6.X Process. This report also includes an analysis of lessons learned for the NWC to use when documenting the activities carried out in the 6.X Process.

NNSA delivers and releases refurbished weapons into DoD custody on a schedule agreeable to both DoD and NNSA.

Phase 6.6 ends when all planned activities, certifications, and reports are complete.

Figure 7.4 illustrates of the relationship of the 6.X Process to the Phase Process.

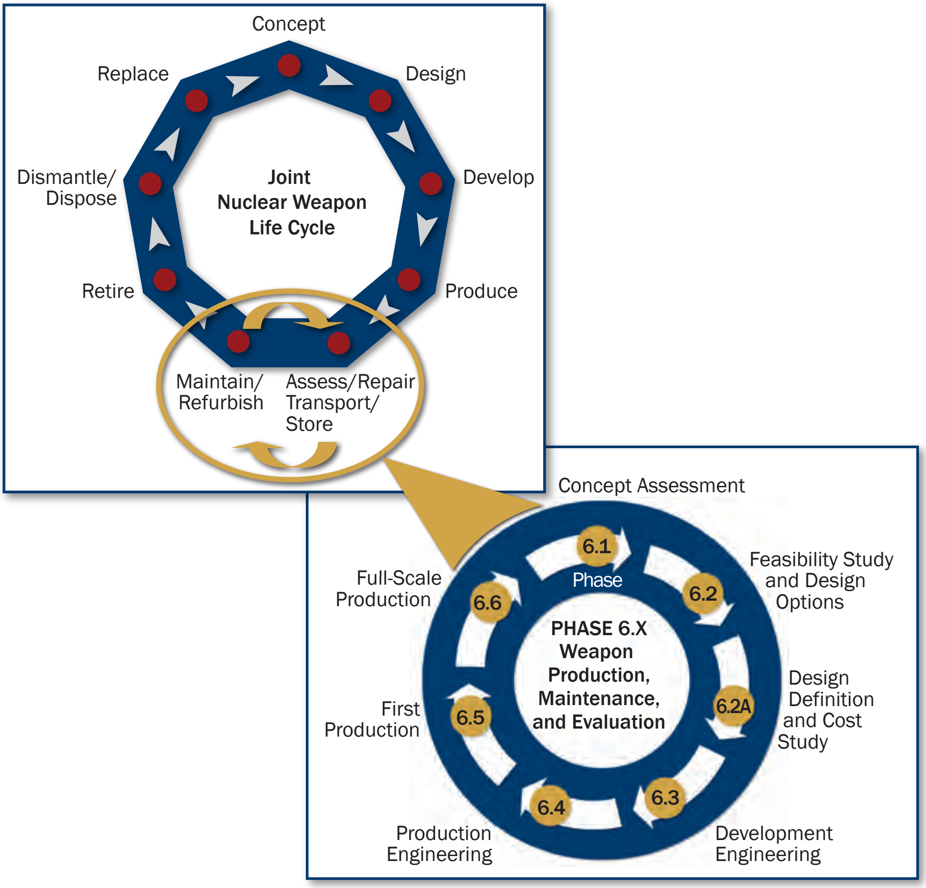

Figure 7.4 Phase 6.X Process Relationship to the Phase Process

PHASE 7 – RETIREMENT, DISMANTLEMENT, AND DISPOSITION

Phase 7 begins with the first warhead retirement of a particular warhead-type. At the national level, retirement is the reduction of the quantity of that warhead-type prescribed in the Nuclear Weapon Stockpile Plan (NWSP) for any reason other than to support quality assurance. This phase initiates a process that continues until all warheads of that type are retired and dismantled. From the DoD perspective, a warhead-type just beginning retirement activities may still be retained in the active and/or inactive stockpiles for a period of years.

In the past, when the retirement of a warhead-type began, a portion of the operational stockpile was retired each year until all the warheads were retired, because at that time, most of the warhead-types were replaced with "follow-on" programs. Currently, Phase 7 is organized into three sub-phases:

- Phase 7A, Weapon Retirement;
- Phase 7B, Weapon Dismantlement; and
- Phase 7C, Component and Material Disposal.

While NNSA is dismantling and disposing of the warheads, if appropriate, DoD is engaged in the retirement, dismantlement, and disposal of associated nuclear weapons delivery systems.

Acoustic Test on a B61-12 System Performed at Sandia National Laboratories


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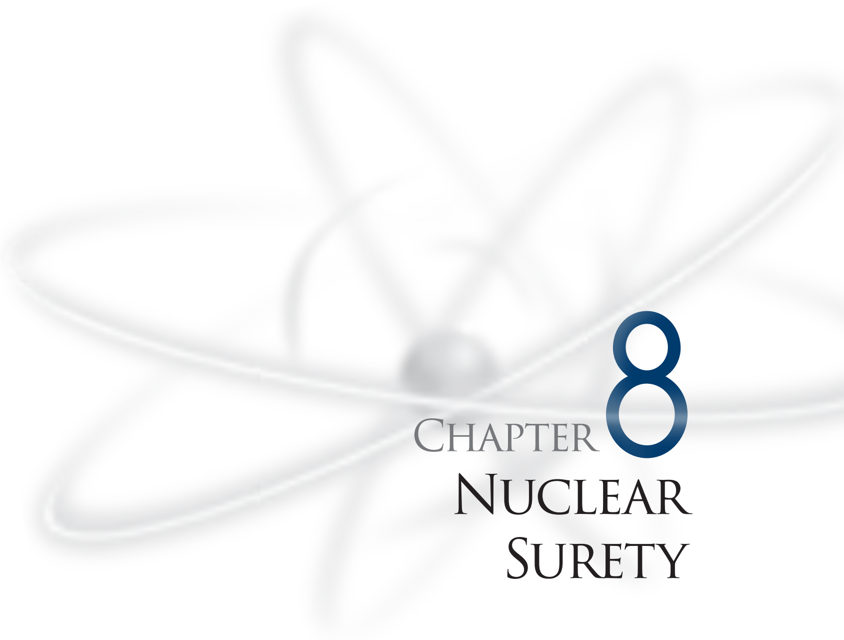

Chapter 8

Nuclear Surety

Overview

A primary responsibility of the Department of Defense and Department of Energy stockpile mission is to ensure U.S. nuclear weapons are safe, secure, and under positive control, a concept commonly referred to as "surety."[1] Safe, secure, and under positive control applies across the stockpile, to individual weapons, throughout the U.S. nuclear weapons life cycle. Simply stated, a nuclear weapon must always detonate on an intended target when authorized by the President, and never detonate in any other environment or for any other reason.[2] The consideration of safety, security, and control begins with the earliest design phase—through sustainment and deployment—to employment or retirement. This consideration is applied to weapons, material, components, information, personnel, and all activities associated with U.S. nuclear weapons.

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[1] There is no universally accepted definition of the term "nuclear surety" within the U.S. nuclear community. For the purposes of this handbook we discuss surety in the context of safety, security, and control.

[2] Colloquially, insiders refer to the "always/never rule." Nuclear weapons must always work when they are supposed to, and never detonate when they are not supposed to.

DUAL-AGENCY SURETY RESPONSIBILITIES

Nuclear surety is a shared responsibility between DoD and DOE/NNSA. A 1983 MOU, signed by the Secretaries of Defense and Energy, reaffirmed the obligation of DoD and DOE to protect public health and safety and provided the basic premise for dual-agency judgment and responsibility for safety, security, and control of nuclear weapons. In 2011, the Deputy Secretaries of Defense and Energy signed a DoD-DOE *Nuclear Physical Security Collaboration Memorandum*, which further solidified the DoD-DOE commitment to develop common standards for the physical security of nuclear weapons and special nuclear material (SNM).

Because a nuclear weapon is in DoD custody for the majority of its lifetime, DoD is responsible for a wide range of operational requirements. NNSA is responsible for the design, production, assembly, surety technology, disassembly, and dismantlement of U.S. nuclear weapons. NNSA is also responsible for the transportation of weapons to and from the Military First Destination (MFD). There are, however, overlaps in responsibility between DoD and NNSA, requiring considerable coordination between the two regarding surety issues. For example, DoD and NNSA share responsibility for the interface between the weapon and the delivery system and for accident prevention and response.

DOD AND DOE SURETY PROGRAMS

The objective of the DoD Nuclear Weapons Surety Program and the DOE Nuclear Explosive and Weapon Surety Program is to ensure adequate safety and security of nuclear weapons and to prevent the inadvertent or unauthorized use of U.S. nuclear weapons. DoD surety standards are promulgated under DoDD 3150.02, *DoD Nuclear Weapons Surety Program*. DOE continues to revise its standards to emphasize its responsibilities for nuclear explosive operations with DOE Order (DOE O) 452.1E, *Nuclear Explosive and Weapon Surety Program*. Although the operating environments differ significantly, DoD and DOE standards share many similarities. Figure 8.1 compares DoD and DOE nuclear weapons surety standards.

NUCLEAR WEAPON SYSTEM SAFETY

Nuclear weapons require special safety consideration due to their unique destructive power and the catastrophic consequences of an accident or unauthorized act. Nuclear weapons system safety refers to the collection of positive measures designed to minimize the possibility of a nuclear detonation resulting from accidents, unauthorized actions, errors, or acts of nature. For

The 4 DoD Nuclear Weapon System Surety Standards

There shall be positive measures to:

1. Prevent nuclear weapons involved in accidents or incidents, or jettisoned weapons, from producing a nuclear yield.
2. Prevent deliberate pre-arming, arming, launching, or releasing of nuclear weapons, except upon execution of emergency war orders or when directed by competent authority.
3. Prevent inadvertent pre-arming, arming, launching, or releasing of nuclear weapons in all normal and credible abnormal environments.
4. Ensure adequate security of nuclear weapons.

The 6 DOE Nuclear Explosive and Weapon Surety Standards

There shall be positive measures to:

1. Effectively interrupt each credible scenario that leads to an unintended nuclear explosive detonation or main charge High Explosive Violent Reaction (HEVR).
2. Effectively interrupt each credible scenario that leads to an unintended nuclear explosive detonation or main charge HEVR given the first measure fails.
3. Prevent unauthorized access, intentional physical damage, misuse, and theft of nuclear explosives.
4. Prevent malevolent acts that could lead to deliberate unauthorized use—a combination of site, facility, or nuclear explosive operation-specific actions as appropriate.

New and refurbished nuclear weapons must have design attributes to:

5. Prevent nuclear explosive detonation and main charge high explosive violent reaction given an adverse environment or unauthorized act.
6. Prevent deliberate unauthorized use, given a malevolent act.

▨ Safety
▨ Control
▨ Security

Figure 8.1 Comparison of DoD Nuclear Weapon System Surety and DOE Nuclear Explosive and Weapon Surety Standards

safety purposes, a nuclear detonation is defined as an instantaneous release of energy from nuclear events (i.e., fission or fusion) exceeding the energy released from an explosion of four pounds of TNT. Nuclear safety also encompasses design features and actions to reduce the potential for dispersal of radioactive materials in the event of an accident. Nuclear weapons system safety integrates policy, organizational responsibilities, and the conduct of safety-related activities throughout the life cycle of a nuclear weapon system. For additional information on DoD policy, see DoD Directive (DoDD) 3150.02, *DoD Nuclear Weapons Surety Program*.

The nuclear weapon safety philosophy deviates from many other performance criteria, insofar as safety is not synonymous with reliability. Safety is concerned with how things fail, as opposed to focusing on what must work for reliability, and relies mostly on passive approaches rather than on active ones. Nuclear weapons safety requirements must be met in the event of an accident, with or without human intervention. For nuclear weapons, reliability is the probability that a weapon will perform in accordance with its design intent or military requirements, whereas safety focuses on preventing a nuclear detonation under all circumstances except when directed by the President. High reliability is required for expected operational, or normal, wartime employment environments. Safety is required for normal wartime employment environments, normal environments, and abnormal environments, such as a weapon involved in a vehicle or aircraft accident.

Normal environments are the expected logistical and operational environments, as defined in a weapon's military characteristics (MCs) and stockpile-to-target sequence (STS) documents, in which the weapon is expected to survive without degradation in operational reliability. Normal environments include a spectrum of conditions that the weapon could be subjected to in peacetime logistical situations and in wartime employment conditions up to the moment of detonation. For example, a normal environment may include conditions such as a temperature range of minus 180 to plus 155 degrees Fahrenheit, a force of 10G set-back upon missile launch, or shock from an impact of a container being dropped from a height of up to two inches.

Abnormal environments are the expected logistical and operational environments, as defined in a weapon's MCs and STS documents, in which the weapon is not expected to retain full operational reliability. Abnormal environments include conditions not expected in normal logistical or operational situations, but could occur in credible accidental or unusual situations, including an aircraft or vehicle accident, lightning strike, shipboard fire, or a bullet, missile, or fragmentation strike.

The following are safety criteria design requirements for all U.S. nuclear weapons:

- *Normal environment* – Prior to receipt of the enabling input signals and the arming signal, the probability of a premature nuclear detonation must not exceed one in a billion per nuclear weapon lifetime.
- *Abnormal environment* – Prior to receipt of the enabling input signals, the probability of a premature nuclear detonation must not exceed one in a million per credible nuclear weapon accident or exposure to abnormal environments.
- *One-point safety* – Probability of achieving a nuclear yield greater than four pounds of TNT equivalent in the event of a one-point initiation of the weapon's high explosive must not exceed one in a million.

NUCLEAR WEAPON DESIGN SAFETY

Modern nuclear weapons incorporate a number of safety design features. These features provide high assurance that an accident, or other abnormal environment, will not produce a nuclear detonation. These also minimize the probability that an accident or other abnormal environment will cause the scattering of radioactive material. There are performance trade-offs to consider in determining whether to include various safety features in the design of a particular warhead. Thus, not all warhead types incorporate every available safety feature. However, all legacy warheads were designed to meet specific safety criteria across the range of both normal and abnormal environments. U.S. nuclear weapons are extremely safe.

Enhanced Nuclear Detonation Safety

Nuclear detonation safety is intended to prevent nuclear detonation—from either accidental or inadvertent causes. For all current weapons in the U.S. stockpile, the firing system forms a key part of detonation safety implementation. The goal of nuclear safety design is to prevent inadvertent nuclear yield by isolating the components essential to weapon detonation from significant electrical energy. This involves the enclosure of detonation-critical components in a barrier to prevent unintended energy sources from powering or operating the weapon's functions. When a barrier is used, a gateway is required to allow the proper signals to reach the firing set. A gateway can also be used to prevent the firing set stimulus from reaching the detonators. These gateways are known as stronglinks. The enhanced nuclear detonation safety (ENDS) concept is focused on a special region of the weapon system containing safety-critical components designed to respond to abnormal environments in a predictably safe manner. This ensures nuclear safety is achieved in an abnormal environment despite the appearance of premature signals at the input of the special region. Figure 8.2 illustrates this modern nuclear safety architecture.

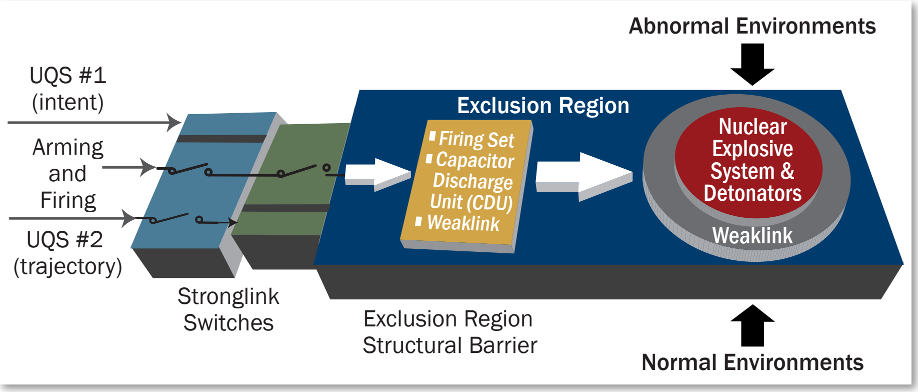


Figure 8.2 Modern Nuclear Safety Architecture

Stronglinks operate upon receipt of a unique signal (UQS). Stronglinks open only upon receipt of a unique signal indicating proper human intent (UQS #1) or a specific weapon trajectory (UQS #2). Stronglinks are designed to withstand severe accident environments including physical shock, high temperatures, and high voltage. Before stronglink failure occurs, another component is designed to render the firing set safe: the weaklink. The weaklink is designed so that, in the event that a certain part is ruptured, it will keep the weapon's electrical system in safe mode, thereby preventing a nuclear detonation. Any force strong enough to pass the stronglink will rupture the weaklink, "freezing" the electrical system in a safe condition.

Modern safety requirements dictate that each firing set contains two independent stronglinks. The UQS for the intent stronglink cannot be stored in the weapon and must be entered by a human. The unique signal pattern for the trajectory stronglink is frequently stored in a device known as a trajectory-sensing signal generator (TSSG). The TSSG is designed to sense when the warhead is progressing along its prescribed environmental path. If the warhead senses the expected STS it will detonate as designed.

To ensure nuclear weapons *only* detonate as a result of authorized use (presidential direction), there are four principal safety themes for nuclear weapons: isolation, incompatibility, inoperability, and independence. The stronglink plays an important role in all four themes.

Isolation. The critical components necessary for a nuclear detonation are isolated from their surroundings by placing them within a physical barrier known as an exclusion region. This barrier blocks all forms of significant electrical energy, such as lightning or power surges, even when the exclusion region is subjected to a variety of abnormal environments.

The barrier is not perfect, because a perfect barrier would make it impossible for the weapon to detonate. To initiate a nuclear detonation, some energy must be permitted inside the exclusion region. Therefore, an energy gateway, or shutter, is required to complete the electrical circuit. When the shutter is closed, it should form an integral part of the barrier. When the shutter is opened, it should readily transfer energy inside the exclusion region to cause a nuclear detonation. Stronglinks are these energy gateways.

Incompatibility. It is critical to ensure only a deliberate authorized act activates the stronglinks and opens the energy circuit. The act can originate from human intent or the delivery environments of the weapon. A ballistic missile, for example, will travel through the atmosphere, into the exo-atmosphere, and back into the atmosphere in a predicable manner. Any deviation from this predicable trajectory will incapacitate the weapon. The stronglink serves as an electrical combination lock preventing weapon usage until deliberate action occurs. The combination to the lock is a complex pattern of binary pulses. To activate the stronglink switch, an operator must input the unique signal information when the weapon is ready for use. This information is converted into a unique pattern of long and short electrical pulses, which is the only signal that will activate the stronglink. Any other pattern is incompatible and will not activate the stronglink. An incompatible pattern will cause the switch to lock up and remain in a safe condition. Figure 8.3 illustrates the concept of incompatibility.

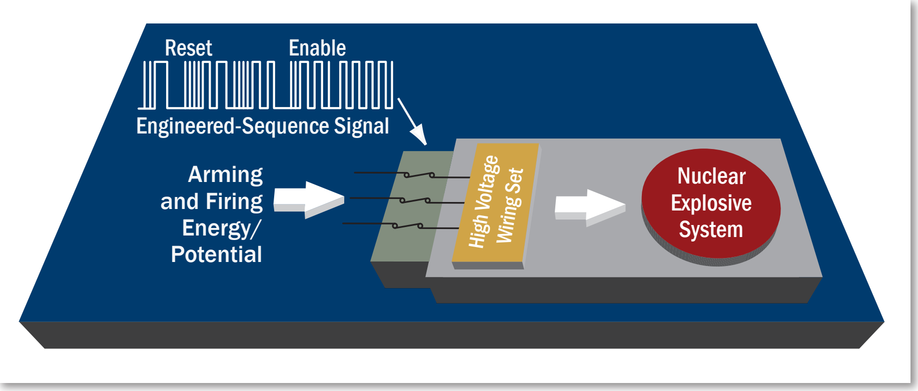


Figure 8.3 Incompatibility

Each stronglink contains one pattern and can only be operated by receiving its unique pattern. Stronglink patterns are analyzed for their uniqueness to ensure they are incompatible with naturally occurring signals. This prevents natural phenomena like lightening strikes and static electricity from activating a stonglink. Additionally, stronglinks are engineered so that the probability of their accidental activation from a naturally occurring source is far less than one in a million.

Inoperability. At some level of exposure to an abnormal environment, the energy from the weapon's surroundings becomes so intense that the barrier loses its integrity and melts or ruptures. Incorporating environmental vulnerability into weaklinks ensures nuclear safety. Weaklinks perform the opposite function of stronglinks. They must be functional for a nuclear detonation, but weaklinks are designed to fail at relatively low environmental levels, thus rendering the weapon inoperable. These levels are low enough to ensure the weaklink fails before the stronglink or exclusion barrier fails. At the same time, weaklinks are designed to withstand the normal activity experienced during the storage and shipping throughout the stockpile-to-target sequence. Ideally, the weaklinks are co-located with the stronglink so both components experience the same environmental assault. Figure 8.4 is a diagram of the concept of inoperability.

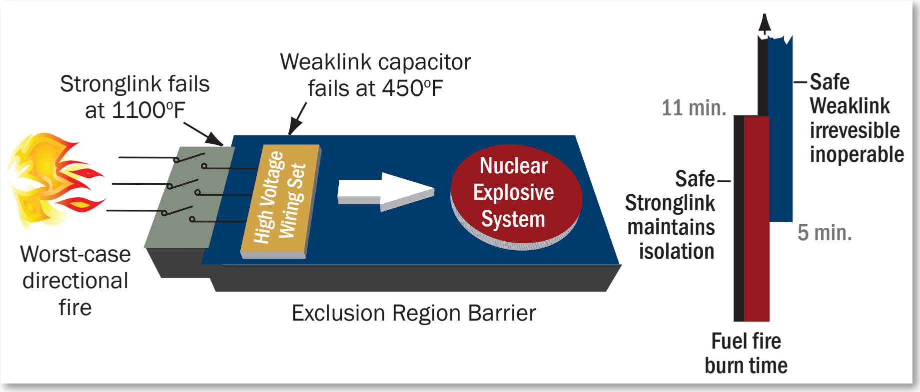


Figure 8.4 Inoperability

Independence. Typically, two different stronglinks with different patterns are used in each weapon to provide the required assurance of safety. With independent stronglinks, a flaw may cause one stronglink to fail, but the other stronglink will still protect the weapon.

Insensitive High Explosive

The definition of insensitive high explosive (IHE) is found in the DOE Explosives Safety Standards which states that some explosive substances, although mass detonating, are so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible. Those explosive substances that have been approved/qualified as IHEs, to date, are TATB (2,4,6-triamino-1,3,5-trinitrobenzene) and its formulations with polychlorotrifluoroethylene (PCTFE). IHE is less sensitive to shock or heat, making the weapon more resistant to accidental detonation than conventional high explosive (CHE). Not all weapons can be designed with IHE because IHE is heavier and takes up more space in the weapon than CHE. As a result, IHE is incompatible for some weapons designed to meet specific operational requirements.

Fire-Resistant Pit

Another feature of enhanced nuclear weapons design safety is the fire-resistant pit (FRP). In an accident, plutonium can be dispersed if it is aerosolized by intense heat, such as that from ignited jet fuel. To prevent this, the nuclear weapon pit can be designed with a continuous barrier around it. This barrier is designed to contain the highly corrosive, molten plutonium for a sufficient amount of time to extinguish the fire.

NUCLEAR WEAPONS SECURITY

Because of their unique characteristics and national significance, nuclear weapons demand the highest standards of physical security. Derived from Presidential policy directives, the employment of interrelated and supporting capabilities, principles, and practices are intended to protect nuclear weapons from unauthorized access, theft, damage, destruction, sabotage, or unauthorized use. Nuclear weapons security integrates technology, security forces, personnel assurance standards, and tactics, techniques, and procedures into a comprehensive security concept. This concept establishes a defense-in-depth framework that ensures the highest physical security standards are employed through the use of active and passive measures throughout a weapon's life cycle.

The Departments are responsible for providing appropriate security for all nuclear weapons in their custody. Custody is defined as the responsibility for controlling the transfer, movement, and access to a nuclear weapon or its components. Inherent in these custodial responsibilities is control and the custodial agent must secure the weapon to ensure positive control is maintained at all times.

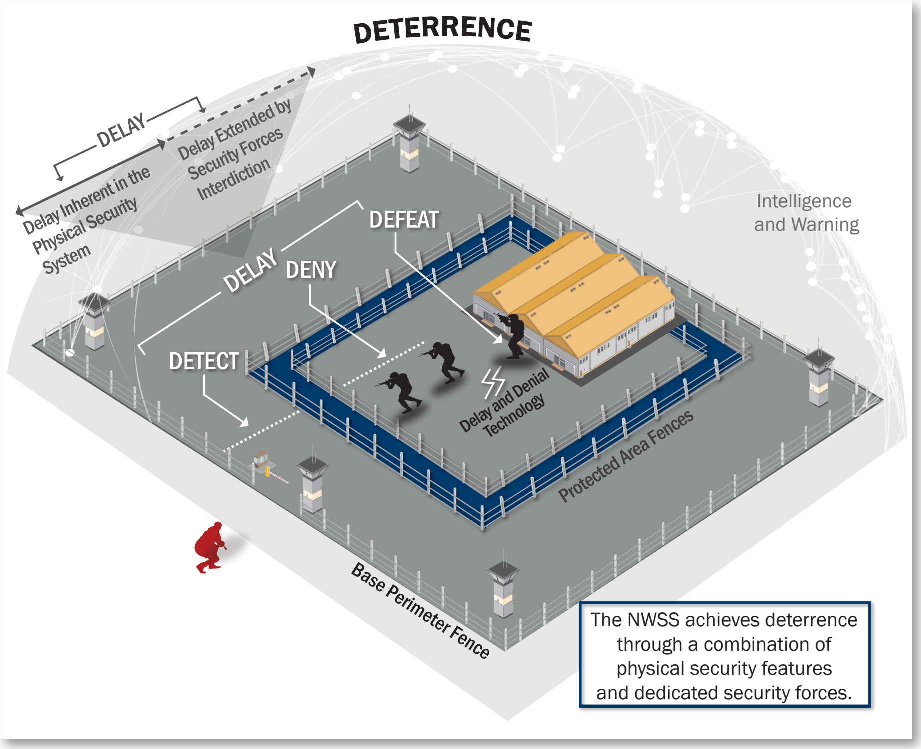
DOD NUCLEAR WEAPON SECURITY STANDARD

DoDD 5210.41, *Security Policy for Protecting Nuclear Weapons*, establishes the DoD Nuclear Weapon Security Standard (NWSS). The objectives of the standard include:

- deny unauthorized access to nuclear weapons;
- prevent loss of control of nuclear weapons;
- prevent an unauthorized nuclear detonation and, to the extent possible, radiological contamination; and
- prevent damage to nuclear weapons.

The NWSS defines two fundamental tenets of nuclear weapons physical security. The first tenet is "to deny unauthorized access to nuclear weapons," and the second is "failing denial, take any and all actions necessary…to regain control of nuclear weapons immediately."

In order to meet the NWSS, the overriding objective of the nuclear weapons security system is to deter attempts at unauthorized access through the combination of physical security features, technology, and dedicated security forces. Together, the security capabilities support the NWSS and are commonly referred to as the five "Ds" of nuclear security: deter, detect, delay, deny, and defeat (Figure 8.5).



The NWSS achieves deterrence through a combination of physical security features and dedicated security forces.

Figure 8.5 DoD Nuclear Weapons Security Standard

Deterrence is the overall goal of the security system and is achieved through the robust application of detection, delay, denial, and defeat capabilities. The inherent features of the physical security system and the capabilities of a dedicated security force visibly discourage adversary actions.

Detection is achieved through effective entry control, vigilant patrolling, and observation supported by a suite of sensors and assessment devices specifically engineered and designed to meet NWSS objectives. Detection and assessment should be accomplished as far away from the nuclear weapon as possible and reported immediately to responding forces. Coupled with support from law enforcement, and with the intelligence community providing situational awareness outside the protected area, full spectrum detection is achieved.

The adversary path to a nuclear weapon is a function of time and is affected by the speed, distance, security force capabilities, and the mission tasks necessary to achieve unauthorized access. Delay is accomplished by prolonging the time it takes an adversary to obtain unauthorized access. The combined effect of physical security features and security force interdiction slows the advance of an adversary, thereby allowing security forces additional time to engage and defeat them.

Denial is the combination of forces, technology, physical infrastructure, and information that denies an adversary strategic and tactical advantages such as surprise, concealment, and terrain. Denial technologies, security force tactics, and structures encompass the operational space from protected areas to a distance that provides the greatest tactical advantage for security forces. Denial can include technologies that have incapacitating or lethal capacity consistent with use of force rules.

If denial fails, security forces and systems must defeat a hostile adversary and immediately regain control of the nuclear weapon. Dedicated security forces are organized, trained, and equipped to survive and prevail while tactically maneuvering to decisively engage and defeat adversaries.

DoD and NNSA regularly evaluate their capability to keep nuclear weapons secure. Through exercises, modeling and simulation, inspections, and corrective action, the Departments continue to evolve their tools, techniques, processes, and procedures. The DoD MIGHTY GUARDIAN (MG) program is designed to test DoD and Military Department-level security policy and ensure the NWSS can be achieved wherever nuclear weapons, materials, and command and control facilities and platforms are operated. The MG process combines force-on-force exercises and engineering assessments to evaluate the effectiveness of nuclear security policy and standards with the goal of improving the U.S. nuclear security system.

To encourage collaboration and develop a standardized approach to nuclear security between DoD and NNSA, the Security Policy Verification Committee (SPVC) is an interagency body that meets bi-annually on nuclear security enterprise matters. From emerging threats and opportunities for joint exercises to pursuing common technological security solutions, the SPVC is a forum for sharing lessons learned and advancing nuclear physical security.

DOE Safeguards and Security

NNSA has programs similar to those of DoD to ensure the physical security of nuclear weapons and SNM in transport to and from NNSA locations, laboratories, and plants. Like DoD, NNSA evaluates its future security capabilities to ensure adequate security is provided to meet identified threats.

DoD and DOE Personnel Security

Both DoD and DOE have personnel reliability assurance programs to ensure personnel assigned to nuclear weapons-related duties are trustworthy. The DoD Personnel Reliability Assurance Program (PRAP) and the DOE Human Reliability Program (HRP) ensure trustworthy personnel possess the necessary judgment to work with nuclear weapons. Within physical proximity of nuclear weapons, unescorted access is limited to those who are subject to a DoD or DOE personnel reliability program (PRP).

DoD-PRAP and DOE-HRP are designed to ensure the highest possible standards of individual reliability for those personnel assigned to nuclear weapons duties. They emphasize the importance of the individual's loyalty, integrity, trustworthiness, behavior, and competence. The programs apply to all personnel who handle nuclear weapons, nuclear weapon systems, or nuclear components, as well as to those who have access to nuclear weapons. DoD and DOE personnel reliability programs ensure authorized access to nuclear weapons is limited to those personnel who have been carefully screened and certified.

Before personnel are assigned to designated DoD-PRAP or DOE-HRP positions, a screening process is conducted that includes:

- personal security investigation and the granting of a security clearance;
- medical evaluation or screening to determine the fitness of the individual;
- review of relevant quality indicators through a check of the individual's personnel file and any other locally available, and relevant, information;
- verification of professional qualifications to ensure the individual is qualified to perform the duties required of the position assigned; and
- personal interview to stress the importance of the duties assigned and provide an opportunity for the individual to disclose information that may affect the final decision to be certified under the applicable reliability program.

The certifying official is responsible for determining a person's overall reliability and for assigning the individual to a substantive nuclear weapons-related position.

Once a person begins to perform duties in a DoD-PRAP or DOE-HRP position, the individual is periodically evaluated to ensure continued conformity to reliability standards. Any information raising questions or concerns about an individual's judgment or reliability is subject to review. Personnel who cannot meet the standards are disqualified from the program and relieved of their nuclear weapons-related responsibilities.

Procedural Security

The most important aspect of procedural security is the two-person rule, which requires the presence of at least two cleared PRAP- or HRP-certified, task-knowledgeable individuals whenever there is authorized access to a nuclear weapon. Figure 8.6 depicts the designation of a no-lone zone. Each person is required to be capable of detecting incorrect or unauthorized actions

Figure 8.6 No-Lone Zone

pertaining to the task being performed. Restricted entry to certain sectors and exclusion areas based on strict need-to-know criteria reduces the possibility of unauthorized access.

USE CONTROL

The term use control refers to the collection of measures that facilitate authorized use of nuclear weapons but protect against deliberate unauthorized use. These measures include a combination of weapon design features and operational procedures.

Use control is achieved by designing weapon systems with electronic and mechanical features that prevent unauthorized use and allow authorized use. Not all use control features are installed on every weapon system.

WEAPONS SYSTEM CODED CONTROL

Both strategic nuclear missile systems and strategic heavy bomber aircraft use system coded control. Intercontinental ballistic missile (ICBM) crews require an externally transmitted launch code in order to dispatch a missile. Similarly, ballistic missile submarine (SSBN) crews require an externally transmitted authorization code to launch a submarine-launched ballistic missile (SLBM). Strategic bomber crews use a pre-arming circuit that also requires an externally transmitted authorization code to employ nuclear bombs or cruise missiles. The externally transmitted authorization code is received via nuclear control order or emergency action message (EAM), once authorized by the President.

Coded Control Device

A coded control device (CCD) is a component that may be part of or inserted into the overall weapons system to ensure proper use and control (via coded electronic or mechanical means).

Command Disablement System

The command disablement system (CDS) allows for manual activation of the non-violent disablement of essential weapons components, which renders the warhead inoperable. The CDS may be internal or external to the weapon and requires human initiation. The CDS is not installed on all weapon systems.

Active Protection System

The active protection system (APS) senses attempts to gain unauthorized access to weapon-critical components. In response to unauthorized access, critical components are physically damaged or destroyed automatically. This system requires no human intervention for activation and is not installed on all weapons systems.

Environmental Sensing Device

The environmental sensing device (ESD) is a feature placed in the arming circuit of a weapon providing both safety and control. It prevents inadvertent functioning of the circuit until the weapon is launched or released and experiences environmental parameters specific to its particular delivery system. For example, accelerometers are a common tool employed for this purpose, detecting when the delivery system is in flight, so that only then will the warhead arm itself.

Permissive Action Link

A permissive action link (PAL) is a device included in or attached to a nuclear weapon system in order to preclude arming and/or launching until the insertion of a prescribed, discrete code or combination. It may include equipment and cabling external to the weapon or weapon system to activate components within the weapon or weapon system. Most modern U.S. PAL systems include a multiple-code coded switch (MCCS) component. Figure 8.7 illustrates an individual entering a simulated PAL authorization code into a bomb during an exercise.

Figure 8.7 Entering a Simulated PAL Authorization Code

DoD Use Control Program

DoD has broad responsibilities in the area of nuclear weapons use control. DoDI S-3150.07, *Controlling the Use of Nuclear Weapons*, establishes policies and responsibilities for controlling the use of nuclear weapons and nuclear weapons systems. It describes:

- the President as the sole authority for employing U.S. nuclear weapons;
- a layered approach to protecting weapons;
- positive measures to prevent unauthorized access and use;
- methods to counter threats and vulnerabilities; and
- the legal and policy requirements to ensure presidential control while simultaneously facilitating authorized use in a timely manner.

NNSA Use Control Program

Use control responsibilities of NNSA include the design and testing of new use control features and their installation into nuclear weapons. Additionally, the national security laboratories provide technical support to reinforce DoD use control efforts. The NNSA Nuclear Explosive and Weapon Security and Control Program comprises an integrated system of devices, design techniques, and other methods to maintain control of nuclear explosives and nuclear weapons at all times. These use control measures allow use when authorized and directed by proper authority and protect against deliberate unauthorized use (DUU). Major elements of the program include:

- use control measures for nuclear explosives and weapons, including design features incorporated and used at the earliest practical point during assembly and removed at the latest practical point during disassembly or dismantlement; and
- measures to assist in the recapture or recovery of lost or stolen nuclear explosives or nuclear weapons.

The use control program encompasses the development, implementation, and maintenance of standards, plans, procedures, and other measures. These include the production of equipment designed to ensure the safety, security, reliability, and control of nuclear weapons and components in coordination with DoD. NNSA conducts research and development on a broad range of use control methods and devices for nuclear weapons and assists DoD in developing, implementing, and maintaining plans, procedures, and capabilities to store and move nuclear weapons. NNSA also assists other departments in developing, implementing, and maintaining plans, procedures, and capabilities to recover lost, missing, or stolen nuclear weapons or components.

E-4 Airborne Command Post on the EMP Simulator for Testing

CHAPTER 9

NUCLEAR SURVIVABILITY AND EFFECTS TESTING

OVERVIEW

Nuclear survivability is the ability of personnel, equipment, and systems to survive the effects of nuclear weapons. These effects include blast, thermal radiation, nuclear radiation, and electromagnetic pulse (EMP). Effective nuclear survivability requires sustained attention across the life cycle of systems and infrastructure—from the definition of system requirements; through acquisition, testing, and certification; to fielding, training, and maintenance. This chapter provides a basic understanding of the various elements contributing to nuclear survivability.

Furthermore, where an adversary might employ nuclear weapons, U.S. general purpose forces may be called upon to survive and operate through all nuclear environments and effects in order to meet operational goals. Their ability to do so enhances deterrence by removing certain benefits of nuclear use to the adversary and enables DoD to fulfill its missions in the event that deterrence fails.

GOVERNANCE

DoD nuclear weapons survivability policy is established in Department of Defense Instruction (DoDI) 3150.09, *The Chemical, Biological, Radiological,* *and Nuclear (CBRN) Survivability Policy.*[1] The policy establishes the CBRN Survivability Oversight Group (CSOG), which is responsible for:

- overseeing implementation of DoD-CBRN survivability policy;
- ensuring CBRN survivability receives proper emphasis during the development of the defense planning guidance and in the acquisition process during a system's requirements definition phase consistent with the CBRN threat;
- referring recommendations for action to the Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)) or others; and
- conducting other responsibilities as outlined in the instruction.

The CSOG is chaired by the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs (ASD(NCB)), and the day-to-day implementation activities are overseen by two principal-level working groups. The CSOG-CBR for contamination survivability is chaired by the Deputy Assistant Secretary of Defense for Chemical and Biological Defense (DASD/CBD) and the CSOG-N for nuclear survivability is chaired by the Deputy Assistant Secretary of Defense for Nuclear Matters (DASD/NM).

DoDI 3150.09 also establishes the mission-critical system (MCS) designation and reporting process for DoD systems. It is DoD policy that the MCS components of the force are equipped to survive and operate in chemical, biological, and radiological (CBR) or nuclear environments as a deterrent to adversary use of weapons of mass destruction against the United States, its allies, and interests. The ability of the force to operate in these environments must be known and assessed on a regular basis and MCS must survive and operate in the CBR, nuclear, or in combined CBRN environments.

The process for reporting those systems is run by the Office of the ASD(NCB). The mission-critical reports (MCRs) identify the mission-critical systems of the Military Departments and Missile Defense Agency (MDA), and the CBRN environments, and assess the current survivability status of their CBRN MCS. Once all the reports are complete, the Military Departments and the MDA review all CBRN MCRs for gaps and limitations in the CBRN survivability of the systems and infrastructure upon which the Military Departments and the MDA rely, and provide a summary of the review to the ASD(NCB). After the MCRs and summary reviews are complete, the Combatant Commanders (CCDRs) review for adequacy in supporting the Combatant Command's (CCMD) operational, contingency, and other plans, which may require

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[1] DoDI 3150.09 was first issued in September 2008 and subsequently updated in 2015; the current version is Change 2, published on August 31, 2018.

operations in CBR-contaminated environments, nuclear environments, or combined CBRN environments. The Joint Staff reviews the CCDRs' assessments and provides (1) an assessment to the ASD(NCB) on the posture of DoD to operate successfully in CBR environments and nuclear environments, and (2) written guidance, if necessary, to the Military Departments and the MDA on which systems should be added to the MCRs.

STRATEGIC RADIATION-HARDENED ELECTRONICS COUNCIL

Strategic radiation-hardened (SRH) electronics technology involves components manufactured to allow exceptional resilience to high levels of radiation. SRH electronics are critical to the execution of military systems that must operate in weapon-induced radiation environments.

The overall market for SRH electronics is small compared with that of non-hardened electronics. While commercial space satellites use electronics hardened to the natural space environment, DoD and DOE are the principal customers for electronics required to meet higher levels of radiation associated with man-made radiation environments. Therefore, it is imperative that trusted and assured SRH electronics and technologies that meet the stringent requirements for DoD and DOE use are readily available and accessible.

The Strategic Radiaton-Hardened Electronics Council (SRHEC) was established to ensure U.S. government (USG) continued access to SRH electronics. In addition, the SRHEC addresses space-related, radiation-hardened electronics in the event issues arise requiring the support of the Council to ensure continued access to these components.

The SRHEC, via its Executive Secretariat and Technical Execution Lead, conducts periodic, DoD-wide assessments of program needs and requirements for SRH electronics. SRH electronics may be required for both strategic and non-strategic weapons.

The Council consists of two Council Chairs, DASD(NM) and Deputy Director, Research, Technologies and Laboratories in OUSD(R&E); an Executive Secretariat (Council-selected), a Technical Execution Lead, Naval Surface Warfare Center (NSWC) Crane; and Council Members from across the USG with equities in SRH electronics.

NUCLEAR WEAPON EFFECTS SURVIVABILITY AND NUCLEAR WEAPON SYSTEM SURVIVABILITY

Nuclear weapons survivability is comprised of two distinct and overlaying principles—nuclear weapons effects survivability and nuclear weapon system survivability. Nuclear weapon effects survivability applies to the ability of any and all personnel and equipment to withstand the effects of a nuclear detonation; this includes, but is not limited to, the survivability of nuclear weapon systems.

Nuclear weapon system survivability is concerned with the ability of U.S. nuclear deterrent forces to survive against the entire threat spectrum that includes, but is not limited to, nuclear weapon effects. The range of potential threats include:

- conventional and electronic weaponry;
- nuclear, biological, and chemical weapons;
- advanced technology weapons, such as high-power microwaves and radio frequency weapons;
- terrorism or sabotage; and
- initial and persistent effects of a nuclear detonation.

NUCLEAR WEAPON EFFECTS SURVIVABILITY

Survivability of **EVERYTHING**
- Nuclear Weapons
- Nuclear Force Personnel
- Nuclear Force Equipment
- Conventional Weapons
- Conventional Force Personnel
- Conventional Equipment

Against the effects of **NUCLEAR WEAPONS**

NUCLEAR WEAPON SYSTEM SURVIVABILITY

Survivability of **NUCLEAR FORCES**
- Nuclear Weapons
- Nuclear Force Personnel
- Nuclear Force Equipment

Against the effects of **ANY THREAT**
- Nuclear Weapons
- Chemical Weapons
- Biological Weapons
- Conventional Weapons
- Advanced Technology Weapons
- Sabotage
- Terrorist Attack

Figure 9.1 Nuclear Weapon Effects vs System Survivability

See Figure 9.1 for a summary of the differences between nuclear weapon effects and nuclear weapon system survivability. An overlap occurs when the threat to the survivability of a nuclear weapon system is a nuclear detonation and its effects. Figure 9.2 illustrates the intersection between nuclear effects survivability and system survivability.

NUCLEAR HARDNESS

Nuclear hardness describes the ability of a system to withstand the effects of a nuclear detonation and to avoid internal malfunction or performance degradation. Hardness measures the ability of a system's hardware to withstand physical effects such as overpressure, peak velocities, absorbed energy, and electrical stress.

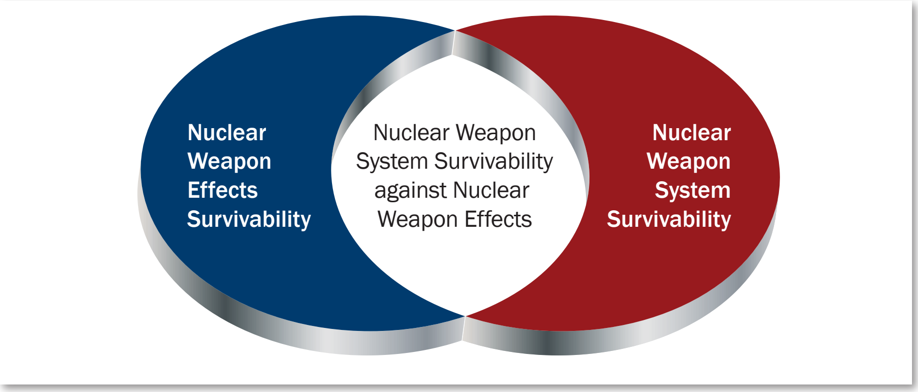

Figure 9.2 Intersection of Nuclear Weapons Effects Survivability and System Survivability

Reduction in hardware vulnerability can be achieved through a variety of well-established design specifications or through the selection of well-built and well-engineered components. (This chapter does not address residual nuclear weapon effects such as fallout, nor does it discuss nuclear contamination survivability.[2])

NUCLEAR WEAPON EFFECTS SURVIVABILITY

Each of the primary (e.g., blast, thermal, and prompt radiation) and secondary (e.g., delayed radiation) environments produced by a nuclear detonation cause a unique set of mechanical and electrical effects. Some effects are permanent while others are transient; however, both can cause system malfunction, system failure, or loss of combat capability.

Nuclear Weapon Effects on Military Systems

The nuclear environments and effects that may threaten the survivability of a military system vary with the altitude of the explosion. The dominant nuclear environment refers to the effects that set the survival range between the target and the explosion.[3] Low-altitude, near-surface, and surface bursts damage most ground targets within the damage radii, which is principally a function of the yield of the weapon. Also, high-altitude bursts produce high-altitude electromagnetic pulse (HEMP) effects over a large area that may damage equipment containing vulnerable electronics on the ground and in the air. Figure 9.3 illustrates the dominant nuclear environments that drive survivability

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[2] For more information on fallout and nuclear contamination, see Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons, 3rd Edition* (U.S. Department of Defense and U.S. Department of Energy, 1977), https://www.dtra.mil/Portals/61/Documents/NTPR/4-Rad_Exp_Rpts/36_The_Effects_of_Nuclear_Weapons.pdf.

[3] The survival range measures the distance from the detonation necessary to survive nuclear weapon effects.

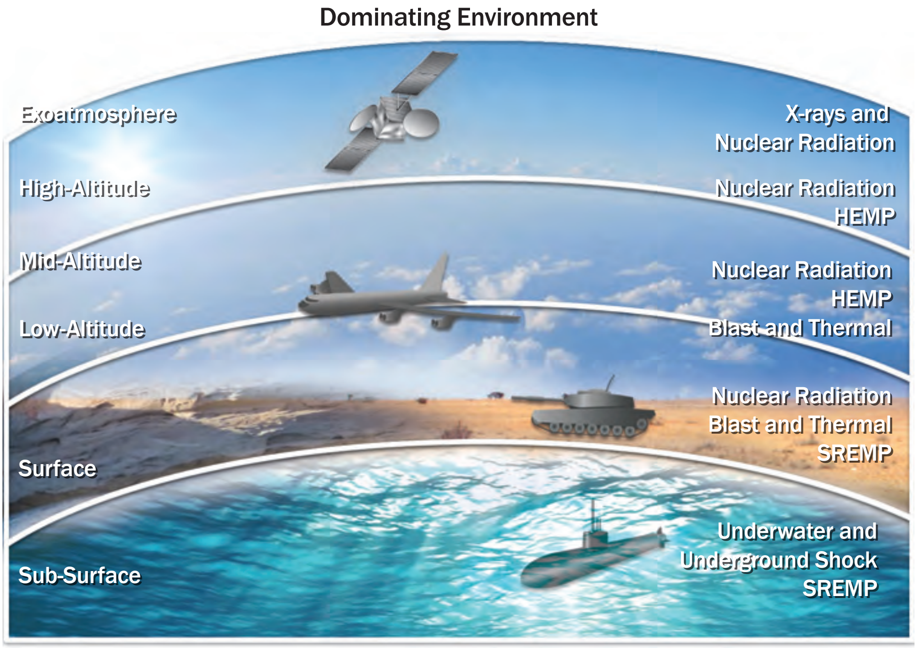

Figure 9.3 Dominant Nuclear Environments as a Function of Altitude

requirements for typical military systems as a function of height of burst ranging from space to below ground.

Nuclear weapon-generated X-rays are the chief threat to the survival of strategic missiles in flight above the atmosphere and to satellites. Neutron and gamma ray effects also create serious problems for these systems but do not normally set the survivability range requirements. Neutron and gamma ray effects dominate at lower altitudes where the air absorbs most of the X-rays. Air-blast and thermal radiation effects usually dominate the survival of systems at or near the surface; however, neutrons, gamma rays, and source-region EMP (SREMP) may also create problems for structurally hard systems that are near the detonation. SREMP is produced by a nuclear burst within several hundred meters of the Earth's surface and is localized out to a distance of three to five kilometers from the burst. SREMP can couple into electrical power lines and other long conductors leading to the potential for damage beyond the localized SREMP field. The final result of the detonation-generated EMP is a tremendous surge of low-frequency electric fields that can couple into a system through designed and unintended antennas, generating a flow of electrical current that overloads and destroys electrical components and renders the equipment nonoperational.

Underwater shock and ground shock are usually the dominant nuclear weapon effects for submerged submarines and buried facilities, respectively. HEMP is the dominant threat for surface-based systems located outside the target zone such as command, control, communications, computers, and intelligence (C4I) facilities or sophisticated electronics associated with ground-based defense systems and equipment.

Nuclear weapon effects survivability requirements vary with the type of system, its mission, operating environment, and the threat. For example, the X-ray, gamma ray, and neutron survivability levels used for satellites are lower than the survivability levels used for missiles and reentry vehicles (RVs) or reentry bodies (RBs). Satellite levels are usually set so that a single nuclear weapon, detonated in the region containing several satellites, does not damage or destroy more than one satellite. The levels used for RVs, however, are very high because the RV or RB is the most likely component of an intercontinental ballistic missile (ICBM) or a submarine-launched ballistic missile (SLBM) to be attacked by a nuclear weapon at close range. The ICBM or SLBM bus and booster have a correspondingly lower requirement in consideration of its range from the target and the time available to target them. Surface-launched missiles and associated buses and payloads are the most challenging systems to design for survivability. They are typically designed to survive the effects of air blast, thermal radiation, HEMP, ionizing radiation, SREMP, and even X-rays in the course of their payload delivery.

When a system is deployed within the Earth's atmosphere, the survivability criteria are different. Systems operating at lower altitudes do not have to consider X-ray effects because the range of damaging X-ray effects is typically contained inside the range for the more dominant thermal and blast effects. Outside the range for damaging blast effects, gamma rays and neutrons generally set the survival range for most systems operating at lower altitudes. The survival ranges associated with gamma rays and neutrons are generally so great that these ranges overcome problems from air blast and thermal radiation. Two of the most challenging problems in this region are the prompt gamma ray effects on electronics, which can disrupt or damage sensitive electronics components, and the total radiation dose delivered to personnel and electronics.

Between an altitude of 10 kilometers and the Earth's surface, there is a transition region in which the denser air begins to absorb more of the ionizing radiation and the air-blast environment becomes more dominant. Aircraft in this region have to survive combined air-blast, thermal radiation, and nuclear radiation effects.

On the Earth's surface, air blast and thermal radiation are the dominant nuclear weapon effects for personnel who must be at a safe distance from the range of these two effects in order to survive. Because of this, air blast and thermal radiation typically set the safe distance, or survival range requirements, at the surface for most systems and particularly for nuclear weapons with yields exceeding 10 kilotons (kt).

This is not necessarily true for blast-hardened systems such as battle tanks or hardened facilities designed to survive closer to a nuclear detonation. The very high levels of ionizing radiation associated with a nuclear detonation usually require systems to be at greater distances from the detonation to avoid personnel casualties and damage to electronic equipment. This is especially true for lower yield weapons, where the effects of radiation can be dominant compared to the air blast. For example, a battle tank survives at a distance of less than half of a kilometer from a 10-kt explosion if the only consideration is structural damage to the tank. However, at the same distance ionizing radiation from the detonation may significantly affect the crew and the tank's electronics.

Because line-of-sight thermal effects are easily attenuated by intervening material (e.g., buildings or trees) and have a large variation of effect on the target, they are harder to predict. Traditionally, thermal effects were not taken into consideration when targeting. Advanced computer modeling and simulation of thermal effects are now at a state of maturity that they can be used to assess effects on buildings, personnel, and equipment. Estimates of ignition probability (the likelihood of fire) for buildings in urban environments can be used to provide higher-fidelity estimates of damage and casualties.

Nuclear Weapon Effects on Personnel

Several of the effects of nuclear weapons are a threat to personnel. The flash from a nuclear weapon can cause temporary blindness to unprotected eyes, even when not looking directly at the detonation. Thermal radiation can cause burns directly to the skin or can ignite clothing, but only via direct line-of-sight exposure. Initial nuclear radiation (gamma rays and neutrons) can cause an acute dose of ionizing radiation leading to degraded performance, radiation sickness, and death. Residual radiation can cause significant exposure for days to weeks after the detonation. The blast wave can cause immediate casualties to exposed personnel or could impact and roll a vehicle causing personnel injuries. EMP does not cause injuries directly but can cause casualties indirectly (e.g., via the instantaneous destruction of electronics in an aircraft in flight).

Effects survivability concepts for manned systems must consider the effect of a temporary loss of the "man-in-the-loop" and, therefore, devise ways of overcoming the problem. Hardened structures provide increased personnel protection against all nuclear weapon effects. As a rule of thumb, survivability criteria for manned systems are based on the ability of 50 percent of the crew to survive the nuclear event and complete the mission; therefore the equipment should be at least as survivable as the crew, and often more survivable than the crew, depending on mission and overall survivability strategy.

Nuclear Weapon Effects Survivability Measures

Nuclear weapon effects survivability may be accomplished by timely resupply, redundancy, mitigation techniques (to include operational techniques), or a combination thereof, as well as hardening. Because these survivability measures can increase the cost and complexity of a system or price of equipment, it is often necessary to consider trade-offs in design and acquisition strategies. It is also important, however, to evaluate the potential consequences of a nuclear attack, despite its low likelihood, and adequately mitigate foreseeable risks.

Timely resupply is the fielding and positioning of extra systems or spares in the theater of operation that can be used for timely replacement of equipment lost to nuclear weapon effects. The decision to rely on reserve assets can significantly affect production because using and replacing them would result in increased production quantities and costs.

Redundancy is the incorporation of extra components into a system or piece of equipment, or the provision of alternate methods to accomplish a function so if one fails, another is available. The requirement for redundancy increases production quantities for the redundant components and may increase the cost and complexity of a system.

Mitigation techniques are methods used to reduce the vulnerability of military systems to nuclear weapon effects. These may include but are not limited to:

- *Avoidance*, such as the incorporation of measures to eliminate detection and attack. Avoidance techniques are very diverse. For example, avoidance may include stealth tactics that use signal reduction or camouflage. This approach may or may not affect production and can be costly.
- *Active defense*, such as radar-jamming or missile defense systems. Active defense can be used to enhance a system's nuclear weapon effects survivability by destroying incoming nuclear weapons or causing them to detonate outside the susceptible area of the protected system.
- *Deception*, such as the employment of measures to mislead the enemy regarding the actual system location. These measures include decoys, chaff, aerosols, and other ways to draw fire away from the target. The effect of deception on production depends on the approach. Some deception measures can be quite complex and costly, such as the decoys for an ICBM system, while others can be relatively simple and inexpensive.

- *Hardening* is the employment of any design or manufacturing technique that increases the ability of an item to survive the effects of a nuclear environment. Systems can be nuclear hardened to survive prompt nuclear weapon effects, including blast, thermal radiation, nuclear radiation, EMP, and in some cases, transient radiation effects on electronics (TREE). Hardening mechanisms include shielding, robust structural designs, electronic circumvention, electrical filtering, and vertical shock mounting.

Hardening impacts production by increasing the complexity of the product. Therefore, hardening measures are less costly if designed and produced as a part of the original system rather than as a retrofit design modification. Production controls to support hardness assurance, especially in strategic systems, may also be required.

Mechanical and structural hardening consists of using robust designs, protective enclosures, protective coatings, and the proper selection of materials. Electronics and electrical effects hardening involve using the proper components, special protection devices, circumvention circuits, and selective shielding. Nuclear weapon effects on personnel are minimized by avoidance, radiation shielding protection, and automatic recovery measures. The automatic recovery measures compensate for the temporary loss of the "man-in-the-loop" and mitigate the loss of military function and the degradation of mission accomplishment.

Trade-off analyses are conducted during the acquisition process of a system to determine the method or combination of methods that provide the most cost-effective approach to nuclear weapon effects survivability. The impact of the approach on system cost, performance, reliability, maintainability, productivity, logistics support, and other requirements is examined to ensure maximum operational effectiveness consistent with program constraints. However, the different approaches to hardening are not equally effective against all initial nuclear weapon effects.

Threat effect tolerance is the intrinsic ability of a component or piece of equipment to survive some level of exposure to nuclear weapons effects. The exposure levels that equipment can tolerate depends primarily on the technologies it employs and how it is designed. The nuclear weapon effects survivability of a system can be enhanced when critical elements of the system are reinforced by selecting and integrating technologies that are inherently harder. This approach may affect production costs because harder components may be more expensive.

NUCLEAR WEAPON SYSTEM SURVIVABILITY

Nuclear weapon system survivability refers to the ability of a nuclear weapon system to withstand exposure to a full spectrum of threats without suffering a loss of ability to accomplish its mission. Nuclear weapon system survivability applies to a nuclear weapon system in its entirety. The entire nuclear weapon system includes all mission-essential assets, the nuclear weapon, and delivery vehicle and platform as well as associated support systems, equipment, facilities, and personnel. Included in a system survivability approach is the survivability of the delivery vehicle (RB, RV, missile, submarine, or aircraft), personnel operating the nuclear weapon system, supporting command and control links, and supporting logistical elements.

System survivability is a critical concern whether nuclear weapons and forces are non-dispersed, dispersing, or already dispersed. The capability to survive in all states of dispersal enhances both the deterrent value and the potential military utility of U.S. nuclear forces.

Nuclear Force Survivability

DoDI 3150.09 establishes policy and procedures for ensuring the survivability of CBRN MCS, which includes all U.S. strategic and tactical nuclear forces, and many U.S. general purpose forces, in CBR, nuclear, or combined CBRN environments. Nuclear survivability is defined in DoDI 3150.09 as "the capability of a system or infrastructure to withstand exposure to nuclear environments without suffering loss of ability to accomplish its designated mission through its life cycle. Nuclear survivability may be accomplished by hardening, timely resupply, redundancy, mitigation techniques (including operational techniques), or a combination. Includes EMP survivability."

It is often difficult to separate measures to enhance survivability from those that provide security. Therefore, in addition to the instruction governing survivability (DoDI 3150.09), DoD Directive (DoDD) 5210.41, *Security Policy for Protecting Nuclear Weapons* and its corresponding manual, DoD S-5210.41-M, govern nuclear force security.

For instance, in hostile environments, hardened nuclear weapon containers as well as hardened weapon transport vehicles provide security and enhance survivability during transit. Many of the measures to enhance nuclear weapon system survivability and protect against the effects of nuclear weapons can be the same. Hardening and redundancy, for example as well as threat tolerant designs, resupply, and mitigation techniques apply to both.

Nuclear Command and Control Survivability

Nuclear weapon systems include the nuclear weapons and the associated nuclear command and control. The security and survivability of weapons systems command and control is addressed in DoDI 3150.09, DoDD 5210.41, DoD 5210.41-M, and DoDD S-5210.81, *United States Nuclear Weapons Command and Control*. These documents establish policy and assign responsibilities and state that the command and control of nuclear weapons shall be ensured through a fully survivable and enduring Nuclear Command and Control System. DoD supports and maintains survivable and enduring facilities for the President and other officials to perform essential nuclear command and control (NC2) functions. The USD(A&S), in conjunction with the Military Departments, establishes survivability criteria for related nuclear weapon equipment. See *Chapter 2: Nuclear Weapons Employment Policy, Planning, and NC3* for more information on Nuclear Command and Control.

Missile Silos

The survivability of ICBM silos is achieved through the physical hardening of the silos and through their underground location, which protects against air-blast effects. The geographical dispersal of the missile fields also adds to system survivability by complicating any adversary targeting calculations.

Containers

Nuclear weapon containers can provide ballistic protection as well as protection from nuclear and chemical contamination. Containers can also provide safety, security, and survivability protection.

Weapon Storage Vault

A weapon storage vault (WSV) is an underground vault located in the floor of a hardened aircraft shelter. A WSV holds up to four nuclear weapons and provides ballistic protection in the lowered position through its hardened lid and reinforced sidewalls. The United States calls the entire system the *weapon storage and security system,* whereas the North Atlantic Treaty Organization (NATO) refers to it as the *weapon security and survivability system*. However, both the United States and NATO denote the entire system by the same acronym, WS3. The WS3 is currently in use in Europe.

MILITARY STANDARDS

The Defense Threat Reduction Agency (DTRA) and its predecessor agencies have developed, and regularly update, military standards (MIL-STDs) designed to aid in the design, development, test, and evaluation of DoD systems subjected to nuclear and EMP environments. These MIL-STDs cover nuclear-generated EMP survivability of aircraft, maritime, and ground-based systems and are developed in coordination with the Air Force and the Navy as well as the broader community of stakeholders. The following are some of the relevant MIL-STDs:

MIL-STD-1766, *Nuclear Hardness and Survivability Program Requirements for ICBM Weapon Systems* defines nuclear hardness and survivability requirements and practices for use during the concept exploration, demonstration and validation, full-scale development, production, and deployment phases of the acquisition life cycle of ICBM weapon systems.

MIL-STD-2169C, *HEMP Environment Standard* (Classified) defines high-altitude EMP threat environments for system hardness design and testing.

MIL-STD-3023, *HEMP Protection for Military Aircraft* establishes design margin, performance metrics, and test protocols for HEMP protection of military aircraft providing three hardness levels for nuclear EMP survivability. This MIL-STD may also be used for aircraft that support multiple missions. Subsystems of the aircraft required to fully comply with the provisions of the standard are designated as mission-critical subsystems having a HEMP survivability requirement. This approach also allows for consideration of platforms not yet addressed in this standard, such as Unmanned Aerial Vehicles.

MIL-STD-188-125, *HEMP Protection for Fixed and Transportable Ground-Based C4I Facilities Performing Critical, Time Urgent Missions* is in the process of being updated. DTRA is investigating present capabilities and shortfalls of power filters as well as implementing lessons learned from simulated EMP testing.

MIL-STD-4023, *HEMP Protection for Military Surface Ships* establishes performance metrics, test protocols, and hardness margin levels for HEMP protection of military surface ships that must function when subjected to a HEMP environment.

Satellite System Nuclear Survivability (SSNS) Environment Standard defines nuclear weapon environment levels for evaluating satellite system performance in nuclear scenarios.

Comprehensive Atmospheric Nuclear Environments Standard (CANES) provides detailed nuclear environments for a number of different nuclear weapon-types as a function of height of burst. A supplement to this MIL-STD covers nuclear-disturbed communication environments and nuclear ground burst environments.

NUCLEAR WEAPONS EFFECTS TESTING[4]

Nuclear weapon effects testing refers to tests conducted to measure the response of objects to the energy output of a nuclear weapon. Testing, which since 1992 has been conducted in the United States through the use of simulators and not actual nuclear detonations, remains essential to the development of nuclear-

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[4] Please refer to *Chapter 13: Basic Nuclear Physics and Weapons Effects* for a detailed discussion of nuclear weapons effects themselves.

survivable systems while test and evaluation of nuclear hardness is considered throughout the development and acquisition process for defense programs. These testing and analysis methods are well-established and readily available, although there is continued need to ensure simulator capabilities are maintained for both DoD and NNSA needs. Modeling and simulation plays an important role in nuclear weapon effects survivability design and development. Computer-aided modeling, simulation, and analysis complements testing by helping engineers and scientists to estimate the effects of the various nuclear environments, design more accurate tests, predict experimental responses, select the appropriate test facility, scale testing to the proper level and size, and evaluate test results. Analysis also helps to predict the response of systems that are too costly or difficult to test.

Simulators used to test nuclear weapons effects are usually limited to a relatively small exposure volume and generally used for single nuclear environment tests, such as X-ray, neutron, prompt gamma ray, or EMP effects. Free-field EMP, high explosive (HE), and shock tube facilities are notable exceptions because these facilities can accommodate system-level testing in many cases. Additionally, the Army Fast Burst Reactor (FBR) at White Sands Missile Range is capable of full-system tests in some cases.

Figure 9.4 lists the types of simulators commonly used for nuclear weapon effects testing. DTRA maintains a *Guide to Nuclear Weapon Effects Simulation Facilities and Applications – Support for the Warfighter*, currently in the 2020 edition, which includes comprehensive descriptions of all available facilities in the United States for nuclear survivability testing. Many of these facilities are currently in the process of being recapitalized or need to be recapitalized.

X-RAY EFFECTS TESTING

X-ray environments are the most challenging to simulate in a laboratory. Historically, underground nuclear effects tests were done principally to study X-ray effects. Existing X-ray facilities only partially compensate for the loss of nuclear explosive testing, and opportunities for improving the capabilities of X-ray facilities are both limited and costly.

Because X-rays are rapidly absorbed in the atmosphere, they are only of concern for systems that operate in space or at high-altitude. Additionally, the X-ray environment within a system is a strong function of the distance and orientation of the system with respect to the nuclear burst.

X-ray effects tests are usually conducted using flash X-ray machines (FXRs) and plasma radiation sources. FXRs are used to simulate the effects from higher-energy hard (hot) X-rays whereas plasma radiation sources are used to simulate the effects from lower-energy (and longer wavelength) soft (cold) X-rays.

Test	Type of Simulator	Test Article
X-ray Effects (Hot)	• Low-Voltage Flash X-ray Machines	• Components and small assemblies
X-ray Effects (Cold)	• Plasma Radiator	• Components
Gamma Ray Effects	• Flash X-ray Machines • Linear Accelerator • Fast Burst Reactor	• Components, circuits, and equipment
Total Dose Gamma Effects	• Cobalt 60 • Fast Burst Reactor	• Components, circuits, and equipment
Neutron Effects	• Pulsed Reactors • Neutron Surrogates (i.e., ions) • Neutron Spallation Sources	• Components, circuits, and equipment
Blast Effects (Overpressure)	• Small Shock Tubes • Large Shock Tubes • HE Tests	• Components, parts, and equipment • Small systems and large equipment • Vehicles, radars, shelters, etc.
EMP	• Pulsed Current Injection (PCI) • Free Field	• Point of Entry (POE) Systems • Aircraft and vehicles
Thermal Effects	• Thermal Radiation Source (TRS) • Flash Lamps and Solar Furnace	• Equipment, large components • Components and materials
Shock Effects (Dynamic Pressure and Overpressure)	• Large Blast Thermal Simulator (LBTS) • Explosives	• Equipment, large components • Systems

Figure 9.4 Simulators Commonly Used for Effects Testing

FXRs store large amounts of electric energy, which is converted into intense, short pulses of energetic electrons. The rapid discharge of this much energy in a short time period results in power levels ranging from billions to trillions of watts. The electrons are normally accelerated into a metal target that converts a small portion of their energy into a pulse of X-rays. The resulting photons irradiate the test specimen. The output characteristics of FXRs depend on the design of the machine and vary considerably from one design to the next. Radiation pulse duration ranges from 10 to 100 nanoseconds and output energies range from a few joules for the smallest machines to several hundred kilojoules for the largest.

X-ray effects testing usually requires a machine capable of producing high power with an output voltage of around one million volts. The resulting radiation tends to resemble the hard X-rays and gamma rays that reach components inside enclosures. Lower output voltages are needed to produce the warm X-rays that are important to many internal component responses. The machine's output energy and power usually determine the exposure level and test area and volume. Most X-ray tests in small FXR machines are limited to components and small assemblies. Larger machines can be used for electronic boxes and sub-assemblies.

Soft X-ray effects testing is designed to replicate surface damage to exposed components in space applications and is normally performed with a plasma radiation source (PRS). The PRS machine generates cold X-rays by driving an intense pulse of electric energy into a bundle of fine wires or a gas puff to rapidly compress a plasma column into a hot, dense plasma that radiates both thermal X-rays and intense line radiation from highly excited ions. The energy of the photons produced by the PRS is a function of the wire material or gas and tends to be in the 1 to 14 kiloelectron-Volt (keV) range. These X-rays have very little penetrating power and deposit most of their energy on the surface of the exposed objects. The exposure level and test volume depends on the size of the machine. Test objects are normally limited to small material samples and components. Coated optics used in satellite and missile defense interceptors can be sensitive to damage from fairly low cold X-ray fluences. The surfaces of RVs and RBs of nuclear warheads can be damaged by the rapid vaporization of surface materials that causes a rocket effect that drives a pressure pulse into the surface called "blow-off impulse." The high fluences required for blow-off impulse testing limits the test object sizes to small material coupons.[5] Figure 9.5 shows the electromagnetic spectrum for the shortest to the longest wavelength which includes all radio waves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays.

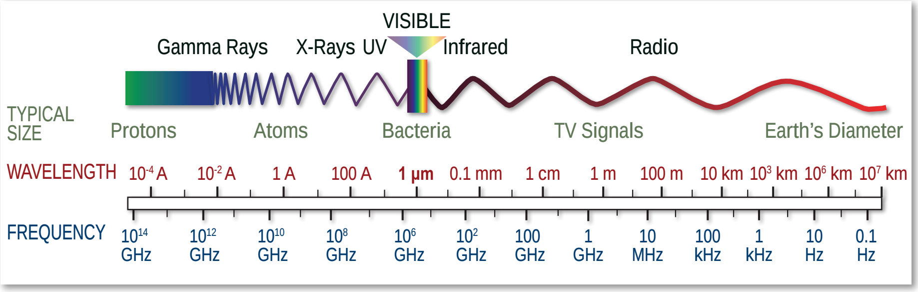

Figure 9.5 Electromagnetic Spectrum

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[5] A coupon is a small sample of the material under test that has been prepared in such a way that its failure mechanism will be representative of the larger production pieces.

The National Ignition Facility (NIF) located at the Lawrence Livermore National Laboratory (LLNL) in California uses high-energy laser beams to create plasma radiating sources generating cold-warm X-rays for component-level testing. Larger test objects can be subjected to blow-off impulse testing using light-initiated high explosives (LIHE) or magnetically driven flyer plates that do not use X-rays and only simulate the pressure pulse seen by the overall system. There is also a new blow-off simulation technique called direct laser impulse (DLI) under development that uses lasers and transparent surface coating to efficiently generate impulse on surfaces without X-rays.

Currently, there are a number of pulsed-power facilities used to generate X-ray environments. NNSA operates the LIHE, Saturn, and Z facilities at Sandia National Laboratories (SNL) and the NIF at LLNL. DoD operates the Modular Bremsstrahlung Source (MBS), Pithon, Short Pulse Gamma, and Double Eagle at the DTRA West Coast Facility in California. These facilities are currently in various states of readiness and are under investigation for replacement based on predicted future test and evaluation needs.

GAMMA DOSE-RATE EFFECTS TESTING

All solid-state components are affected by the rapid ionization produced by prompt X-rays and gamma rays. Gamma dose-rate effects dominate TREE in non-space-based electronics and the effects do not lend themselves to strict analyses because these are usually nonlinear and are very difficult to model. Circuit analysis is often helpful in bounding the problem, but only active tests have proven to be of any real value in replicating the ionizing effects on components, circuits, and systems.

Two machines used for gamma dose-rate testing are FXRs and linear accelerators (LINACs). The FXRs used for gamma dose-rate effects tests operate at significantly higher voltages than FXRs used for X-ray effects tests and produce X-ray radiation that is equivalent in photon energy to the prompt gamma rays produced by an actual nuclear explosion.

LINACs are primarily used for component-level tests because the beam produced by most LINACs is fairly small in size and of relatively low intensity. LINACs produce a pulse or a series of sub-nanosecond pulses of very energetic electrons. The electron pulses may be used to irradiate test objects or to generate bremsstrahlung radiation.[6]

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[6] *Bremsstrahlung* is literally "braking radiation." It is caused by the rapid deceleration of charged particles interacting with atomic nuclei and produces electromagnetic radiation covering a range of wavelengths and energies in the X-ray regions.

LINACs are restricted to piece-part size tests and are typically operated in the electron beam mode when high-radiation dose rates are required. The biggest drawbacks to the use of LINACs are their low temporal fidelity, small exposure volume, and relatively low-output intensity.

Most dose-rate tests are active, that is, they require the test object to be powered up and operating for testing. Effects such as component latch-up, logic upset, and burnout, can only occur using active testing. Tests must be conducted in a realistic operating condition and the test object must be continuously monitored before, during, and after exposure.

SNL operates the High-Energy Radiation Megavolt Electron Source (HERMES) pulsed-power facility to simulate prompt gamma environments at extreme dose rates for NNSA. DoD currently operates smaller gamma ray facilities used to test systems at lower levels, including the Pulserad 1150 and the Short Pulse Gamma at the DTRA West Coast Facility in California, the Pulserad 958 and linear accelerator (LINAC) at Hill Air Force Base (AFB) in Utah, and the LINAC Facility at White Sands Missile Range in New Mexico.

TOTAL DOSE EFFECTS TESTING

The objective of total dose effects testing is to determine the amount of performance degradation suffered by components and circuits exposed to specified levels of gamma radiation. A widely used simulator for total dose effects testing is the cobalt-60 (Co60) radioactive isotope source. Other sources of radiation, such as high-energy commercial X-ray machines, LINACs, and the gamma rays from nuclear reactors, are also used for testing.

NEUTRON EFFECTS TESTING

The objective of most neutron effects testing is to determine the amount of performance degradation in susceptible parts and circuits caused by exposure to a specified neutron fluence at a specified pulse width. Neutron effects on electronics can be simulated using a number of platforms including the FBR at White Sands Missile Range, the pulsed Annular Core Research Reactor (ACRR) located at SNL, the Ion Beam Laboratory surrogate source located at SNL, or the Los Alamos Neutron Science Center (LANSCE) neutron spallation source located at Los Alamos National Laboratory (LANL). Other platforms exploiting nuclear fusion reactions such as the NIF at LLNL and the Z Facility at SNL are currently being investigated for neutron sources, as are techniques using Dense Plasma Focus (DPF); these could potentially provide pulsed neutron capability for future effects testing.

AIR-BLAST EFFECTS TESTING

The military relies more on structural analyses for determining air-blast effects than on testing. This is because of the confidence engineers have in computer-aided structural analyses and the difficulty and costs associated with air-blast testing. Exposed structures and equipment like antennas, radars, radomes, vehicles, shelters, and missiles that have to be evaluated for shock and blast effects are usually subjected to an evaluation consisting of a mix of structural analyses, component testing, or scale-model testing. The evaluation may also include full-scale testing of major assemblies in a HE test or in a large shock tube.

Shock tubes vary in size from small laboratory facilities to large, full-scale devices. The Army Large Blast Thermal Simulator (LBTS) was refurbished for blast in 2018 and is undergoing refurbishment for thermal; it can accommodate test objects as large as a helicopter. The LBTS replicates ideal and non-ideal air-blast environments. Shock tubes have the advantage of being able to generate shock waves and over-pressures with the same positive phase-time duration as the actual nuclear blast environment.

HE tests were conducted by the Defense Nuclear Agency, the DTRA predecessor, at Stallion Range located at White Sands Missile Range. These tests were used to validate the survivability and vulnerability of many systems before the LBTS became operational. The explosive source was normally several thousand tons of ammonium nitrate and fuel oil (ANFO) housed in a hemispherical dome. The test objects were placed around the dome at distances corresponding to the desired peak overpressure, or dynamic pressure of an ideal blast wave. HE tests produced shock waves with fairly short positive duration corresponding to low-yield nuclear explosions. HE test results needed to be extrapolated for survivability against higher yield weapons and for non-ideal air-blast effects. Structures composed of heat sensitive materials, such as fiberglass and aluminum, which lose strength at elevated temperatures, are normally exposed to a thermal radiation source before the arrival of the shock wave.

ELECTROMAGNETIC PULSE EFFECTS TESTING

There are two general classes of EMP effects tests: injection tests and free-field tests. An injection test simulates the effects of the currents and voltages induced by HEMP on cables by artificially injecting current pulses onto equipment cables and wires. Injection tests are particularly well-suited to the evaluation of interior equipment that is not directly exposed to HEMP.

A free-field test is used to expose equipment, such as missiles, aircraft, vehicles, and radar antennas, to HEMP. Most free-field HEMP testing is performed with either a broadcast simulator or a bounded wave EMP simulator. Both types of simulators use a high-power electrical pulse generator to drive the radiating elements. In the broadcast simulator, the pulse generator drives an antenna that broadcasts simulated EMP to the surrounding area. Objects are positioned around the antenna at a range corresponding to the desired electrical field strength. The operation of the equipment is closely monitored for upset and damage. Current and voltage measurements are made on equipment cables and wires to determine the electrical characteristics of the EMP energy coupled into the system.

In the bounded wave simulator, the pulse generator drives a parallel plate transmission line consisting of a horizontal or vertical curtain of wires and a ground plane. The test object is placed between the wires and the ground plane. The energy travels down the line, passes the test object, and terminates in a resistive load. As the pulse passes the test object, it is subjected to the electric field between the lines. Some simulators locate test instrumentation in a shielded chamber below the ground plane.

Free-field EMP simulators are available at the Patuxent River Naval Air Station in Maryland and at White Sands Missile Range in New Mexico.

THERMAL RADIATION EFFECTS TESTING

The majority of thermal radiation effects testing is performed with high intensity flash lamps, solar furnaces, or rocket nozzles using liquid oxygen and powdered aluminum, called a thermal radiation source (TRS). Flash lamps and solar furnaces are normally used on small material samples and components. A TRS is used for larger test objects and have been used in conjunction with the large HE tests. LBTS features a thermal source that is also being refurbished that allows test engineers to examine the combined effects of thermal radiation and air blast.

SHOCK TESTING

High-fidelity tests exist to evaluate systems for survivability to nuclear underwater and ground shock effects because, for these factors, conventional explosive effects are very similar to those from nuclear weapons. Machines such as hammers, drop towers, and slapper plates are used for simulating shock effects on equipment. Explosives are also used for shock testing. The Navy uses explosives on floating shock platforms (barges) to simulate underwater shock and subjects one ship of each class to an explosive test at sea. The Army and the Air Force employ similar methods.


White Sands Missile Range is a restricted military installation. No unauthorized frequencies are allowed. Violators will be escorted off the installation and equipment may be confiscated.
CAUTI
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CHAPTER 10

INTERNATIONAL NUCLEAR COOPERATION

OVERVIEW

One of the critical roles of U.S. nuclear weapons is to contribute to the assurance of U.S. allies. The United States provides extended deterrence to a variety of countries and alliances, minimizing the need for other nations to pursue nuclear weapons capabilities of their own. In addition, nuclear terrorism and nuclear proliferation are global problems requiring cooperation among the United States and international partners and allies. The United States engages with North Atlantic Treaty Organization (NATO) allies within the NATO nuclear structure to coordinate operations associated with forward-deployed U.S. nuclear weapons that would be used in defense of NATO allies. The United States participates in various Programs of Cooperation (i.e., legal frameworks for international information exchange) with a number of international partners, including the United Kingdom, France, and NATO itself.[1]

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[1] This chapter deals with U.S. cooperation on nuclear weapons with other countries. While the U.S. nuclear umbrella extends deterrence to U.S. allies in Asia, the U.S. does not share any nuclear weapons related information with any of these non-nuclear nations. The Extended Deterrence Dialogue (EDD) is a U.S.-Japan forum. The Korea-U.S. Integrated Defense Dialogue (KIDD) is a U.S.-Republic of Korea forum. The United States does not currently forward-deploy nuclear weapons in Asia.

Within the United States, the *Atomic Energy Act* (AEA) governs the exchange of nuclear-related information. Sections 91c, 123, and 144 of the AEA describe the different types of exchanges in which the United States may legally engage. According to the AEA, all international information exchanges are predicated on the existence of an Agreement for Cooperation, such as a mutual defense agreement (MDA), with the individual nation or organization. For example, the MDA between the United States and the United Kingdom was originally signed in 1958.[2] This MDA serves as a bilateral treaty between the United States and United Kingdom and is renewed every ten years.

Given the existence of a formal MDA, the AEA further stipulates that all exchanges conducted under the auspices of such an agreement must be approved by the President of the United States. The mechanisms for authorizing specific international transmissions were called presidential determinations. However, in 1959 and 1961, Presidents Eisenhower and Kennedy, respectively, delegated this authority to the Secretary of Defense and the Chairman of the Atomic Energy Commission through Executive Orders (EO) 10841 and 10956. As a result of these orders, presidential determinations became statutory determinations (SDs). EO 10956 stipulates that SDs under certain sections of the AEA must continue to be referred to the President for final approval.

SDs are still the mechanism for authorizing specific information exchanges concerning nuclear weapons with foreign partners. SDs are decided jointly by the Secretaries of Defense and Energy. Each SD must explain the purpose of the international communication (i.e., why the information should be transmitted) and specify the exact nature of what is authorized for transmission. The SD must also delineate any restrictions of what is not transmissible because it is not authorized to be shared. Most SDs relate to weapon design information, although increasingly SDs are being developed and approved to share nuclear information to counter the threats of nuclear terrorism and nuclear proliferation.

U.S. NUCLEAR COOPERATION WITH NATO

On April 4, 1949, the *North Atlantic Treaty* was signed in Washington by the founding members of NATO: Belgium, Canada, Denmark, France, Iceland, Italy, Luxembourg, the Netherlands, Norway, Portugal, the United Kingdom, and the United States. Article 5 of the Treaty guarantees the mutual defense of its

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[2] *The Agreement Between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the United States of America for Cooperation on the Uses of Atomic Energy for Mutual Defense Purposes* is commonly called the Mutual Defense Agreement. The agreement was first signed on July 3, 1958.

members. In December 1949, the first *Strategic Concept for the Defense of the North Atlantic Area* was published which outlined different areas for cooperation among NATO member countries in military doctrine and procedure, combined training exercises, and intelligence sharing.

The Nuclear Planning Group (NPG), established in December 1966, provides a forum for NATO member nations to exchange information on nuclear forces and planning. Held at the ministerial level, the NPG is composed of the defense ministers of NATO nations that take part in the NATO Defense Planning Committee. The NPG serves as the formal Alliance consultative body on nuclear forces planning and employment and is the ultimate authority within NATO with regard to nuclear policy issues. NPG discussions cover a broad range of nuclear policy matters, including the safety, security, and survivability of nuclear weapons; communications and information systems; and deployment issues. The NPG also covers other issues of common concern such as nuclear arms control and nuclear proliferation.

The role of the NPG is to review the Alliance nuclear policy in light of the ever-changing security challenges of the international environment and to adapt it as necessary to address these challenges. It also provides a forum in which member countries can participate in the development of Alliance nuclear policy and in decisions on NATO nuclear posture, regardless of whether they host U.S. nuclear weapons. Decisions within the NPG are made by consensus. Thus, the policies agreed upon by the NPG represent the common position of all participating countries.

The senior advisory body to the NPG on nuclear policy and planning issues, as well as nuclear weapons safety, security, and survivability matters, is the High Level Group (HLG). The HLG is chaired by the United States and is composed of national policy makers and experts. The HLG meets approximately twice a year, or as necessary, to discuss aspects of NATO nuclear policy, planning, and force posture, and matters concerning the safety, security, and survivability of nuclear weapons. The HLG relies on the technical work of its subordinate body, the Joint Theater Surety Management Group (JTSMG), to maintain the highest standards in nuclear surety.

The JTSMG was established in August 1977 to seek active participation and consultation among the NATO Nuclear Program of Cooperation nations to ensure an effective theater nuclear surety program. The JTSMG serves as the focal point for the resolution of technical matters pertaining to nuclear surety. The group reports to the HLG vice chairman, the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs (ASD(NCB)), who provides high-level attention and oversight to JTSMG activities. The JTSMG is co-chaired by representatives from U.S. European Command (USEUCOM) and Supreme Headquarters Allied Powers Europe (SHAPE). The JTSMG meets in working group sessions four times annually and in plenary sessions twice annually.

In the latest *Strategic Concept for the Defense and Security of the Members of the North Atlantic Treaty Organization*, adopted by NATO Heads of State and Government in Lisbon in November 2010, NATO members affirmed that deterrence, based on an appropriate mix of nuclear and conventional capabilities, remains a core element of the overall NATO strategy. The members further affirmed that as long as nuclear weapons exist, NATO will remain a nuclear alliance. The Strategic Concept has been periodically updated and published since 1949. Subsequently, NATO mandated the *Deterrence and Defence Posture Review*, which reaffirmed nuclear weapons as a core component of NATO overall capabilities. As a contributor to the strategic nuclear forces of the NATO alliance, U.S. nuclear cooperation with NATO will continue to remain important.

U.S.-UK MUTUAL DEFENSE AGREEMENT

The United States and United Kingdom have worked closely on nuclear weapons issues since the 1940s. During the early days of World War II, the work of Otto Frisch and Rudolph Peierls in England identified the means by which the potential for an atomic explosion could be contained in a device small enough to be carried by an aircraft. This information was shared with the United States and ultimately contributed to the decision to pursue the Manhattan Project.

Since 1958, under the auspices of the *Atomic Energy Act of 1946*, key aspects of the U.S. and UK nuclear programs have been the subject of technical and information exchange. At the strategic policy level, the United States and the United Kingdom share a common view. U.S. and UK contributions to NATO extended nuclear deterrence form a visible and shared commitment to NATO security. To facilitate this cooperation, both nations maintain liaison officers assigned within their respective nuclear oversight organizations. The closeness of the relationship and the level of nuclear cooperation between the two sovereign nations should never be mistaken for an inability to act alone. The President of the United States is the only person who can authorize the use of U.S. nuclear weapons, while the Prime Minister of the United Kingdom is the sole individual able to authorize the launch of a UK nuclear missile.

Under the U.S.-UK MDA, there are regular exchanges of information and expertise at all levels. Thus, both countries are able to benefit from shared knowledge and experience as they work together to counter nuclear threats and independently advance the status of their respective nuclear weapons programs.

Since the MDA was first signed in 1958, the technical areas of collaboration have reflected the scientific, military, and political focal points of the times. Historically, the technical areas of information exchange were authorized by specific SDs on a case-by-case basis, taking into account the desired outcomes of the proposed collaboration and potential risks to national security of sharing such sensitive nuclear weapons information.

The intent of the SDs is to share only certain atomic (nuclear) information deemed necessary for the furtherance of mutual objectives that would benefit both countries' nuclear deterrent programs. Collectively, the SDs make eligible much, but not all, U.S. atomic information for sharing with the United Kingdom.

Under the terms of the AEA, DoD and DOE are responsible for controlling the dissemination of U.S. atomic information. This information may not be disclosed to foreign nations or regional defense organizations unless it meets the criteria specified in applicable agreements for cooperation and SDs. Once the criteria have been met, there are a number of mechanisms for such exchanges. Examples of these mechanisms include Management Arrangements, Joint Handbook and Administrative Arrangements, Joint Atomic Information Exchange Group (JAIEG), Strategic Collaborations, Joint Working Groups (JOWOG), Exchanges of Information by Visit and Report (EIVR), and Channels.

MANAGEMENT ARRANGEMENTS

Management Arrangements detail the means of supervisory oversight over U.S.-UK nuclear warhead interactions under the MDA. The two management levels are known as "Stocktake" and "Second Level," depicted in Figure 10.1.[3] The Stocktake Principals, which include the ASD(NCB), the National Nuclear Security Administration (NNSA) Administrator, and the Director General Nuclear in the UK Ministry of Defence, meet approximately every 12–18 months to take stock of the enterprise. During Stocktake, the Principals review the long-term strategic direction of the enterprise and issue guidance for future collaborations. In support of the Stocktake Principals, the Second Level, comprised of the Deputy Assistant Secretary of Defense for Nuclear Matters (DASD(NM)), the Deputy Administrator NNSA Defense Programs (NA-10), and the Director Warhead, Defence Nuclear Organisation (UK Ministry of Defence), is responsible for oversight of the exchanges, including government commitment of resources. The Second Level Principals meet approximately every six months and are led by government officials one step below the Stocktake Principals. Second Level meetings review technical information, approve new aegises and changes to existing work programs, prepare materials, and elevate issues for the Stocktake meetings.

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[3] This figure derives from the 2019 *U.S.-UK Management Arrangements* document.

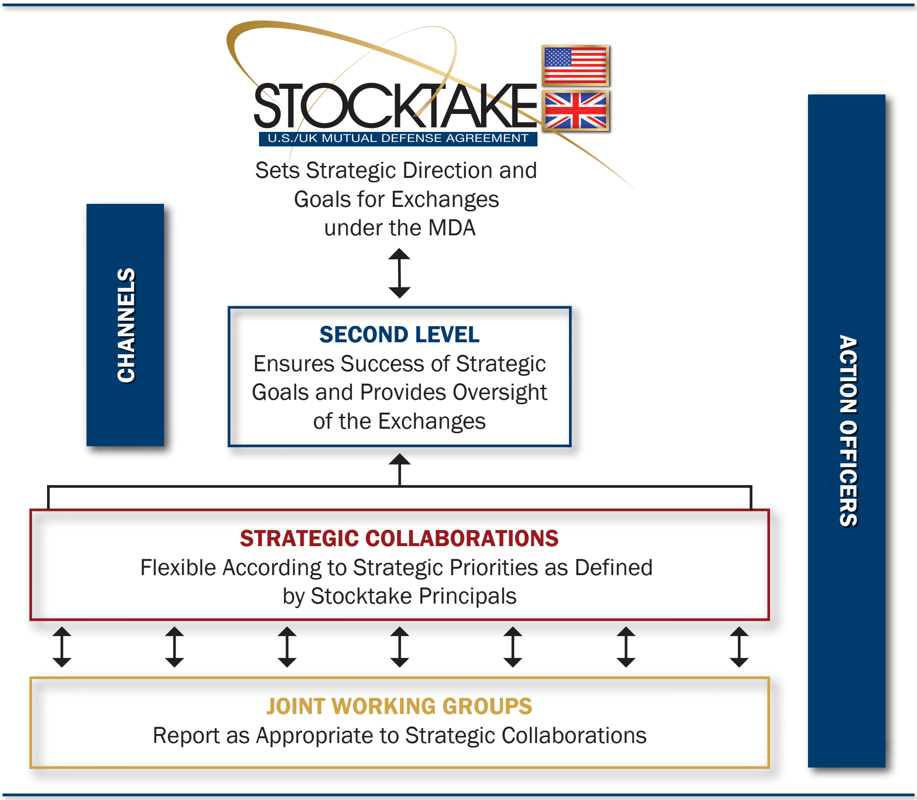


Figure 10.1 Management Arrangements

Joint Handbook and Administrative Arrangements

Administrative Arrangements with various nations and regional defense organizations lay out specific mechanisms for information exchange, whether in person, in written form, or electronically. The Joint Handbook and Administrative Arrangements supporting the 1958 U.S.-UK MDA detail administrative procedures and guidance on the exchange of atomic information between the two nations. The arrangements cover topics such as transmission channels, visit requests, requests for information, marking and reproduction of documents, classification, reports, transmission to third nations, and dissemination.

Joint Atomic Information Exchange Group

The JAIEG is the U.S. entity, jointly operated by DoD and DOE, responsible for reviewing and making determinations on the transmissibility of atomic information related to U.S. nuclear weapons sponsored for disclosure. JAIEG is also responsible for providing support to DoD, DOE/NNSA, and other requesting U.S. agencies in implementing and formulating administrative arrangements such as reporting, accounting, and dissemination procedures with other nations or regional defense organizations. For the United Kingdom, the Atomic Control Office in London or the Atomic Control Office in Washington, D.C., act for the UK Ministry of Defence in these matters as they pertain to the MDA.

STRATEGIC COLLABORATIONS

Strategic Collaborations are multi-disciplinary groups responsible for ensuring that MDA collaboration is aligned with strategic national goals as determined by Stocktake and directed by the Second Level. Strategic Collaborations are dynamic and flexible to support evolving strategic goals and coordinate across Joint Working Groups to achieve goals through alignment, integration, and enhanced communication. Strategic Collaborations facilitate communication between the working level and MDA leadership to ensure the Principals' direction is filtered down to the working level. Each Strategic Collaboration requires a scope statement outlining activities to maintain high confidence in the safety, security, reliability, and near/long-term sustainability of each nation's nuclear arsenal. Examples of current Strategic Collaborations include component maturation, warhead safety and security, and weapons effects.

JOINT WORKING GROUPS

JOWOGs are collaborative bodies composed of members representing the U.S. and UK laboratories and/or agencies dedicated to the advancement of knowledge in a designated field. JOWOGs are co-chaired by the United States and the United Kingdom. JOWOGs meet periodically to consider progress made, suggest further avenues for investigation, and propose divisions of work between participating laboratories or agencies. Under JOWOG auspices, visits between laboratories or agencies are made to review a particular project or to accomplish a specific objective. Examples of current JOWOGs include nuclear counterterrorism and counterproliferation technology, nuclear warhead physics, nuclear warhead accident response technology, and methodologies for nuclear weapon safety assurance.

EXCHANGE OF INFORMATION BY VISIT AND REPORT

In addition to JOWOGs, the United States has developed an EIVR concept to be used as an administrative instrument to promote a controlled oral or visual exchange of atomic information. EIVRs differ from JOWOGs in that they are normally not granted continuous authorization for the exchange of atomic information. Authorization to exchange U.S. atomic information under the aegis of an EIVR must be requested from the JAIEG on a case-by-case basis. Recent EIVR topics include nonproliferation and arms control technology, safety and security, and nuclear intelligence.

CHANNELS

In most cases, information exchanges must be approved on a case-by-case basis. Sometimes, however, when the nature of the exchange is predictable and repetitive, blanket approval for that type of information exchange may be granted. Therefore, a method of information sharing between the United States and a foreign government is called a channel. A channel is a joint arrangement between the United States and a foreign government for the exchange of specific project or program-type information. Channels are reserved for management executives and a few specific project-type data exchanges. The establishment of transmission channels with foreign governments and regional defense organizations are held to the minimum consistent with operational and security requirements. Currently approved channels between the United States and the United Kingdom include the U.S.-UK Executive Channel, the Trident Warhead Project Group Channel, and the U.S.-UK Nuclear Threat Reduction (NTR) Channel.

U.S.-UK NUCLEAR THREAT REDUCTION

The United States and United Kingdom have built on their existing relationship to develop a series of scientific programs to address and reduce the threat posed by nuclear proliferation and nuclear terrorism. As part of this work, the United States and United Kingdom are jointly working to further develop each nation's capabilities in nuclear forensics to identify sources of radioactive material, improve capabilities to detect nuclear material, and enhance abilities to respond to a terrorist nuclear incident. The United States and United Kingdom are also working together on techniques to verify nuclear disarmament.

U.S.-UK-FRANCE (P3) TRILATERAL PARTNERSHIP

In addition to bilateral relationships, the United States also coordinates with both the United Kingdom and France (P3) to maintain a program of enhanced technical collaborations on a wide range of NTR subjects. This robust partnership strengthens collective efforts to reduce the risks of nuclear terrorism. The P3 cooperation is based on a strong pillar of mutual trust and respect, and the three nations remain dedicated to improving technical and operational capabilities to diagnose, render safe, characterize, and dispose of a nuclear threat device. The P3 partnership has established a framework for cooperation on incident response and crisis management, nuclear energy and materials security, and sharing of threat-related information. These exchanges have had far-reaching effects not only on the policies of the three countries, but also on international nuclear security policy.

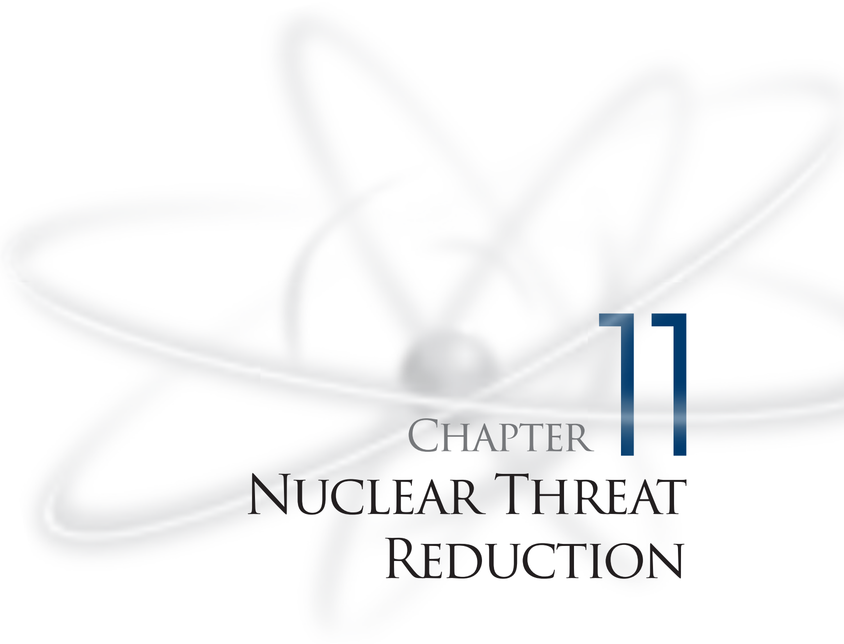
NNSA INTERNATIONAL NTR COOPERATIVE ACTIVITIES

Nuclear/radiological terrorism is a global issue because a nuclear terror event anywhere in the world would have international implications and breach what had been the nuclear "taboo." As such, NNSA works bilaterally and in multilateral fora with key international nuclear partners and advanced civil nuclear energy countries around the world to address shared nuclear/radiological terrorism concerns and jointly reduce associated risks. These bilateral and multilateral engagements include mutually beneficial international nuclear counterterrorism dialogues that allow for regular discussion among the U.S. interagency with their foreign counterparts on topics critical to reducing terrorist risks associated with civilian nuclear facilities and materials.

NNSA works with key partners to lead exchanges on technologies and approaches to secure and protect nuclear facilities and materials. NNSA conducts joint nuclear emergency preparedness and response exercises and training with foreign partners, including support to multilateral nuclear counterterrorism initiatives such as the Global Initiative to Combat Nuclear Terrorism and other international nuclear security initiatives.

NNSA also helps reduce terrorism risks associated with nuclear/radiological materials, facilities, or weapons of mass destruction (WMD)-related materials through outreach and training that strengthens counterterrorism capabilities and policies at home and overseas. For example, domestically, NNSA designs, produces, and conducts tailor-made tabletop exercises for public and private sector partners that have key roles and responsibilities in nuclear security. Designed to build teamwork and an in-depth understanding of the roles and responsibilities of agencies charged with responding to terrorist-related radiological, nuclear, or WMD-related incidents, these private—but unclassified—exercises bring together federal, state, and local decision makers and emergency responders.

Fissile Material Storage Facility (FMSF), Mayak, Russia



CHAPTER 11

NUCLEAR THREAT REDUCTION

OVERVIEW

Nuclear Threat Reduction (NTR) refers to the integrated and layered activities across the full range of U.S. government efforts to prevent and counter radiological and nuclear incidents. Reducing nuclear threats applies across a spectrum ranging from potential state adversaries to non-state actors. For state threats, NTR counters the emergence of challenges to the United States from the proliferation of nuclear weapons by emphasizing the detection of potential problems as early as possible. For non-state threats, NTR includes the capabilities to prevent, attribute, and recover from a terrorist attack that used nuclear and/or radiological materials.

DOD NTR EFFORTS

DoD NTR efforts are focused on three end states. The first goal of NTR is to prevent the acquisition of new nuclear weapons. For nation-states, this effort encompasses the prevention of vertical and horizontal proliferation of nuclear weapons, nuclear materials, and related technology. Vertical proliferation is the advancement or modernization of a state's nuclear weapons capability, and horizontal proliferation is the direct or indirect transfer of nuclear weapons technologies or materials to a non-nuclear weapons state. This threat is primarily reduced through nonproliferation and arms control activities, which are supported by robust U.S. capabilities to detect proliferation. For non-state actors, the goal is to prevent terrorists and violent extremist organizations from acquiring a nuclear weapon or radiological or nuclear materials. The *2018 Nuclear Posture Review* reiterated that, "Nuclear terrorism remains among the most significant threats to the security of the United States, allies, and partners. The Joint Chiefs of Staff, in 2015, emphasized, 'Nuclear, chemical, and biological agents pose uniquely destructive threats. They can empower a small group of actors with terrible destructive potential. Thus combating weapons of mass destruction (WMD) as far from our homeland as possible is a key mission for the U.S. military.'" For non-state actors, there are numerous programs described later in this chapter to reduce the risk of radiological and nuclear materials and weapons falling out of regulatory control. Additionally, the United States seeks to deter terrorists through advanced nuclear technical forensics capabilities that can identify the source of an attempted or actual attack that included nuclear or radiological materials.

The second goal of nuclear threat reduction is to prevent the use of nuclear or radiological weapons. For state actors, this goal is accomplished primarily through strategic deterrence. For non-state actors, it is generally assumed that if a violent extremist organization obtained a nuclear or radiological weapon, it would use that weapon, making prevention paramount. There are numerous programs in place to detect and interdict nuclear and radiological materials before they could be transported to their intended target.

The third NTR goal is the minimization of the effects of a nuclear or radiological attack by state or non-state actors. DoD, primarily through its Chemical and Biological Defense Program, ensures the Joint Force can operate effectively and personnel are protected in all environments, including radiologically contaminated environments. Additionally, the United States devotes significant resources to consequence management activities to ensure the safety of the public and to support recovery efforts in the aftermath of a nuclear or radiological incident. The U.S. whole-of-government response to a nuclear or radiological incident would be led by the Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA). The policies, situations, concepts of operations, and responsibilities of the responding Federal departments and agencies are described in the Nuclear/Radiological Incident Annex of the National Response Framework (NRF).

UNDERSTANDING STATE THREATS

On December 8, 1953, at the 470th Plenary Meeting of the United Nations General Assembly, President Dwight Eisenhower delivered his famous "Atoms for Peace" address, pledging to support the peaceful use of atomic energy in exchange for a commitment to forego the development of nuclear weapons. Less than three years later, 81 countries unanimously approved the statute for the establishment of the International Atomic Energy Agency (IAEA). As defined in Article II of the IAEA statute, "The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose."

On March 5, 1970, the *Treaty on the Non-Proliferation of Nuclear Weapons*, commonly referred to as the Non-Proliferation Treaty or NPT, entered into force, and on May 11, 1995, it was extended indefinitely. The NPT is regarded as the cornerstone of the global nuclear nonproliferation regime, and with 191 nations participating, the NPT has the largest number of signatories of any other arms limitation or disarmament agreement.[1] The NPT establishes a safeguards system, operated under the responsibility of the IAEA, to verify through safeguards agreements that countries are not diverting or misusing nuclear materials or facilities.

According to the United National Office for Disarmament Affairs, as of 2019, more than 30 countries possess nuclear power plants, and another 28 countries are interested in introducing nuclear power. Additionally, more than 50 countries possess research reactors that are used to produce medical and industrial isotopes. To reduce the possibility of nuclear proliferation at the state level, NTR focuses U.S. capabilities on detecting and countering any clandestine effort to misuse nuclear power for military use as early as possible. There are a number of activities a state must take to develop a nuclear weapon program from a peaceful nuclear energy program. These activities, which need not be done sequentially, increase the risk of proliferation such that a states's investment in any one of them is cause for concern. There are a number of programs and strategies to address each of these proliferation activities to prevent states from developing nuclear weapons. For more information, see *Chapter 15: Nuclear Fuel Cycle and Proliferation*.

MOTIVATION AND PLANNING

Currently, there are a handful of countries with the facilities, material, and advanced technical expertise necessary for a successful nuclear weapons program. However, for a variety of reasons, these nations have decided not to pursue the development of nuclear weapons.

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[1] "Treaty on the Non-Proliferation of Nuclear Weapons," United National Office for Disarmament Affairs, accessed April 2019, https://www.un.org/disarmament/wmd/nuclear/npt.

For decades, the United States has effectively assured the security of its allies under the U.S. nuclear "umbrella." These allies and partners rightly place enormous value on U.S. extended nuclear deterrence which, in turn, is a key to nonproliferation. For their part, potential adversaries' motivation not to pursue nuclear weapons may also be influenced in part by the U.S. declaratory policy regarding the potential employment of nuclear weapons:

> *"The United States will not use or threaten to use nuclear weapons against non-nuclear weapons states that are party to the NPT and in compliance with their nuclear non-proliferation obligations."*[2]

Should a state decide to pursue nuclear weapons, there are measures that can be taken to try to reverse the decision to pursue such weapons, as indicated by the numerous U.N. Security Council resolutions and sanctions applied to North Korea and Iran. It is imperative that illicit proliferation activities be detected as early as possible so the United States and the international community can act to try to prevent acquisition.

Developing Infrastructure

Nuclear weapons require a significant infrastructure. While all nations have the right to nuclear technology for peaceful uses, elements of a peaceful nuclear infrastructure are inherently dual-use and can contribute to a nuclear weapons program. Of these elements, the two fuel cycle facilities that are considered the greatest risk to potential proliferation are enrichment and reprocessing facilities. In fact, the science for these facilities was a major focus of the Manhattan Project.

There are two primary means to reduce the risk that peaceful nuclear infrastructure could be misused. The first is to alleviate the need for states to develop some of the most sensitive fuel cycle facilities. One example is the establishment of a low-enriched uranium bank to provide assurance that fuel for nuclear power will be available to all states who are party to the NPT, alleviating the need for clandestine uranium enrichment. The second is the application of NPT safeguards, which provide transparency and confidence that programs are being used for the stated purpose and not contributing to proliferation. Led by the Department of Energy (DOE) through the National Nuclear Security Administration (NNSA), the United States invests significant resources in nonproliferation research and development to improve the IAEA safeguards inspection regime.

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[2] This has been a longstanding policy of the United States that was most recently reiterated in the *2018 Nuclear Posture Review*.

ACQUIRING EXPERTISE, TECHNOLOGY, AND MATERIAL

Nuclear weapons technology is 75 years old, and the basic weapon design information has been spread widely since the development of the first atomic bomb. The most famous example of the illicit proliferation of nuclear technology was Abdul Qadeer Khan (A.Q. Khan) and his network, which provided nuclear weapons and missile technology to Pakistan, North Korea, Libya, and Iran.

Based on the relative availability of nuclear weapons design information, the best way to halt the spread of weapons is to prevent states from acquiring sufficient quantities of special nuclear material required for a nuclear weapons program. At the same time, it is also important to limit the further spread of information on nuclear weapons design, non-nuclear components, and delivery system technology.

As required by the *Atomic Energy Act of 1954*, the United States provides special protection to any information related to the design, manufacture, or use of atomic weapons; the production of special nuclear material; and the use of special nuclear material. This information is classified as Restricted Data.[3] Other nations with nuclear weapons similarly provide the highest level of protection to their equivalent of Restricted Data.

Outside of Restricted Data information, there are dual-use technologies that may aid a nation in developing nuclear weapons. There are a number of regimes and agreements that provide assurance that technologies will not contribute to a weapons program. The U.S. Department of State (DOS), with support from the Departments of Commerce, Homeland Security, Treasury, Defense, and Energy, leads U.S. efforts in support of export control and nonproliferation activities. The two primary international groups are the Nuclear Suppliers Group and the Zangger Committee. The Nuclear Suppliers Group is a voluntary, multilateral export control regime with 48 participating governments that was founded in response to India's 1974 nuclear test. The Nuclear Suppliers Group governs the transfer of civilian nuclear material and nuclear-related equipment and technology to prevent nuclear exports for peaceful purposes from being used to make nuclear weapons. The Zangger Committee was established in 1971 following the entry into force of the NPT to assist nuclear suppliers in complying with Article III.2 of the NPT which states, "Each State Party to the Treaty undertakes not to provide: (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon

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[3] "Restricted Data" is a proper noun referring to a category of classified information relating to nuclear weapons. See *Chapter 18: Classification* for more information.

State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this Article." The Committee currently has 39 member states, including all of the nuclear-weapons states, as defined by the NPT. The Zangger Committee developed a list of equipment that may only be exported to non-nuclear weapons states outside of the NPT when three conditions are met, and continues to maintain and update this list. These conditions are an assurance of non-explosive use, a requirement to place the items under IAEA safeguards, and an assurance that the receiving country would apply the same restrictions on any further transfer. The primary difference between the Nuclear Suppliers Group and the Zangger Committee is that the former focuses on the transfer of non-nuclear items to all non-nuclear weapons states regardless of their NPT status, while the Zangger Committee focuses on transfers to states outside of the NPT.

In addition to limiting nuclear materials and technology, preventing states from obtaining the capability to deliver nuclear weapons is another focus of nonproliferation. The Missile Technology Control Regime is a multilateral, informal political understanding among 35 member states that seeks to limit the proliferation of missiles and missile technology. The regime was formed in 1987 by the G7 industrialized countries and aims to limit nuclear weapons proliferation by controlling the transfer of missile equipment, complete rocket systems, unmanned air vehicles, and related technology for those systems capable of carrying a 500-kilogram payload at least 300 kilometers.

Nuclear and Non-Nuclear Testing

The first nuclear weapon, a gun-type uranium weapon, was detonated in 1945 without ever being tested. While this demonstrates that testing is not required to develop nuclear weapons, testing can support a country in developing more advanced types and designs of nuclear weapons. All countries that currently possess nuclear weapons have conducted at least one weapons-related nuclear test. There are a number of treaties that limit or ban certain types of nuclear weapons tests. The 1963 Limited Test Ban Treaty bans nuclear weapons testing in the atmosphere, in outer space, and under water. The 1974 Threshold Test Ban Treaty limits the size of underground nuclear tests to 150 kilotons, and the 1976 Peaceful Nuclear Explosion Treaty prohibits the testing of nuclear devices outside of agreed treaty sites.

The capability to detect nuclear weapons tests is paramount to ensuring compliance with these treaties and ensuring that no state can covertly test a nuclear weapon. The Air Force Technical Applications Center (AFTAC) is the sole U.S. organization with the mission to detect and report technical data from foreign nuclear explosions. AFTAC monitors signatory countries' compliance with these treaties.

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is a legally binding global ban on nuclear explosive testing; however, it has not been ratified by the United States and is not currently in force. Since 1992, the United States has observed a unilateral moratorium on nuclear explosive testing. The United States does not intend to seek ratification of the CTBT, but it continues to support the CTBT Preparatory Committee as well as the International Monitoring System and the International Data Center. Both AFTAC and the Defense Threat Reduction Agency (DTRA) provide direct support to the CTBT. The U.S. government maintains that it will not resume nuclear explosive testing unless necessary to ensure the safety and effectiveness of the U.S. nuclear arsenal, and calls on all states possessing nuclear weapons to declare or maintain a moratorium on nuclear testing.

Understanding Non-State Threats

Terrorist groups have declared their intent to obtain fissile materials to create a nuclear threat device (NTD), which can be anything from a crude, homemade nuclear device, an improvised nuclear device (IND), a radiological dispersal device (RDD), a radiological exposure device (RED), or a weapon acquired from one of the established nuclear states that has fallen out of state control. The risk of terrorists acquiring nuclear or radiological materials that could be used in a weapon is reduced through numerous interagency programs, including those that enhance partner capabilities to interdict and prosecute nuclear smuggling, deter material support to potential terrorists, and advance nuclear forensics and attribution capabilities, which enable the United States to identify the source of fissile material.

There are a number of generic steps that must be taken to successfully carry out a radiological or nuclear attack. These "nuclear event pathway" steps are illustrated in Figure 11.1.

Figure 11.1 Nuclear Event Pathway

Terrorists do not share the same goals or need the same capabilities as states. In addition, they are not bound by international law or nuclear treaties and agreements. For a fabricated nuclear device, weight and size constraints may not be important to a terrorist; unsafe designs may be acceptable, as may hazardous materials and higher dose rates. Finally, a wide variety of delivery methods could be used, with no regard for collateral damage to civilian populations or the terrorists themselves.

A pathway to an attack begins with motivation, planning, and intent. Next, for a credible threat, the acquisition of radiological materials, nuclear materials, nuclear components, or a nuclear device is an essential step. Material acquisition of weapons-usable special nuclear material is the most critical step for a terrorist group, as the enrichment and reprocessing steps that are critical to a nation-state's program are currently beyond the known capability of terrorist groups.

If successful in acquiring materials, a potential adversary must then design and fabricate an NTD (or be able to use a stolen or procured device), transport and store the device, get it to its intended target, and achieve successful detonation, dispersal, or exposure. There are difficulties associated with every step along this pathway, and there are specific indicators associated with each step that can facilitate the detection and interdiction of an NTD. Failing successful interdiction, rendering the device safe or unusable is the last defense in preventing a nuclear detonation.

In a post-detonation environment, the focus of the NTR mission shifts, in parallel with consequence management actions, to nuclear forensics and ultimately attribution to support prevention of subsequent attacks.

At each step along the pathway, a potential adversary must be successful; that is, failure at any point results in the overall failure of the objective. Therefore, efforts to counter the nuclear threat must only succeed in thwarting a potential adversary at any one point along the pathway to prevent a nuclear event. Additionally, even in the worst-case scenario of a nuclear detonation, there are effective steps to be taken to manage the consequences of such an event and appropriately deal with the perpetrators.

The spectrum of NTR activities against the non-state threat is illustrated in Figure 11.2. The figure highlights activities beginning well before a potential nuclear event. Materials security is the first step in preventing nuclear terrorism and nuclear proliferation. There is a continued need to scrutinize and modify the nuclear fuel cycle to ensure the production of weapons-usable materials is limited and minimize any proliferation risks inherent in the use of nuclear power for peaceful purposes.

The uncertainty involved with identifying specific NTDs remains a significant challenge. When dealing with a potential NTD, it is critical to identify what the device is made of, how it is configured, how it might work, and if it will produce

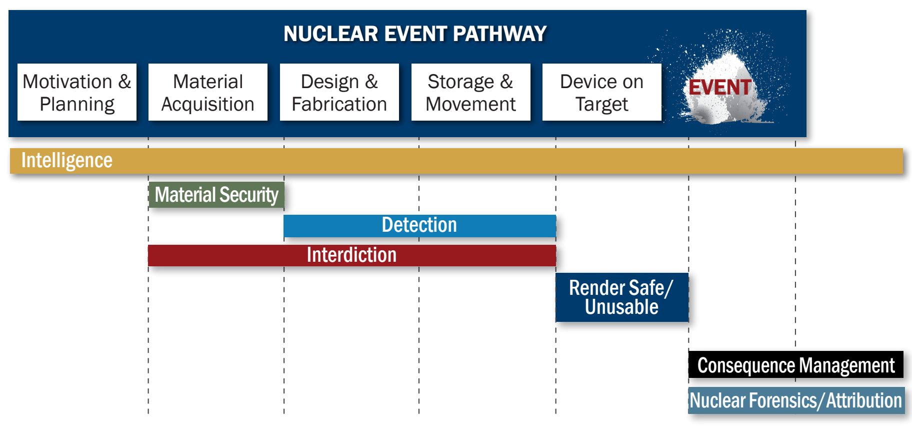

Figure 11.2 Spectrum of NTR Activities Against the Non-State Threat

a nuclear yield. As a result, there is no fixed set of NTD concepts or designs, and the United States' understanding of possibilities continues to evolve. NTDs can be developed from a variety of materials and may be configured with a high level of complexity. In general, less sophisticated devices require more nuclear material and produce lower yields. A crude device tends to be large and bulky, while sophisticated designs are smaller and lighter and achieve greater yields in relation to the mass of the fissile material.

The uncertainties associated with NTDs directly impact the ability to detect, interdict, and render a device safe. It is imperative that the United States continue its work to understand and characterize the full range of potential NTDs, including the characterization of nuclear and explosive materials as well as the range of potential configurations. Figure 11.3 illustrates the relationship between technical understanding of NTD designs and elements of a strong program for NTR.

DoD, especially through DTRA, and NNSA work with domestic and international partners to perform nuclear and explosive materials characterization, device modeling, and simulation analyses to enhance the scientific and technical understanding of NTDs. Additional efforts are spent to identify and discriminate among nuclear and explosive signatures for materials security and to perform diagnostics and threat analyses. Understanding the threat also involves the development of tools, techniques, and procedures to facilitate nuclear device vulnerability exploitation and help to perform render safe functions in a timely and effective manner.

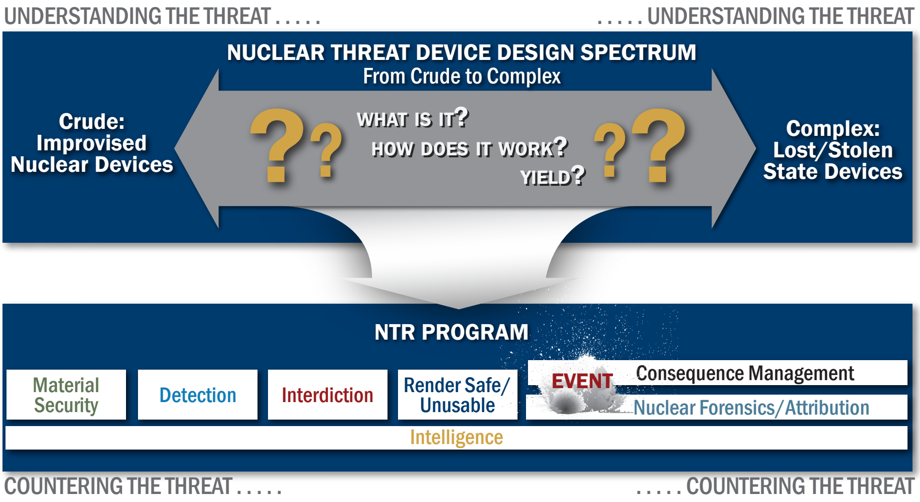

Figure 11.3 Understanding the Threat

Actions to Reduce Non-State Nuclear Threats

U.S. strategy to combat the threat of nuclear terrorism encompasses a wide range of activities that comprise a defense-in-depth against current and emerging dangers. Under this multilayered approach, the United States strives to prevent terrorists from obtaining nuclear weapons or weapons-usable materials, technology, and expertise; counter terrorist efforts to acquire, transfer, or employ these assets; and respond to nuclear incidents, by locating and disabling a nuclear device or managing the consequences of a nuclear detonation. Key U.S. efforts under this strategy include:

- securing nuclear weapons, materials, related technology, and knowledge to prevent their malicious use;
- enhancing cooperation with allies, partners, and international institutions to combat nuclear terrorism;
- deterring state support for nuclear terrorism through advanced forensics and attribution capabilities;
- strengthening defenses against nuclear terrorism to protect the American people and U.S. interests at home and abroad; and
- enhancing preparedness to mitigate the effects of nuclear incidents.

Numerous departments and agencies within the U.S. government and in the international arena continue their efforts to better characterize the nuclear threat. Work in these areas is divided into categories of material security, detection, interdiction, render safe, consequence management, nuclear forensics, and attribution.

MATERIAL SECURITY

Weapons-usable highly enriched uranium (HEU) and separated plutonium exist in hundreds of locations around the world under varying levels of security. While the large percentage of facilities are under strong, usually military, control with continual monitoring, a significant breach at one of these locations could have an impact that would profoundly change the way the world sees and addresses nuclear terrorism today. Since the early 1990s, there have been multiple instances of collaboration among countries to minimize the threat of nuclear terrorism, with a prime example being the 1991 *Nunn-Lugar Cooperative Threat Reduction Act*.

The Material Protection, Control, and Accounting (MPC&A) program is part of the NNSA nonproliferation program and seeks to improve the security of nuclear weapons and material accounting within former nuclear sites in Russia and other countries of the former Soviet Union (FSU) that house radiological materials. The United States has funded this program and hopes it will serve as a template for future programs with other countries. The ultimate goal of the program is to improve global nuclear security and ensure that radiological sources are not accessible to illicit markets. Since the program's inception as part of the DoD Cooperative Threat Reduction (CTR) program, it has secured thousands of tons of weapons-grade nuclear material in the FSU.

Under the auspices of the Nunn-Lugar Act, the United States and Russia worked to build the Mayak storage facility in Russia. The facility was built to enhance security for nuclear material recovered from dismantled nuclear warheads in Russia. With space to permanently store 50,000 containers of weapons-grade plutonium from 12,500 dismantled nuclear warheads, the Mayak facility demonstrates a significant achievement in the reduction of the Russian nuclear stockpile and improved security for nuclear materials.

On July 15, 2006, President George W. Bush and Russian President Vladimir Putin launched the Global Initiative to Combat Nuclear Terrorism (GICNT). The initiative aims to broaden and enhance international partnerships to strengthen global capacity to prevent, detect, and respond to nuclear terrorism. Currently, 88 countries are involved in the initiative. Members work to integrate collective capabilities and resources to strengthen the overall global architecture to combat nuclear terrorism. They bring together experience and expertise from the nonproliferation, counterproliferation, and counterterrorism disciplines, and provide the opportunity for nations to share information and expertise in a voluntary, non-binding framework.

Domestically, DoD and NNSA are responsible for special nuclear material and nuclear weapons in their custody. Additionally, the Federal Bureau of Investigation (FBI) Nuclear Site Security Program requires each FBI field office to establish close liaison with security personnel at critical nuclear facilities, including DoD and NNSA sites as well as commercial nuclear power facilities operating under the Nuclear Regulatory Commission. This program also requires field offices to develop site-specific incident response plans and to exercise those plans with facility security personnel. Lastly, each field office has a designated, full-time special agent for all WMD-related activity, including nuclear threats.

DETECTION

The radiation detection mission is diverse and will not be solved by any single technology or configuration in the near term. The detection and identification of nuclear threats by current passive detection technologies is limited by three factors. First, the size and activity of the radiological sample is directly correlated with detectability. The quantities of interest for nuclear materials can be very small and some fissile materials have minimal radioactive emissions, limiting their detection by passive means. Second, shielding degrades the ability to detect radiological materials. Finally, the distance between the material and the detector limits the ability to passively detect radiological materials. Nuclear radiation, like other forms of electromagnetic radiation, decreases in intensity with the square of distance (i.e., the signal drops by a factor of four when the distance between the nuclear source and detector is doubled).

The detection mission is being addressed in interagency forums to help offset the complexity of the mission and many U.S. government components are involved in improving radiation detection. In 2005, presidential policy established the DHS Domestic Nuclear Detection Office (DNDO) to assist in management and improvement of U.S. capabilities to detect and report unauthorized attempts to import, possess, store, develop, or transport radiological and nuclear material. *The Countering Weapons of Mass Destruction Act of 2018* transferred these responsibilities to the DHS Countering Weapons of Mass Destruction Office (DHS/CWMD). DHS/CWMD is responsible for enhancing and coordinating efforts to detect and prevent nuclear and radiological terrorism against the United States. In this role, it is responsible for effective sharing and use of appropriate information generated by the intelligence and counterterrorism communities, law enforcement agencies, and other government agencies as well as foreign governments. As such, DHS/CWMD conducts research, development, testing, and evaluation of detection technologies; acquires systems to implement the domestic portions of the architecture; and coordinates international detection activities. DHS/CWMD also provides support to other U.S. government agencies through the provision of standardized threat assessments, technical support, training, and response protocols. The NNSA Global Material Security

Nuclear Smuggling Detection and Deterrence Program to prevent and detect nuclear smuggling also plays a significant role in countering possible terrorist activities involving nuclear weapons or devices.

Detecting Nuclear Threats

While the technical challenges to building advanced designs such as staged nuclear weapons are significant, the relative simplicity of a gun assembly (GA) design raises the possibility non-state actors with sufficient fissile material could assemble a supercritical mass and produce a nuclear detonation using an IND. The best protection from this threat is to prevent terrorists from acquiring nuclear materials for use in an IND. Maintaining close coordination between the science and the operations of countering nuclear threats is paramount.

Fission Yield and Nuclear Forensics

The fission process produces isotopes with a wide range of atomic masses and atomic numbers, though some fission fragments are more likely to be produced than others. Atomic masses follow a characteristic twin-peaked distribution and most of the isotopes produced have atomic masses near 95 and 140. The detailed shape of this fission product yield curve depends on the specific nucleus undergoing fission and on the energy of the neutrons inducing fission. Fission from Pu-239 results in relatively more heavy nuclei than from U-235 as well as higher yields.

These differences in yield can be used by nuclear forensic scientists to provide information about a nuclear device. By measuring the relative quantities of fission fragments after detonation, scientists can construct a yield curve and infer which fissile material was used in the device. This, in turn, may help with attribution efforts.

Detection of Nuclear Material

The same principles of personal protective equipment (PPE), time, distance, and shielding, which protect personnel from radiation, complicate the detection of nuclear materials. Charged particles from radioactive decay (alpha and beta particles) are easily shielded in transport. In most cases, gamma rays and neutrons emitted from shielded sources are comparable with natural background readings at distances greater than 10 meters.

The penetrating power of radiation varies greatly depending on the type of radiation in question. In general, charged particles can be shielded more easily, while neutral particles penetrate matter more deeply. Alpha particles have the least penetrating power and can be stopped by a sheet of paper or human skin. Beta particles are lighter than alpha particles and permeate more deeply, penetrating skin and traveling several feet in air, but are stopped by a fraction of an inch of metal or plastic. Gamma rays are energetic photons that can transfuse matter deeply. These require a layer of dense material, such as lead, for shielding.

Because neutrons are electrically neutral, they interact weakly with matter. Neutrons are absorbed by successively bouncing off light nuclei. As a result, shielding neutron radiation requires thick layers of materials rich in hydrogen, such as water or concrete. Figure 11.4 compares the penetration of various types of radiation.

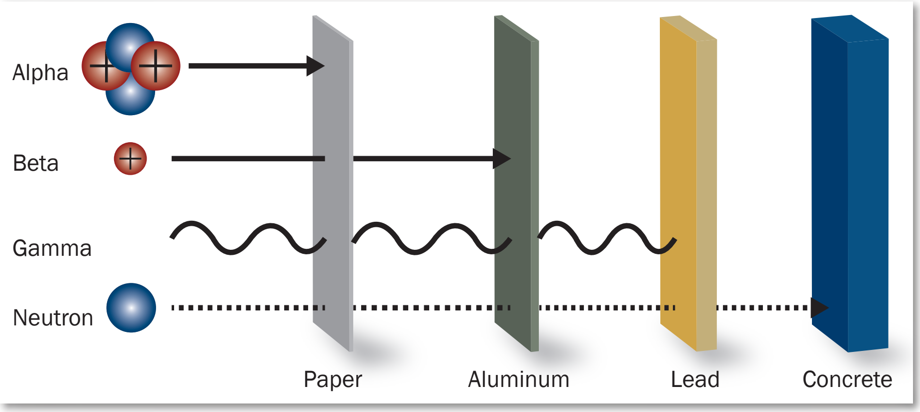

Figure 11.4 Penetrating Power of Various Types of Radiation

INTERDICTION

Interdiction includes the seizure of materials or technologies that pose a threat to global security. Efforts in this area include research, development, testing, and evaluation of detection and interdiction technologies conducted by many federal agencies. Additional activities in this area include efforts to create exclusion zones, increase surveillance, identify transit routes, monitor choke points and known smuggling routes, sustain nuclear detection programs, and support technological enablers for these efforts. The Nuclear Trafficking Response Group (NTRG) is an interagency body responsible for coordinating the U.S. government response to nuclear and radiological smuggling incidents overseas. The NTRG supports foreign government efforts to secure smuggled material, prosecute those responsible, and develop information on smuggling-related threats.

Presidential policy articulates roles and responsibilities for U.S. government departments and agencies, both within the United States and overseas, and identifies the Attorney General as lead for coordination of law enforcement activities involving terrorist acts. The FBI response is fully coordinated with the DOS, DHS, and NNSA, while DoD provides support to each of the civil authorities, as requested. This process ensures the response is integrated and coordinated. NNSA acts as a cooperating federal agency, bringing assets and deployable technical teams to aid in the overall federal response and can assist, if requested, with the search of an asset or tactical operation. DoD has responsibility for interdicting a nuclear weapon in transit outside the United States. For this reason, DoD maintains the capabilities to interdict a weapon in the maritime, aerial, and terrestrial domains. DoD has built upon current capabilities to ensure that, should the location of a terrorist-controlled IND, RDD, or RED be known, forces can successfully and safely recover the device.

In addition to being responsible for the criminal prosecution of acts of terrorism, the Attorney General is responsible for ensuring the implementation of domestic policies directed at preventing terrorist acts. The execution of this role ensures that individuals within terrorist groups can be prosecuted under U.S. law.

Render Safe

The ability to render a nuclear device[4] safe is complex. Each device (IND, RDD, and RED) is unique and requires a distinct approach to be rendered safe. The initial phase for the render safe process is the identification of the device, meaning the determination of which types of materials were used and understanding the composition of the device and how it was designed to work. In the second phase, the responders gather and analyze information as well as take appropriate render safe actions until the weapon is ready for transport. Diagnostics of a nuclear or radiological weapon will help determine render safe procedures and the weapon's final disposition. The final phase is the disposition of the weapon, during which the radiological material and other components of the weapon are properly transported and stored. DoD and the FBI maintain specific teams trained in rendering safe these types of ordnance.

Within the United States, the FBI holds the responsibility for render safe procedures involving terrorist activity and WMD. As the primary law enforcement agency and lead federal agency for such operations, the FBI may request cooperative assistance from DoD and/or NNSA. DoD, the FBI, and NNSA execute training exercises individually and jointly to streamline the render safe process and to build relationships and share technologies across the U.S. government.

Consequence Management

Post-event consequence management activities are necessary in the event of a successful attack, but also necessary following a smaller-scale event or even a successful render safe mission. National-level guidance, such as the National Response Framework and other documents, outline interagency roles and responsibilities and guide U.S. efforts in response planning, exercises, and

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[4] Device and weapon are being used interchangeably in this chapter.

training. Consequence management activities include securing the incident site, assessing the dispersal of radioactive material, enhancing first responder capabilities, ensuring availability of decontamination and site remediation resources, providing radiological medical triage capabilities, and increasing population resilience and recovery capabilities. In addition to managing consequences, which minimizes the disastrous effects desired by the adversary, demonstrated preparedness can have a deterrent effect.

The FBI is the lead federal agency for crisis management response (interdiction), while FEMA is the lead federal agency for consequence management. FEMA manages and coordinates any federal consequence management response in support of state and local governments, in accordance with the NRF and the National Incident Management System (NIMS). Additionally, the *Homeland Security Act of 2002* requires that specialized NNSA emergency response assets fall under DHS/FEMA operational control when they are deployed in response to a potential nuclear incident in the United States.

NNSA provides scientific and technical personnel and equipment during all aspects of a nuclear or radiological terrorist incident, including consequence management. NNSA capabilities include threat assessment, technical advice, forecasted modeling predictions, radiological medical expertise, and operational support. Deployable capabilities include radiological assessment and monitoring, identification of material, development of federal protective action recommendations, provision of information on the radiological response, hazards assessment, post-incident cleanup, radiological medical expertise, and on-site management and radiological assessment to the public, the White House, members of Congress, and coordinated through the DOS to applicable foreign governments.

NUCLEAR FORENSICS, ATTRIBUTION, AND DETERRENCE

Nuclear forensics provides information outside the scope of traditional forensics on interdicted materials or devices before detonation and on post-detonation signals and debris to support attribution. Attribution is an interagency effort requiring coordination of law enforcement, intelligence, and technical forensics information to allow the U.S. government to determine the source of the material and device as well as its pathway to its target.

The National Technical Nuclear Forensics (NTNF) program assists in identifying material type and origin, potential pathways, and design information. Technical nuclear forensics (TNF) refers to the thorough analysis and characterization of pre- and post-detonation radiological or nuclear materials, devices, and debris, as well as prompt effects from a nuclear detonation. The attribution process merges TNF results with traditional law enforcement and intelligence information to identify those responsible for the planned or actual attack.

The nuclear forensics and attribution capabilities are part of the broader NTR mission within DoD. Knowledge of the NTNF program capabilities can discourage countries from transferring nuclear or radiological materials and devices to non-nuclear states or non-state actors and can encourage countries with nuclear facilities or materials to improve their security. Aside from its necessity in detonation response, the capability also contributes to prevention by providing a viable deterrent.

The NTNF program is an interagency mission drawing on capabilities of the Department of Justice (DOJ), DoD, NNSA, DHS, DOS, and the Office of the Director of National Intelligence (ODNI). Additionally, nuclear forensics provides an important means for the global community to work together in the fight against nuclear terrorism. Because success in this effort is improved with nations acting collaboratively, the U.S. government NTNF community is engaged in a number of bilateral and multilateral activities with foreign partners.

Attribution is a confluence of intelligence, investigative, and forensics information to arrive at the nature, source, perpetrator, and pathway of an attempted or actual attack (see Figure 11.5). This includes rapid and comprehensive coordination of intelligence reporting, law enforcement information, nuclear forensics information, and other relevant data to evaluate an adversary's capabilities, resources, supporters, and modus operandi. Forensics is the technical and scientific analysis that provides a basis for attribution or exclusion.

Figure 11.5 The Attribution Calculus

The United States has stated the importance of holding accountable any state, terrorist group, or other non-state actor that supports or enables terrorist efforts to obtain or employ nuclear devices. It is critical that the United States maintain advanced nuclear forensics capabilities to identify the source of the material used in a nuclear device and continue to improve the ability to attribute the source of a nuclear attack. A terrorist nuclear attack against the United States or its allies would qualify as an "extreme circumstance" under which the United States could consider a nuclear response.

Chapter 12

Nuclear Treaties and Agreements

Overview

Throughout the history of nuclear weapons, arms control treaties and agreements and nonproliferation efforts have been used to promote and implement U.S. national security objectives. The United States engages in arms control arrangements when they serve U.S. national security. Arms control and nonproliferation efforts have produced formal treaties and agreements, informal arrangements, cooperative threat reduction and monitoring mechanisms, and consultation summits. The United States and the Soviet Union began to sign agreements limiting their strategic offensive nuclear weapons in the early 1970s. While several arms control agreements restrict the deployment and use of nuclear weapons, no conventional or customary international law prohibits nations from employing nuclear weapons in armed conflict. This chapter describes the treaties and international agreements that have affected the size and composition of the U.S. nuclear weapons stockpile as well as those that promote the goals of nuclear nonproliferation.

List of Nuclear-Related Treaties and International Agreements

Antarctic Treaty

Opened for signature: 1959 | Entry into force: 1961

Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water (Limited Test Ban Treaty or LTBT)
Opened for signature: 1963 | Entry into force: 1963

Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco)
Opened for signature: 1967 | Entry into force: 1968

Treaty on the Nonproliferation of Nuclear Weapons (Nuclear Nonproliferation Treaty or NPT)
Opened for signature: 1968 | Entry into force: 1970

Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems (Anti-Ballistic Missile Treaty or ABM Treaty)
Signed: 1972 | Entry into force: 1972 | U.S. Withdrawal: 2002

Interim Agreement Between the United States of America and the Union of Soviet Socialist Republics on Certain Measures with Respect to the Limitation of Strategic Offensive Arms (Strategic Arms Limitation Talks or SALT I)
Signed: 1972 | Entry into force: 1972

Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitations of Underground Nuclear Weapon Tests (Threshold Test Ban Treaty or TTBT)
Signed: 1974 | Entry into force: 1990

Treaty Between the United States of America and the Union of Soviet Socialist Republics on Underground Nuclear Explosions for Peaceful Purposes (Peaceful Nuclear Explosions Treaty or PNET)
Signed: 1976 | Entry into force: 1990

Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Strategic Offensive Arms (Strategic Arms Limitation Treaty or SALT II)
Signed: 1979 | SALT II never entered into force, although both sides complied with its provisions until 1986

South Pacific Nuclear-Free Zone Treaty (Treaty of Rarotonga)
Opened for signature: 1985 | Entry into force: 1986

Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of their Intermediate-Range and Shorter-Range Missiles (Intermediate-Range Nuclear Forces Treaty or INF Treaty)
Signed: 1987 | Entry into force: 1988 | U.S. Withdrawal: 2019

Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Reduction and Limitation of Strategic Offensive Arms (Strategic Arms Reduction Talks (START) Treaty)
Signed: 1991 | Entry into force: 1994

Presidential Nuclear Initiatives (PNI)
Announced: 1991 (The PNI were "reciprocal unilateral commitments" and thus are politically, not legally, binding and non-verifiable)

Treaty on Open Skies
Signed: 1992 | Entry into force: 2002

Treaty Between the United States of America and the Russian Federation on Further Reduction and Limitation of Strategic Offensive Arms (START II)
Signed: 1993 | START II never entered into force

Treaty on the Southeast Asia Nuclear Weapon-Free Zone (Bangkok Treaty)
Opened for signature: 1995 | Entry into force: 1997

African Nuclear Weapon-Free Zone Treaty (ANWFZ or Treaty of Pelindaba)
Opened for signature: 1996 | Entry into force: 2009

Comprehensive Nuclear Test-Ban Treaty (CTBT)
Opened for signature: 1996 | CTBT never entered into force

Treaty Between the United States of America and the Russian Federation on Strategic Offensive Reductions (Strategic Offensive Reductions Treaty, SORT, or Moscow Treaty)
Signed: 2002 | Entry into force: 2003

Central Asian Nuclear Weapon-Free Zone Treaty (CANWFZ)
Opened for signature: 2006 | Entry into force: 2009

Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START Treaty)
Signed: 2010 | Entry into force: 2011

The Joint Comprehensive Plan of Action (JCPOA) (aka the Iran nuclear deal)

Signed: 2015 | United States terminated participation: 2018

NUCLEAR WEAPON-FREE ZONES

Nuclear Weapon-Free Zones prohibit the stationing, testing, use, and development of nuclear weapons inside a particular geographical region. This is true whether the area is a single state, a region, or land governed solely by international agreements. There are several regional agreements to exclude or preclude the development and ownership of nuclear weapons. These agreements were signed under the assumption that it is easier to exclude/preclude weapons than to eliminate or control them once they have been introduced.

There are six existing Nuclear Weapon-Free Zones (see Figure 12.1) established by treaty: Antarctica, Latin America, the South Pacific, Southeast Asia, Africa, and Central Asia.

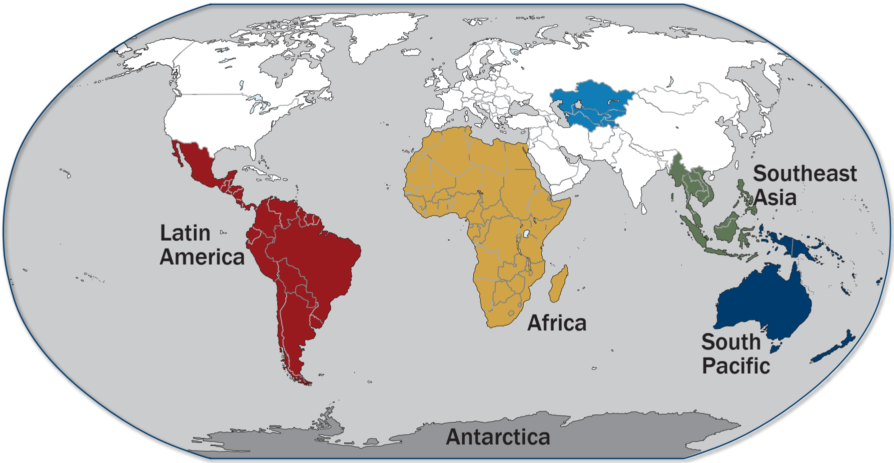
ANTARCTIC TREATY

Scientific interests rather than political, economic, or military concerns dominated the expeditions sent to Antarctica after World War II. International scientific associations made informal agreements to guide scientific study and cooperation in Antarctica. On May 3, 1958, the United States proposed a conference to consider the points of agreement that had been reached in informal multilateral discussions. Specifically, the conference sought to formalize international recognition that:

- the legal status quo of the Antarctic Continent would remain unchanged;
- scientific cooperation would continue; and
- the continent would be used for peaceful purposes only.

The Washington Conference on Antarctica culminated in a treaty signed on December 1, 1959. The Treaty entered into force on June 23, 1961, when the formal ratifications of all participating nations had been received.

The Treaty provides that Antarctica shall be used for peaceful purposes only. It specifically prohibits "any measures of a military nature, such as the establishment of military bases and fortifications, the carrying out of military maneuvers as well as the testing of any type of weapons." Military personnel or equipment, however, may be used for scientific research or for any other peaceful purpose. Nuclear explosions and the disposal of radioactive waste material in Antarctica are prohibited, subject to certain future international agreements on these subjects. There are provisions for amending the Treaty, for referring disputes



Africa	Algeria, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Chad, Comoros, Congo, Cote d'Ivoire, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Lesotho, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Rwanda, Sahrawi Arab Democratic Republic, Senegal, South Africa, Swaziland, Togo, Tunisia, Tanzania, Zambia, Zimbabwe
Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
Latin America (Mexico, Central America, South America)	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican, Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
Southeast Asia	Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam
South Pacific	Australia, Cook Islands, Fiji, Kiribati, Nauru, New Zealand, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu

Figure 12.1 Map of Nuclear Weapon-Free Zones

that cannot be handled by direct talks, mediation, arbitration, or other peaceful means to the International Court of Justice, and for calling a conference 30 years post-entry into force to review the implementation of the Treaty if any parties so request.

TREATY FOR THE PROHIBITION OF NUCLEAR WEAPONS IN LATIN AMERICA (TREATY OF TLATELOLCO)

The concept of a Latin American Nuclear Weapon-Free Zone was first introduced to the United Nations General Assembly in 1962. On November 27, 1963, this concept was codified and received the support of the U.N. General Assembly, with the United States voting in the affirmative.

On February 14, 1967, the Treaty was signed at a regional meeting of Latin American countries in Tlatelolco, a section of Mexico City. The Treaty entered into force in 1968.

The basic obligations of the Treaty are contained in Article I:

> The Contracting Parties undertake to use exclusively for peaceful purposes the nuclear material and facilities which are under their jurisdiction, and to prohibit and prevent in their respective territories: (a) the testing, use, manufacture, production, receipt, storage, installation, deployment, or acquisition by any means whatsoever of any nuclear weapons by the parties themselves, directly or indirectly, on behalf of anyone else or in any other way, and (b) the receipt, storage, installation, deployment and any form of possession of any nuclear weapons, directly or indirectly, by the parties themselves, or by anyone on their behalf or in any other way.

In Additional Protocol II to the Treaty, states outside of Latin America undertake to respect the denuclearized status of the zone, not to contribute to acts involving violation of obligations of the parties, and not to use or threaten to use nuclear weapons against the Contracting Parties.

The United States ratified Additional Protocol II on May 8, 1971, and deposited the instrument of ratification on May 12, 1971, subject to several understandings and declarations. France, the United Kingdom, China, and Russia are also parties to Protocol II.

SOUTH PACIFIC NUCLEAR-FREE ZONE TREATY (TREATY OF RAROTONGA)

On August 6, 1985, the South Pacific Forum, a body comprising the independent and self-governing countries of the South Pacific, endorsed the text of the South Pacific Nuclear-Free Zone Treaty and opened it for signature.

The Treaty is in force for 13 of the 16 South Pacific Forum members (Australia, Cook Islands, Fiji, Kiribati, Nauru, New Zealand, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu). The Federated States of Micronesia, the Marshall Islands, and Palau are not eligible to be parties to the Treaty because of their Compact of Free Association with the United States. The

United States, the United Kingdom, France, Russia, and China have all signed the Protocols that directly pertain to them (France and the UK have ratified all three protocols. Russia and China have only ratified Protocols II and III). U.S ratification of all three protocols is pending.

The parties to the Treaty agreed:

- not to manufacture or otherwise acquire, possess, or have control over any nuclear explosive device by any means anywhere inside or outside the South Pacific Nuclear-Free Zone;
- not to seek or receive any assistance in the manufacture or acquisition of any nuclear explosive device;
- to prevent the stationing of any nuclear explosive device in their territory;
- to prevent the testing of any nuclear explosive device in their territory; and
- not to take any action to assist or encourage the testing of any nuclear explosive device by any state.

TREATY ON THE SOUTHEAST ASIA NUCLEAR WEAPON-FREE ZONE (BANGKOK TREATY)

Indonesia and Malaysia originally proposed the establishment of a Southeast Asia Nuclear Weapon-Free Zone in the mid-1980s. On December 15, 1995, ten Southeast Asian states signed the Treaty on the Southeast Asian Nuclear Weapon-Free Zone at the Association of Southeast Asian Nations (ASEAN) Summit in Bangkok.

The Treaty commits parties not to conduct or receive, or to aid in the research, development, manufacture, stockpiling, acquisition, possession, or control over any nuclear explosive device by any means. Each state party also undertakes not to dump at sea or discharge into the atmosphere any radioactive material or wastes anywhere within the zone. Under the treaty protocol, each state party undertakes not to use or threaten to use nuclear weapons against any state party to the Treaty and not to use or threaten to use nuclear weapons within the zone. The Treaty entered into force in 1997.

The United States has not signed the Protocol to the Bangkok Treaty.

AFRICAN NUCLEAR WEAPON-FREE ZONE (ANWFZ) TREATY (PELINDABA TREATY)

The Organization of African Unity (OAU) first formally enunciated the desire to draft a treaty ensuring the denuclearization of Africa in July 1964. No real progress was made until South Africa joined the Nuclear Nonproliferation Treaty (NPT) in 1991. In April 1993, a group of United Nations and OAU experts convened to begin drafting a treaty.

The Pelindaba Treaty commits parties not to conduct or receive or give assistance in the research, development, manufacture, stockpiling, acquisition, possession, or control over any nuclear explosive device by any means anywhere.

The Treaty was opened for signature on April 11, 1996, and entered into force on July 15, 2009. The United States, the United Kingdom, France, China, and Russia and Russia have all signed the relevant treaty protocols. The United States has not ratified the treaty.

CENTRAL ASIAN NUCLEAR WEAPON-FREE ZONE (CANWFZ) TREATY

The concept of a Central Asian Nuclear Weapon-Free Zone (CANWFZ) first arose in a 1992 Mongolian initiative in which the country declared itself a nuclear weapon-free zone and called for the establishment of a regional NWFZ. A formal proposal for a Central Asian Nuclear Weapon-Free Zone was made by Uzbekistan at the 48th session of the United Nations General Assembly in 1993, but a lack of regional consensus on the issue blocked progress on a CANWFZ until 1997. On February 27, 1997, the five presidents of the Central Asian states (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) issued the Almaty Declaration, which called for the creation of a CANFWZ.

The text of the CANWFZ Treaty was agreed upon at a meeting held in Uzbekistan from September 25–27, 2002. On February 8, 2005, the five states adopted a final draft of the Treaty text, and the Treaty was opened for signature on September 8, 2006. The Treaty establishing the CANWFZ entered into force on March 21, 2009. The United States did not ratify the treaty.

NUCLEAR WEAPONS TREATIES

LIMITED TEST BAN TREATY

The Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, or the Limited Test Ban Treaty (LTBT) of 1963, prohibits nuclear weapons tests "or any other nuclear explosion" in the atmosphere, in outer space, and under water. While the Treaty does not ban tests underground, it does prohibit nuclear explosions in this environment if they cause "radioactive debris to be present outside the territorial limits of the state under whose jurisdiction or control" the explosions were conducted. In accepting limitations on testing, the nuclear powers accepted as a common goal "an end to the contamination of the environment by radioactive substances."

The LTBT is of unlimited duration. The Treaty is open to all states, and most of the countries of the world are parties to it. The Treaty has not been signed by France, the People's Republic of China (PRC), or North Korea.

NUCLEAR NONPROLIFERATION TREATY

In 1968, the United States signed the Treaty on the Nonproliferation of Nuclear Weapons, often called the Nuclear Nonproliferation Treaty. Most nations of the world are parties to the Treaty; it forms the cornerstone of the international nuclear nonproliferation regime. The NPT recognizes the five nuclear powers that existed in 1968: the United States, the Soviet Union,[1] the United Kingdom, France, and China. The Treaty prohibits all other signatories from acquiring or even pursuing a nuclear weapons capability. This requirement has prevented three states from signing onto the Treaty: India, Israel, and Pakistan. (In 2003, North Korea, a former signatory, formally withdrew from the NPT.)

While the non-nuclear signatories to the NPT are prohibited from developing nuclear weapons, the nuclear weapons states are obligated to assist them in acquiring peaceful applications for nuclear technology.

In broad outline, the basic provisions of the Treaty are designed to:

- prevent the spread of nuclear weapons (Articles I and II);
- provide assurance, through international safeguards, that the peaceful nuclear activities of states that have not already developed nuclear weapons will not be diverted to making such weapons (Article III);
- promote, to the maximum extent consistent with the other purposes of the Treaty, the peaceful uses of nuclear energy, including the potential benefits of any peaceful application of nuclear technology to be made available to non-nuclear parties under appropriate international observation (Articles IV and V); and
- express the determination of the parties that the Treaty should lead to further progress in comprehensive arms control and nuclear disarmament measures (Article VI).

In accordance with the terms of the NPT, a conference was held in 1995 to decide whether the NPT should continue in force indefinitely or be extended for an additional fixed period. On May 11, 1995, more than 170 countries attending the NPT Review and Extension Conference in New York decided to extend the Treaty indefinitely and without conditions.

STRATEGIC ARMS LIMITATION TALKS/TREATY

The first series of Strategic Arms Limitation Talks (SALT) extended from November 1969 to May 1972. During that period, the United States and the

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[1] On January 30, 1992, the Russian Embassy in the United States informed the State Department that the Russian Federation would continue to exercise the rights and fulfill the obligations arising from the Treaty as a nuclear-weapon state.

Soviet Union negotiated the first agreements to place limits and restraints on some of their most important nuclear weapons systems.

At the time, American and Soviet weapons systems were far from symmetric. Further, the defense needs and commitments of the two superpowers differed considerably. The United States had obligations for the defense of allies overseas, including the nations of the North Atlantic Treaty Organization, Japan, and South Korea, while the Soviet Union's "allies" were its near neighbors. All these circumstances made for difficulties in equating specific weapons, or categories of weapons, and in defining overall strategic equivalence.

The first round of SALT was brought to a conclusion on May 26, 1972, after two and a half years of negotiation, when President Richard Nixon and General Secretary Leonid Brezhnev signed the Anti-Ballistic Missile Treaty and the Interim Agreement on strategic offensive arms.

ANTI-BALLISTIC MISSILE TREATY

In the Treaty on the Limitation of Anti-Ballistic Missile (ABM) Systems, the United States and the Soviet Union agreed that each party may have only two ABM deployment areas, restricted and located to preclude providing a nationwide ABM defense or from becoming the basis for developing one. Thus, each country agreed not to challenge the penetration capability of the other's retaliatory nuclear missile forces.

The Treaty permitted each side to have one ABM system to protect its capital and another to protect one ICBM launch area. The two sites defended had to be at least 1,300 kilometers apart to prevent the creation of any effective regional defense zone or the beginnings of a nationwide system. A 1974 protocol provided that each side could only have one site, either to protect its capital or to protect one ICBM launch area.

Precise quantitative and qualitative limits were imposed on the deployed ABM systems. Further, to decrease the pressures of technological change and corresponding unsettling effect on the strategic balance, both sides agreed to prohibit the development, testing, or deployment of sea-based, air-based, or space-based ABM systems and their components, along with mobile land-based ABM systems. Should future technology bring forth new ABM systems "based on other physical principles" than those employed in then-current systems, it was agreed that limiting such systems would be discussed in accordance with the Treaty's provisions for consultation and amendment.

In June 2002, the United States withdrew from the ABM Treaty to pursue a national ballistic missile defense program.

INTERIM AGREEMENT—STRATEGIC ARMS LIMITATION TALKS (SALT) I

As its title suggests, the Interim Agreement on Certain Measures with Respect to the Limitation of Offensive Arms was limited in duration and scope. It was intended to remain in force for only five years. Both countries agreed to continue negotiations toward a more comprehensive agreement as soon as possible. The scope and terms of any new agreement were not to be prejudiced by the provisions of the 1972 interim accord.

Thus, the Interim Agreement was intended as a holding action, which was designed to complement the ABM Treaty by limiting competition in offensive strategic arms and by providing time for further negotiations. The agreement essentially froze existing levels of strategic ballistic missile launchers (operational or under construction) for both sides. It permitted an increase in submarine-launched ballistic missile (SLBM) launchers up to an agreed level for each party provided that the party dismantle or destroy a corresponding number of older ICBM or SLBM launchers.

In view of the many asymmetries between the United States and the Soviet Union, imposing equivalent limitations required complex and precise provisions. At the date of signing, the United States had 1,054 operational land-based ICBM launchers, with none under construction, and the Soviet Union had an estimated 1,618 ICBM launchers, including operational launchers and launchers under construction. Launchers under construction were permitted to be completed. Yet, neither side would be authorized to start construction of additional fixed land-based ICBM launchers during the period of the agreement, excluding the relocation of existing launchers. Launchers for light or older ICBMs could not be converted into launchers for modern heavy ICBMs. This prevented the Soviet Union from replacing older missiles with missiles such as the SS-9, which in 1972 was the largest and most powerful missile in the Soviet inventory and a source of particular concern to the United States.

Within these limitations, modernization and replacements were permitted, but in the process of modernizing, the dimensions of silo launchers could not be significantly increased. A discussion on mobile ICBMs was not included in the text of this Treaty.

STRATEGIC ARMS LIMITATION TREATY—SALT II

In accordance with Article VII of the Interim Agreement, in which the sides committed themselves to continue active negotiations on strategic offensive arms, the SALT II negotiations began in November 1972. The primary goal of SALT II was to replace the Interim Agreement with a long-term comprehensive treaty providing broad limits on strategic offensive weapons systems. The principal

U.S. objectives as the SALT II negotiations began were: to provide for equality in the aggregate numbers of strategic nuclear delivery vehicles for the two sides, to begin the process of reducing the number of these delivery vehicles, and to impose restraints on qualitative developments that could threaten future stability.

Early discussion focused on two key areas: the weapon systems to be included and factors used to determine equality in numbers of strategic nuclear delivery vehicles. Such factors accounted for the important differences between each side's military forces, bans on new systems, qualitative limits, and a Soviet proposal to restrict U.S. forward-based systems. The two sides held widely diverging positions on many of these issues. In subsequent negotiations, the United States and the Soviet Union agreed on a general framework for SALT II.

The Treaty included detailed definitions of limited systems, provisions to enhance verification, a ban on circumvention of the provisions of the agreement, and a provision outlining the duties of the Security Council in connection with SALT II. The terms of the Treaty were intended to remain in force through 1985.

The completed SALT II agreement was signed by President Jimmy Carter and General Secretary Leonid Brezhnev in Vienna on June 18, 1979. President Carter transmitted it to the Senate on June 22, 1979, for ratification. U.S. ratification of SALT II was delayed due to the Soviet invasion of Afghanistan. Although the Treaty remained unratified, each party was individually bound under international law to refrain from acts that would defeat the object and purpose of the Treaty until the country had made its intentions clear not to become a party to the Treaty.

SALT II never entered into force.

Threshold Test Ban Treaty

The Treaty on the Limitation of Underground Nuclear Weapon Tests, also known as the Threshold Test Ban Treaty (TTBT), was signed in July 1974. It established a nuclear "threshold" by prohibiting tests with a yield exceeding 150 kilotons (equivalent to 150,000 tons of TNT).

The TTBT included a Protocol that specified the technical data to be exchanged and limited weapon testing to designated test sites to simplify verification efforts. The data to be exchanged included information on geographical boundaries and the geology of the testing areas. Geological data, including such factors as density of rock formation, water saturation, and depth of the water table, are useful in verifying test yields because the seismic signal produced by a given underground nuclear explosion varies with these factors at the test location. After an actual test had taken place, the geographic coordinates of the test location were to be furnished to the other party to help in assessing geological setting and yield.

The Treaty also stipulated that data would be exchanged on a certain number of tests for calibration purposes. By establishing the correlation between the stated yield of an explosion at the specified sites and the seismic signals produced, both parties could more accurately assess the yields of explosions based primarily on the measurements derived from their seismic instruments.

Although the TTBT was signed in 1974, it was not sent to the U.S. Senate for ratification until July 1976. Submission was held in abeyance until the companion Treaty on Underground Nuclear Explosions for Peaceful Purposes (or the Peaceful Nuclear Explosions Treaty (PNET)) had been successfully negotiated in accordance with Article III of the TTBT.

Neither the United States nor the Soviet Union ratified the TTBT or the PNET until 1990. However, in 1976 each party separately announced its intention to observe the Treaty limit of 150 kilotons, pending ratification.

The United States and the Soviet Union began negotiations in November 1987 to reach an agreement on additional verification provisions that would make it possible for the United States to ratify the two treaties. In 1990, the parties reached an agreement on additional verification provisions; these provisions were introduced in new protocols substituting for the original protocols. The TTBT and PNET both entered into force on December 11, 1990.

PEACEFUL NUCLEAR EXPLOSIONS TREATY

In preparing the TTBT, the United States and the Soviet Union recognized the need to establish an appropriate agreement to govern underground nuclear explosions for peaceful purposes.

In the Treaty on Underground Nuclear Explosions for Peaceful Purposes, the United States and the Soviet Union agreed not to carry out:

- any individual nuclear explosions with a yield exceeding 150 kilotons;
- any group explosion (consisting of a number of individual explosions) with an aggregate yield exceeding 1,500 kilotons; and
- any group explosion with an aggregate yield exceeding 150 kilotons unless the individual explosions in the group could be identified and measured by agreed verification procedures.

The parties reserved the right to carry out nuclear explosions for peaceful purposes in the territory of another country if requested to do so, but only in full compliance with the yield limitations and other provisions of the PNET and in accordance with the NPT.

The Protocol to the PNET sets forth the specific agreed arrangements for ensuring that no weapons-related benefits precluded by the TTBT are derived by carrying out a nuclear explosion used for peaceful purposes.

The agreed statement that accompanies the Peaceful Nuclear Explosions Treaty specifies that a "peaceful application" of an underground nuclear explosion would not include the developmental testing of any nuclear explosive. Nuclear explosive testing must be carried out at the nuclear weapon test sites specified by the terms of the TTBT and would be treated as the testing of a nuclear weapon.

The provisions of the PNET, together with those of the TTBT, establish a comprehensive system of regulations to govern all underground nuclear explosions of the United States and the Soviet Union. The interrelationship of the TTBT and the PNET is further demonstrated by the provision that neither party may withdraw from the PNET while the TTBT remains in force. Conversely, either party may withdraw from the PNET upon termination of the TTBT.

INTERMEDIATE-RANGE NUCLEAR FORCES TREATY

The Treaty between the United States of America and the Union of Soviet Socialist Republics on the Elimination of their Intermediate-Range and Shorter-Range Missiles, commonly referred to as the Intermediate-Range Nuclear Forces (INF) Treaty, was signed by President Ronald Reagan and General Secretary Mikhail Gorbachev on December 8, 1987, at a summit meeting in Washington, D.C. The INF Treaty required the destruction of ground-launched ballistic and cruise missiles with ranges between 500 and 5,500 kilometers, their launchers, and their associated support structures and support equipment within three years following the Treaty's entry into force. It also established a verification regime to help ensure compliance with the total ban on possession and use of these missiles. At the time of its signature, the Treaty's verification regime was the most detailed and stringent in the history of nuclear arms control.

The Treaty entered into force upon the exchange of instruments of ratification in Moscow on June 1, 1988. In late April and early May 1991, the United States eliminated its last ground-launched cruise missile and ground-launched ballistic missile covered under the INF Treaty. The last declared Soviet SS-20 was eliminated on May 11, 1991. In total, 2,692 missiles were eliminated after the Treaty's entry into force.

Following the December 25, 1991, dissolution of the Soviet Union, the United States informed 12 former Soviet Republics that it held them accountable as successor States under the INF Treaty; however, some of these states never agreed. Six of these 12 former Soviet Republics had facilities subject to inspection on their territory, namely Russia, Ukraine, Belarus, Kazakhstan, Turkmenistan, and Uzbekistan. Converting what was previously a bilateral U.S.-Soviet INF Treaty to a multilateral treaty required establishing agreements between the United States and the relevant Soviet successor states on numerous issues. Among the tasks undertaken were: the settlement of costs connected with implementation of the new, multilateral treaty; the establishment of new points of entry in Belarus, Kazakhstan, and Ukraine through which to conduct inspections of the former INF Treaty facilities in those countries; and the establishment of communications links between the United States and those countries for the transmission of various treaty-related notifications.

In a joint statement to the United Nations General Assembly in 2007, the United States and the Russian Federation called on all countries to join a global INF Treaty. The leadership of the Russian Federation cited concerns that, without other countries joining the Treaty, it would no longer prove useful. Since that time both the Obama and Trump administrations, as well as NATO leaders, have stated Russia was in breach of the Treaty. Specifically, the concern was the Russian SSC-8 ground-launched cruise missile violated the Treaty. Russia has denied these accusations.

As a result, on December 4, 2018, the United States announced that the Russian Federation was in material breach of the INF Treaty and that unless Russia returned to full and verifiable compliance in 60 days, the United States would suspend its obligations under the Treaty as a consequence for Russia's material breach. On February 2, 2019, the United States suspended its obligations under the INF Treaty and provided Russia and other Treaty Parties with formal notice that the United States would withdraw from the INF Treaty in six months, pursuant to Article XV of the Treaty. On May 4, 2019, President Putin signed an executive order suspending Russia's compliance with the INF Treaty and on July 3, 2019, signed into law Russia's suspension of its obligations under the INF Treaty. The United States officially withdrew from the Treaty on August 2, 2019.

Strategic Arms Reduction Talks (START) Treaty

After nine years of negotiations, the Treaty on the Reduction and Limitation of Strategic Offensive Arms, or START Treaty, was signed in Moscow on July 31, 1991. Five months later, the Soviet Union dissolved, and four independent states with strategic nuclear weapons on their territories came into existence: Belarus, Kazakhstan, Russia, and Ukraine.

Through the Lisbon Protocol to the START Treaty, signed on May 23, 1992, Belarus, Kazakhstan, Russia, and Ukraine became parties to the Treaty as legal successors to the Soviet Union. In December 1994, the parties to START I exchanged instruments of ratification and the START Treaty entered into force. In parallel with the Lisbon Protocol, the three non-Russian states agreed to send all nuclear weapons back to the Russian Federation and join the NPT as non-nuclear weapons states.

The Treaty required reductions in strategic offensive arms to equal aggregate levels, from a high of some 10,500 in each arsenal. The central limits include:

- 1,600 strategic nuclear delivery vehicles;
- 6,000 accountable warheads;
- 4,900 ballistic missile warheads;
- 1,540 warheads on 154 heavy ICBMs; and
- 1,100 warheads on mobile ICBMs.

While the Treaty called for these reductions to be carried out over seven years, in practice, all the Lisbon Protocol signatories began deactivating and eliminating systems covered by the agreement prior to its entry into force. START I was negotiated with effective verification in mind. The basic structure of the Treaty was designed to facilitate verification by national technical means (NTM),[2] and the Treaty contains detailed, mutually reinforcing verification provisions to supplement NTM.

On December 5, 2001, the United States and Russia announced that they had met the final START Treaty limits. This completed the largest arms control reductions in history.

The START Treaty was intended to be a 15-year commitment with the option to extend it in 5-year increments. However, the United States and the Russian Federation allowed the Treaty to expire on December 5, 2009. By that time, negotiations for the New START Treaty were ongoing, and the agreement, called New START, was signed in Prague on April 8, 2010.

1991 Presidential Nuclear Initiatives

On September 27, 1991, President George H.W. Bush announced that the United States would eliminate its entire worldwide inventory of ground-launched tactical nuclear weapons and would remove tactical nuclear weapons from all U.S. Navy surface ships, attack submarines, and land-based naval aircraft bases during normal circumstances. In addition, President Bush declared that U.S. strategic bombers would be taken off alert and that ICBMs scheduled for deactivation under the START Treaty would also be taken off alert. These unilateral arms reductions are known as the 1991 Presidential Nuclear Initiatives.

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[2] National technical means of verification are monitoring techniques, such as satellite photography, used to verify adherence to treaties.

On October 5, 1991, about one week after President Bush announced the U.S. initiatives, Soviet President Mikhail Gorbachev pledged to destroy all nuclear artillery ammunition and nuclear mines, to remove nuclear warheads from anti-aircraft missiles and all theater nuclear weapons on surface ships and multi-purpose submarines, to de-alert strategic bombers, and to abandon plans of developing a small mobile ICBM and not to increase or modernize mobile ICBMs. He also pledged to reduce an additional 1,000 nuclear warheads beyond the reductions required by the START Treaty and stated that the country would observe a one-year moratorium on nuclear weapons testing. In January 1992, Russian President Boris Yeltsin asserted Russia's status as a legal successor to the Soviet Union in international obligations. President Yeltsin also made several pledges to reduce Russian nuclear capabilities.

TREATY ON OPEN SKIES

The Treaty on Open Skies was signed in Helsinki, Finland, on March 24, 1992, and entered into force on January 1, 2002. The Eisenhower Administration originally proposed the notion of an Open Skies regime in 1955, but the proposal was rejected by the Soviet Union. The Open Skies concept was revisited in 1989, and in February 1990, members of NATO and the Warsaw Pact began negotiations to establish an Open Skies regime. Additional negotiations in Vienna, Austria, included observers from the Organization for Security and Cooperation in Europe, and concluded in 1992 with the signing of the Treaty on Open Skies. The Treaty currently includes 34 State Parties (Kyrgyzstan has signed, but not ratified) and is unlimited in duration.

The Treaty aims to promote openness and transparency of military forces and activities among its State Parties. Additionally, it provides further means of verifying states' compliance with other arms control agreements. It establishes a regime of observation flights over its signatories' territories with unarmed, fixed-wing aircraft that must be equipped with specific types of sensors and camera resolution. Each State Party is allocated a certain number of observation flights it may conduct and a certain number of observation flights it must accept over its own territory. The allocated observation flights are referred to as "quotas," which are reviewed annually. State Parties are also able to conduct shared missions with each other, which fosters collaboration and relationships among the member states. In accordance with the Treaty, all State Parties receive advanced notification of any observation flight and mission status. Additionally, any member may purchase the data collected from these observation missions.

The Open Skies Consultative Commission (OSCC) is the Treaty's implementing body and meets monthly in Vienna, Austria. The Commission is charged with responding to technical, procedural, and financial issues as well as resolving any issues related to Treaty implementation and compliance. Review conferences for the Treaty are held every five years—the next conference will take place in 2020.

START II

Negotiations to achieve a follow-on to the START Treaty began in June 1992. The United States and Russia agreed on the text of a Joint Understanding on the Elimination of MIRVed ICBMS and Further Reductions in Strategic Offensive Arms. The Joint Understanding called for both sides to promptly conclude a new treaty that would further reduce strategic offensive arms by eliminating all ICBMs containing Multiple Independently-Targetable Reentry Vehicles (MIRVs), including all heavy ICBMs, limiting the number of SLBM warheads to no more than 1,750, and reducing the total number of accountable warheads for each side to between 3,000 and 3,500.

On January 3, 1993, President George H.W. Bush and President Boris Yeltsin signed the Treaty between the United States of America and the Russian Federation on Further Reduction and Limitation of Strategic Offensive Arms. The Treaty, often called START II, codifies the Joint Understanding signed by the two Presidents at the Washington Summit on June 17, 1992.

The 1993 START II never entered into force because of the long delay in Russian ratification and because Russia conditioned its ratification of START II on preservation of the ABM Treaty.

COMPREHENSIVE NUCLEAR-TEST-BAN TREATY

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) was negotiated at the Geneva Conference on Disarmament between January 1994 and August 1996. The United Nations General Assembly voted on September 10, 1996, to adopt the Treaty by a vote of 158 in favor, three opposed, and five abstentions. President Bill Clinton was the first world leader to sign the CTBT on September 24, 1996. The CTBT bans any nuclear weapon test explosion or any other nuclear explosion. The CTBT is of unlimited duration. Each State Party has the right to withdraw from the CTBT under the standard "supreme national interest" clause. President Clinton submitted the Treaty to the U.S. Senate for ratification in 1999, but the Senate failed to ratify the Treaty by a vote of 51 to 48.

The Treaty will enter into force following ratification by the United States and 43 other countries listed in Annex 2 of the Treaty; these "Annex 2 States" are states that participated in CTBT negotiations between 1994 and 1996 and possessed nuclear power reactors or research reactors during that time. Eight of the Annex 2 States have not yet ratified the Treaty, to include the United States. Therefore, the Treaty has not entered into force. Nevertheless, the United States has observed a self-imposed moratorium on underground nuclear explosive testing since 1992.

STRATEGIC OFFENSIVE REDUCTIONS TREATY

On May 24, 2002, President George W. Bush and Russian President Vladimir Putin signed the Moscow Treaty on Strategic Offensive Reductions, also called SORT or the Moscow Treaty. Under the terms of this Treaty, the United States and Russia pledged to reduce their operationally deployed strategic nuclear warheads to a level between 1,700 and 2,200 by December 31, 2012, nearly two-thirds below levels at the time it was signed. Each side was to determine for itself the composition and structure of its strategic forces consistent with this limit.

Both the United States and Russia pledged to reduce their strategic offensive forces to the lowest possible levels consistent with their national security requirements and alliance obligations. The United States considered operationally deployed strategic nuclear warheads to be: reentry vehicles on ICBMs in their launchers; reentry vehicles on SLBMs in their launchers onboard submarines; and nuclear armaments loaded on heavy bombers or stored in weapon storage areas at heavy bomber bases.

The Moscow Treaty entered into force on June 1, 2003. When the New START Treaty entered into force on February 5, 2011, the Moscow Treaty was terminated.

NEW START TREATY

Negotiations for a new follow-on agreement to the START Treaty began in May 2009. A Joint Understanding for a Follow-on Agreement to the START Treaty was signed by the Presidents of the United States and Russia in Moscow on July 6, 2009. The successor Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms was signed by President Barack Obama and President Dmitry Medvedev in Prague, Czech Republic, on April 8, 2010.

Under the New START Treaty, the United States and Russia agreed to significantly reduce strategic arms within seven years from February 5, 2011, the date the Treaty entered into force. According to the Treaty, each party has the flexibility to determine the structure of its strategic forces within the aggregate limits of the Treaty. The aggregate limits set by the Treaty are:

- 1,550 deployed warheads. Warheads on deployed ICBMs and deployed SLBMs count toward this limit and each deployed heavy bomber equipped for nuclear armaments counts as one warhead toward this limit;
- a combined limit of 800 deployed and non-deployed ICBM launchers, SLBM launchers, and heavy bombers equipped for nuclear armaments; and

- a separate limit of 700 deployed ICBMs, deployed SLBMs, and deployed heavy bombers equipped for nuclear armaments.

The Treaty has a verification regime that includes some elements of the START Treaty with new elements tailored to the limitations of the New START Treaty. Measures under the Treaty include on-site inspections and exhibitions, data exchanges and notifications related to strategic offensive arms and facilities covered by the Treaty, and provisions to facilitate the use of national technical means for Treaty monitoring. The Treaty also provides for the exchange of telemetry to increase confidence and transparency.

The Treaty's duration will be ten years unless it is superseded by a subsequent agreement, and parties may agree to extend the Treaty for a period of no more than five years.

The Joint Comprehensive Plan of Action (JCPOA)

The Joint Comprehensive Plan of Action (JCPOA), known as the Iran nuclear deal, is an agreement on the Iranian nuclear program reached in Vienna on July 14, 2015, between Iran, the five permanent members of the United Nations Security Council—China, France, Russia, United Kingdom, United States—plus Germany (the P5+1), and the European Union.

Under JCPOA, Iran agreed to eliminate its stockpile of medium-enriched uranium, cut its stockpile of low-enriched uranium by 98%, and reduce by about two-thirds the number of its gas centrifuges for 13 years. For the next 15 years, Iran would only enrich uranium up to 3.67%. Iran also agreed not to build any new heavy-water facilities for the same period of time. Uranium enrichment activities would be limited to a single facility using first-generation centrifuges for ten years. The International Atomic Energy Agency (IAEA) would monitor and verify compliance at Iran's nuclear facilities. In return for verifiably abiding by its commitments, Iran would receive relief from U.S., European Union, and United Nations Security Council nuclear-related sanctions.

Citing issues with JCPOA, on October 13, 2017, President Donald Trump announced that the United States would not make the certification provided for under U.S. domestic law, but stopped short of terminating the agreement. Then, on April 30, 2018, the United States and Israel stated that Iran had not disclosed a past covert nuclear weapons program to the IAEA, which was required in JCPOA.

On May 8, 2018, President Trump announced U.S. withdrawal from JCPOA, stating it failed to protect America's national security interests. Subsequently, the United States re-imposed sanctions targeted at critical sectors of Iran's economy, such as its energy, petrochemical, and financial sectors.

NUCLEAR TREATY MONITORING AND VERIFICATION TECHNOLOGIES

To ensure confidence in the treaty regimes, a vast array of technical and non-technical verification technologies and procedures are utilized to guard against illicit nuclear activities. There are two main types of verification procedures: those designed to uncover and inhibit nuclear weapons development and/or nuclear weapons testing; and those designed to account for and monitor reductions in existing nuclear stockpiles. There are some technologies and procedures that apply to both counterproliferation activities and stockpile monitoring activities.

COUNTERPROLIFERATION VERIFICATION TECHNOLOGIES

Counterproliferation verification technologies are most commonly employed to support and ensure confidence in nuclear weapons treaties affecting non-nuclear weapons states and/or those states not in compliance with either the NPT or IAEA safeguards. These activities include: intrusive, short-notice inspections by the IAEA; a declaration of nuclear materials; satellite surveillance of suspected nuclear facilities; and, in the event of a confirmed or suspected nuclear detonation, international seismic monitoring, air and materials sampling, hydroacoustic and infrasound monitoring, and space-based nuclear energy detection resources.

Inspections of nuclear or suspected nuclear facilities as well as reporting requirements are generally administered by the IAEA, under the auspices of the NPT and the Additional Protocols. During these inspections, trained IAEA inspectors collect environmental samples to scan for illicit nuclear substances, verify facility design information, and review the country's nuclear fuel cycle processes. Remote inspection activities can also be used to monitor movements of declared material in a facility and to evaluate information derived from a country's official declarations and open source information.

Satellite surveillance of suspected nuclear facilities is generally not proscribed by nonproliferation treaties and agreements with non-nuclear weapons states, but it is employed by domestic intelligence collection programs and can aid in counterproliferation verification. These activities, for instance, can remotely monitor and verify either the destruction or expansion of existing nuclear facilities.

International seismic monitoring is conducted by both the international community, through a network of CTBT Organization (CTBTO) monitoring stations, and the United States, through an independent network of monitoring stations. Both systems rely on strategically placed seismic monitors to detect nuclear detonations on or below the Earth's surface.

Air and materials sampling and hydroacoustic and infrasound monitoring are also recognized verification technologies that could be used to detect and/or confirm a nuclear detonation. Nuclear events produce very specific, and generally easily recognizable, post-detonation characteristics, to include the dispersal of radioactive fallout, atmospheric pressure waves, and infrared radiation. These sampling and monitoring activities are generally considered to be national technical nuclear forensics activities. (For more information on national technical nuclear forensics, see *Chapter 11: Nuclear Threat Reduction*.)

Lastly, space-based nuclear energy sensors are particularly adept at detecting surface and above surface nuclear detonations. These satellites use X-ray, neutron, electromagnetic pulse (EMP) and gamma-ray detectors as well as detectors capable of distinguishing the characteristic "double flash" of a nuclear burst. Sub-surface bursts, however, would go largely undetected by this set of technologies.

STOCKPILE MONITORING

Stockpile monitoring includes those activities designed to ensure compliance with nuclear weapons reductions or stockpile surveillance, for example, the NPT (as it relates to declared and allowed nuclear weapons states) and New START. These activities include bilateral on-site inspections, unique identifiers for nuclear warheads, national technical means, data exchange and notifications, and telemetric information from intercontinental and submarine-launched ballistic missile (ICBM and SLBM) launches. These procedures are designed to balance the sovereignty and security interests of each participating nation against denuclearization goals.

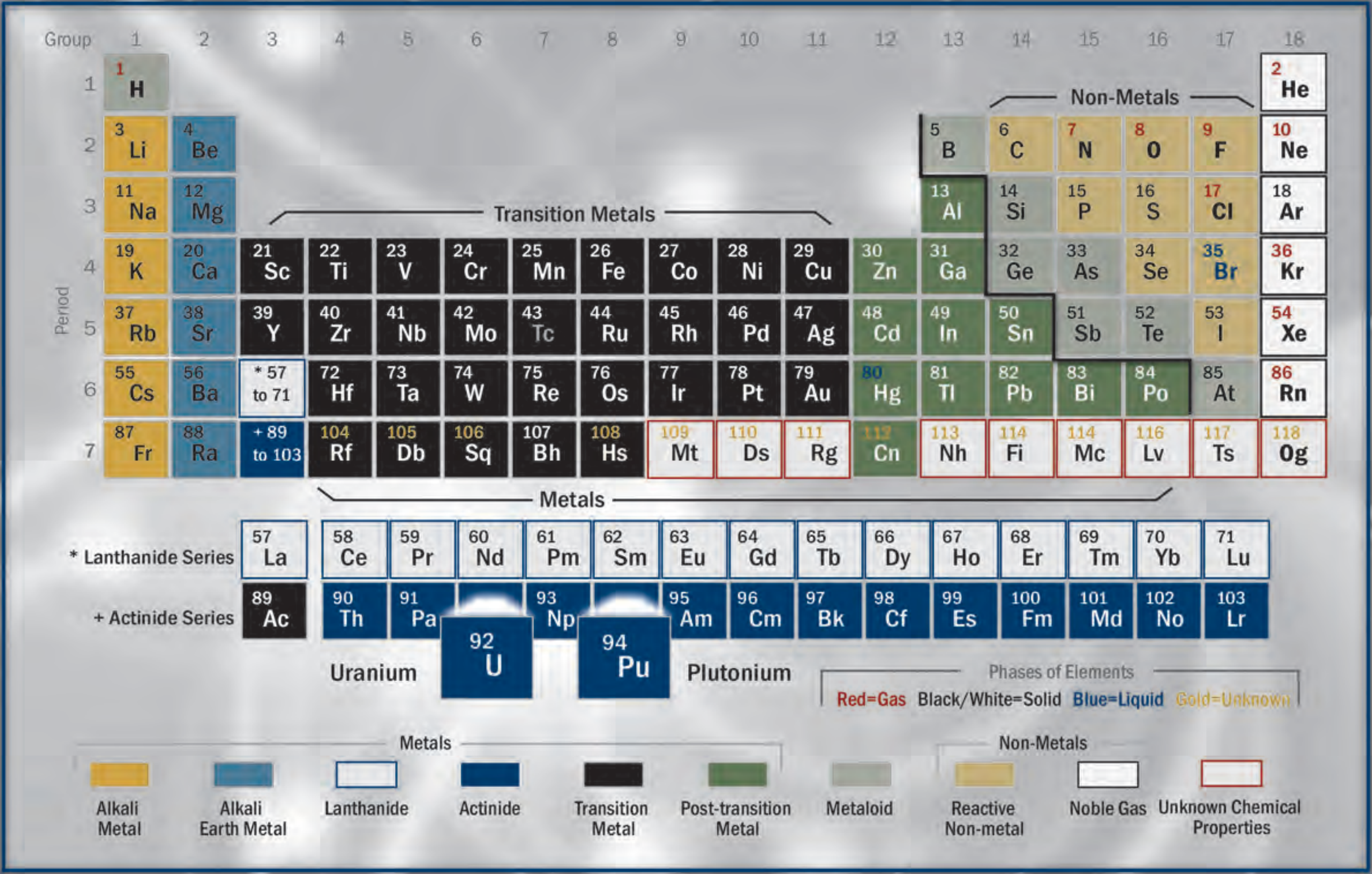
Bilateral on-site inspections are conducted under the auspices of bilateral treaty organizations, which stipulate the number and type of inspections. For the United States, the only major nuclear treaty that allows for bilateral inspections is New START. New START allows for two different types of inspections, with a total of 18 possible inspections each year. The first type focuses on sites with deployed and non-deployed strategic systems; whereas the second focuses on sites with only non-deployed (or converted non-nuclear) strategic systems. During the inspections, inspectors are allowed to confirm the number of reentry vehicles on deployed ICBMs and SLBMs, numbers related to non-deployed launcher limits, weapons system conversions or eliminations, and facility eliminations. To aid in the inspection process, unique identifiers are assigned to each nuclear delivery vehicle (i.e., ICBMs, SLBMs, and heavy bombers). These are confirmed against data exchange and notification figures, which list the numbers, location, and technical characteristics of delivery vehicles and facilities.

NUCLEAR SECURITY SUMMITS

In April 2010, in response to U.S. prompting for a new international effort to secure vulnerable nuclear material around the world, the first Nuclear Security Summit on nuclear terrorism was hosted by the United States. Four Nuclear Security Summits were convened with a total of four international organizations and 53 countries, including the P5 nations (nuclear weapons states) and states not party to the NPT. The Summits were held on the following dates:

- April 12–13, 2010, Washington, D.C., United States
- March 26–27, 2012, Seoul, South Korea
- March 24–25, 2014, The Hague, Netherlands
- March 31–April 1, 2016, Washington, D.C., United States

The summit series addressed cooperative measures necessary for the international community to combat the threat of nuclear terrorism, protect nuclear materials and facilities, and prevent illicit trafficking of nuclear weapons. Each summit addressed key nuclear security issues with the understanding that the threat of nuclear terrorism cannot be undertaken by any individual nation but must be confronted by the international community writ large.



Period \ Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	* 57 to 71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	+ 89 to 103	104 Rf	105 Db	106 Sq	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fi	114 Mc	116 Lv	117 Ts	118 Og

Transition Metals

Non-Metals

Metals

* Lanthanide Series	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
+ Actinide Series	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Uranium

Plutonium

Phases of Elements

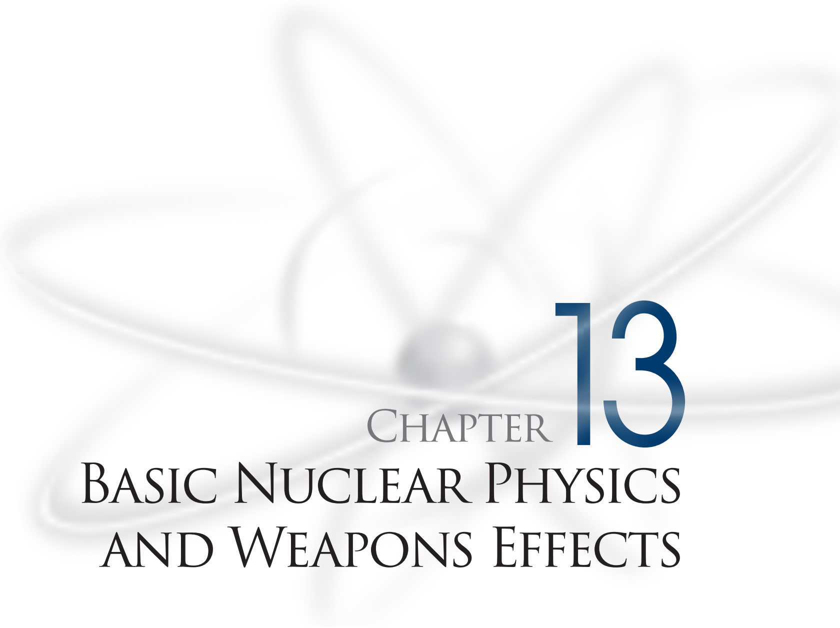
Red=Gas Black/White=Solid Blue=Liquid Gold=Unknown

Metals

- Alkali Metal
- Alkali Earth Metal
- Lanthanide
- Actinide
- Transition Metal
- Post-transition Metal
- Metaloid

Non-Metals

- Reactive Non-metal
- Noble Gas
- Unknown Chemical Properties



CHAPTER 13

BASIC NUCLEAR PHYSICS AND WEAPONS EFFECTS

OVERVIEW

Nuclear weapons depend on the potential energy that can be released from the nuclei of atoms. The splitting apart of atoms, called *fission*, and joining together of atoms, called *fusion*, are nuclear reactions that can be induced in the nucleus. All current nuclear weapons use the basic approach of producing a very large number of fission events through a multiplying chain reaction and releasing a huge amount of nuclear energy in a very short period of time. This chapter provides an overview of nuclear physics, basic nuclear weapon designs, and the effects of nuclear detonations.

NUCLEAR PHYSICS

The fundamentals of nuclear weapons design and function include atomic structure, radioactive decay, fissile material, and nuclear reactions.

ATOMIC STRUCTURE

Matter is the material substance in the universe that occupies space and has mass. All matter in the observable universe is made up of various combinations of separate and distinct particles. When these particles (primarily protons, neutrons, and electrons) are combined to form atoms, they are called elements. There are more than 110 known chemical elements, each of which cannot be broken down further without changing its chemical properties. The number of protons in an atom's nucleus identifies the atomic element.

Atoms have a densely packed core, or nucleus, comprised of electrically neutral neutrons and positively charged protons (except for hydrogen whose nucleus contains only a single proton) that is surrounded by rings or shells of orbiting, negatively charged electrons as illustrated in Figure 13.1. Interactions with an atom's electrons determine an element's chemical characteristics whereas interactions with an atom's nucleus determine an element's nuclear characteristics. Examples of chemical characteristics include the tendency of elements to combine with other elements (e.g., hydrogen and oxygen combine to form water), the ability to conduct electricity, and the ability to undergo chemical reactions, such as oxidation (e.g., iron and oxygen combine to form iron oxide or rust). Examples of nuclear characteristics include the tendency of a nucleus to split apart or fission, the ability of a nucleus to absorb a neutron, and radioactive decay where the nucleus emits a particle from the nucleus. An important difference between chemical and nuclear reactions is that there can neither be a loss nor a gain of mass during a chemical reaction; however, mass can be converted into energy in a nuclear reaction. This change of mass into energy is what is responsible for the tremendous release of energy during a nuclear detonation.

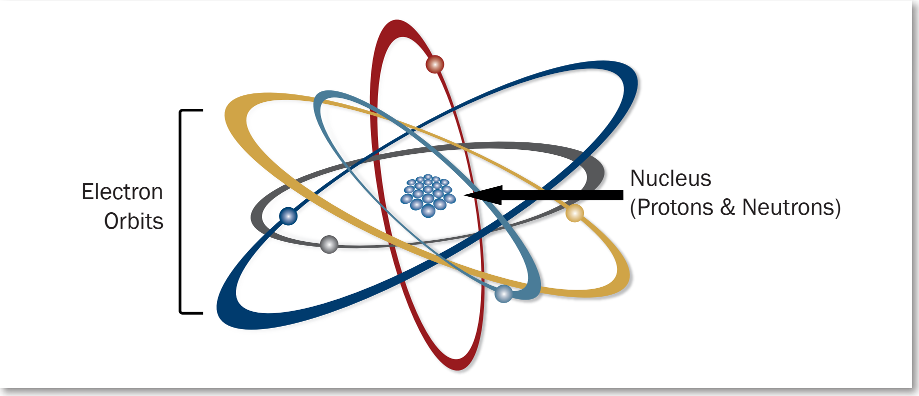


Figure 13.1 Diagram of an Atom

Isotopes are atoms of the same element that have identical atomic numbers (same number of protons) but a different atomic mass (also called atomic weight) due to a different number of neutrons in the nuclei. Isotopes are identified by their atomic mass, which is the sum of all protons and neutrons in the nucleus. Different isotopes of the same element have different nuclear characteristics, e.g., uranium-235 (U-235) has significantly different nuclear characteristics than U-238. See Figure 13.2 for an illustration of two of the 23 currently known isotopes of uranium.

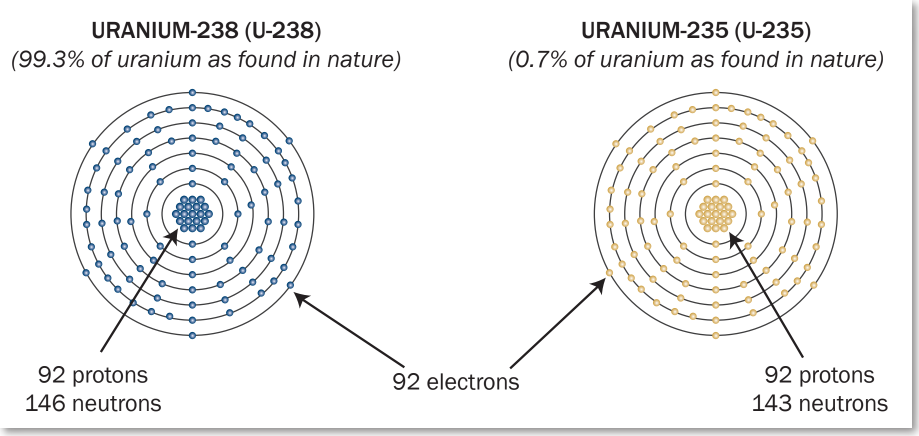


Figure 13.2 Isotopes of Uranium

RADIOACTIVE DECAY

Radioactive decay is the process of spontaneous nucleus breakdown and the resultant particle and/or energy release as the nucleus attempts to reach a more stable configuration. The nuclei of many isotopes are unstable and have statistically predictable timelines for radioactive decay. These unstable isotopes are known as radioisotopes. Radioisotopes have several decay modes, including alpha, beta, and gamma decay and spontaneous fission. The rate of decay is characterized in terms of "half-life," or the amount of time required for half of a given amount of the radioisotope to decay. Half-lives of different isotopes range from a tiny fraction of a second to billions of years. Rate of decay is also characterized as activity, or the number of decay events or disintegrations that occur in a given time.

FISSILE MATERIAL

Fissile material is material consisting primarily of atoms of *fissile isotopes*, i.e., those atoms of certain heavy elements that have a high probability of undergoing immediate fission of the nucleus by absorbing neutrons of any energy level.[1] Other isotopes whose atoms can undergo fission are called fissionable isotopes, but they are not fissile because they only have a high probability of fission when interacting with neutrons of some energy levels.[2]

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[1] All fissile material has a very small percentage of atoms that are non-fissile because all fissile isotopes are radioactive, and at any given time, a very small percentage of those atoms are decaying to other non-fissile, radioactive elements (also called daughter products). Some of these radioactive decay products may have a tendency to absorb neutrons which would reduce the efficiency of the fissile material, and are therefore considered impurities in the fissile material.

[2] Some references use the terms *fissile* and *fissionable* interchangeably. This chapter considers fissionable isotopes to be inadequate to be used as fissile material in a nuclear weapon.

NUCLEAR REACTIONS

Fission, the splitting apart of nuclei, and fusion, the joining or fusing together of nuclei, are key examples of nuclear reactions that can be induced in the nucleus. Fission occurs when a large nucleus, such as in a plutonium atom, is split into smaller fragments. Fusion occurs when the nuclei of two light atoms, each with a small nucleus, such as hydrogen, collide with enough energy to fuse two nuclei into a single larger nucleus.

Fission

Fission may occur spontaneously or when a subatomic particle, such as a neutron, collides with the nucleus and imparts sufficient energy to cause the nucleus to split into two or more fission fragments, which become the nuclei of newly created lighter atoms and are almost always radioactive. Fission releases millions of times more energy than the chemical reactions that cause conventional explosions. The fission that powers both nuclear reactors and weapons is typically the neutron-induced fission of certain isotopes of uranium or plutonium. The neutrons produced by fission events, as shown in Figure 13.3, can interact with the nuclei of other fissile atoms and produce other fission events, referred to as a *chain reaction*.

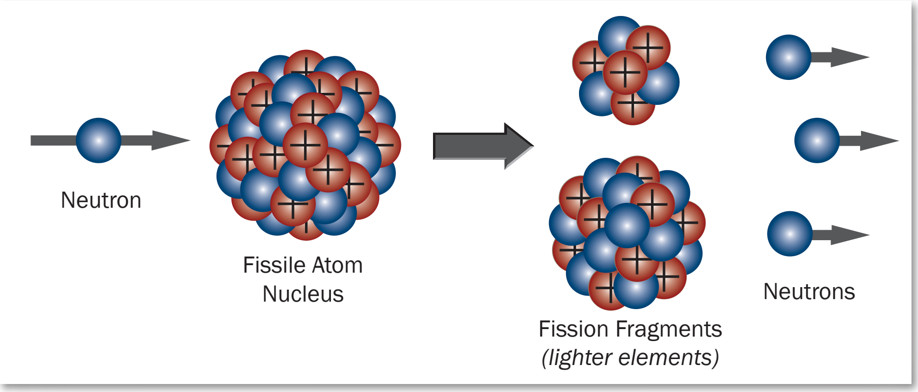

Figure 13.3 Fission Event

Criticality describes whether the rate of fission is increasing (supercritical), remaining constant (critical), or decreasing (subcritical). See Figure 13.4 for an illustration of a sustained chain reaction of fission events. In a highly supercritical configuration, the number of fission events increases very quickly, which results in the release of tremendous amounts of energy in a very short time, causing a nuclear detonation.

Fissile material is called a *subcritical mass*, or *subcritical component*, when the amount is so small and the configuration is so spread out that any fission event

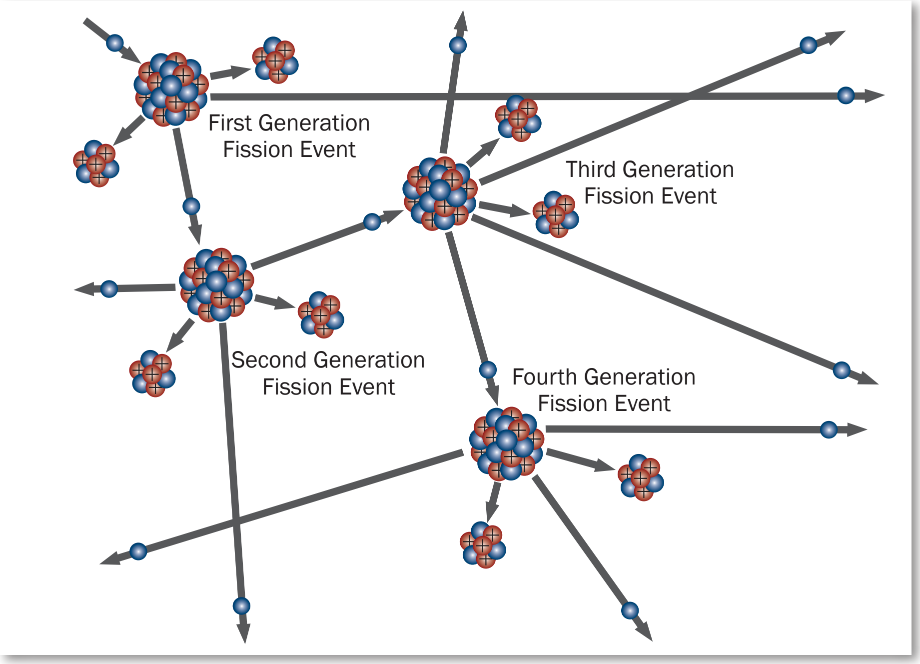

Figure 13.4 Chain Reaction of Fission Events

caused by a random neutron does not cause a sustained chain reaction of fission events. This is because almost all neutrons produced escape without producing a subsequent fission event. However, a *critical mass* of fissile material is the minimum amount of fissile material needed to support a self-sustaining nuclear chain reaction. Examples of fissile material are uranium-235, uranium-233, and plutonium-239.

Different types of fissile isotopes have different probabilities of fission when their nuclei are struck with a neutron and each fissile isotope produces a different average number of neutrons per fission event. These are the two primary factors in determining the material's fissile efficiency. Only fissile isotopes can undergo a multiplying chain reaction of fission events to produce a nuclear detonation. If the number of fission events is increasing with each generation of fission events, it is considered *supercritical*. There are seven factors affecting criticality:

- *Type of Fissile Material* – Isotopes with higher fissile efficiency can more readily achieve supercriticality.
- *Amount of Fissile Material* – Generally, the larger the amount of fissile material, the closer it is to approaching criticality if it is subcritical, and the more effectively it can sustain a multiplying chain reaction if it is supercritical.

- *Shape of the Mass of Fissile Material* – Fissile material in the shape of a sphere will be closer to a critical mass than the same material in a long thin strand because in the latter, more neutrons will escape the fissile mass without producing a subsequent fission event.
- *Density of the Fissile Material* – If a given amount of fissile material is subcritical in a spherical shape, it may become supercritical if that sphere is imploded, compressing the fissile material, causing the nuclei of fissile atoms to be closer together, and increasing the probability that any neutron produced by fission events will interact with another fissile nucleus and produce a subsequent fission event.
- *Enrichment* – The larger the percentage of fissile isotopes, the more readily that material can achieve criticality, and the more it is considered enriched.
- *Environment* – If a supercritical mass has neutron-reflecting material surrounding the outside edges, neutrons will be reflected back into the fissile mass to produce subsequent fission events that would not happen without the reflecting material.
- *Purity* – Any atoms of another element or isotope imbedded in the fissile material may cause a decrease in fissile efficiency by absorbing neutrons as the fissile material becomes supercritical. It is also possible that atoms of another element may cause a rearrangement of molecular structure, and thus a less efficient configuration for achieving criticality.

Fusion

Nuclear fusion is the combining of two light nuclei to form a heavier nucleus. For the fusion process to take place, two nuclei must be forced together by sufficient energy so that the strong, attractive, short-range, nuclear forces overcome the electrostatic forces of repulsion. Because the positively charged protons in the colliding nuclei repel each other, it takes a huge amount of energy to get the nuclei close enough to fuse. It is, therefore, easiest for nuclei with smaller numbers of protons, such as the isotopes of hydrogen, to achieve fusion. In almost all cases, a fusion event will produce one high-energy free neutron (a neutron unattached to a nucleus), which can be used in a nuclear weapon to cause another fission event that would not occur without the fusion neutron. Thus, with a relatively small amount of fusion gas in the middle of a supercritical mass, there may be a significant increase in yield (total energy released by the nuclear detonation) without any increase in the size or weight of the nuclear weapon. See Figure 13.5 for an illustration of a fusion event.

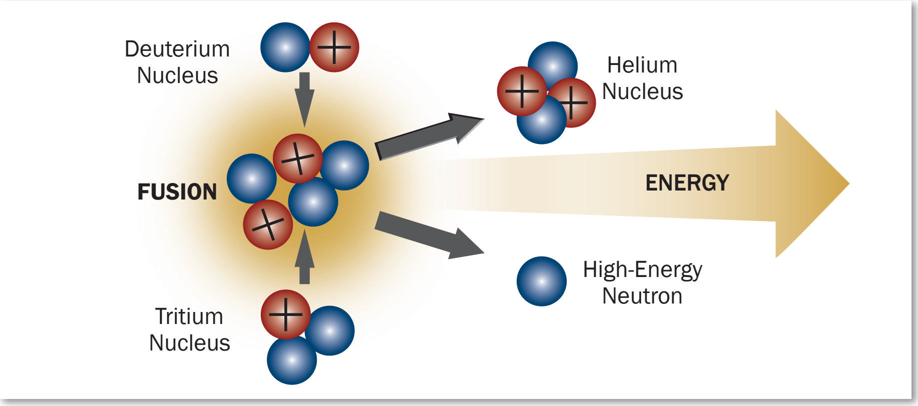

Figure 13.5 Fusion Event

BASIC NUCLEAR WEAPON DESIGNS

All current nuclear weapons use the basic approach of producing a very large number of fission events through a multiplying chain reaction and releasing a huge amount of nuclear energy in a very short period of time. Typically dozens of generations of fission events in a nuclear detonation will take only approximately one millionth of a second.

The earliest name for a nuclear weapon was *atomic bomb* or *A-bomb*. This term has been criticized as a misnomer because all conventional explosives generate energy from reactions between atoms (i.e., the release of binding energy that had been holding atoms together as a molecule). However, the name is still associated with current nuclear weapons and is accepted by historians, the public, and even by some of the scientists who created the first nuclear weapons. A fission weapon is a nuclear weapon whose energy release is due to fission of the fissile atoms. Fusion weapons are nuclear weapons whose energy release is increased beyond that caused by fission alone because isotopes of hydrogen are used to achieve fusion that in turn causes additional fission events beyond those that occur without the added fusion. Nuclear weapons that include fusion are called hydrogen bombs or H-bombs (since the fusion is generated using isotopes of hydrogen) and are also referred to as thermonuclear weapons due to the high temperature and pressure required for the fusion reactions to occur.[3]

Achieving Supercritical Mass

To produce a nuclear detonation, a weapon must contain enough fissile material to achieve a supercritical mass and a multiplying chain reaction of fission events.

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[3] The term *thermonuclear* is also used to refer to a two-stage nuclear weapon.

A supercritical mass can be achieved in two different ways. The first way is to have two subcritical components positioned far enough apart so any stray neutrons that cause a fission event in one subcritical component cannot begin a sustained chain reaction of fission events between the two components. At the same time, the components must be configured in such a way that when the detonation is desired, one component can be driven toward the other to form a supercritical mass when they are positioned together.

The second approach is to have one subcritical fissile component surrounded with high explosives (HE). When the detonation is desired, the HE is exploded, with force pushing inward to compress the fissile component to a point where it goes from subcritical to supercritical, because the fissile nuclei become closer to each other with less space between them for neutrons to escape. This causes most of the neutrons produced to cause subsequent fission events and achieve a multiplying chain reaction. Both of these approaches can be enhanced by using a proper casing as a tamper to hold in the explosive force. By using a neutron reflecting material around the supercritical mass, and by using a neutron generator to produce a large number of neutrons at the moment the fissile material reaches its designed supercriticality, the first generation of fission events in the multiplying chain reaction becomes a larger number of fission events.

Currently, nuclear weapons use one of four basic design approaches: gun assembly, implosion, boosted, or staged.

Gun Assembly Weapons

Gun assembly (GA) weapons (Figure 13.6) rapidly assemble two subcritical fissile components into one supercritical mass. This assembly is structured in a tubular device in which a propellant is used to drive one subcritical mass into another, forming one supercritical mass and causing a nuclear detonation. In general, the GA design is less technically complex than other designs and is also the least efficient.

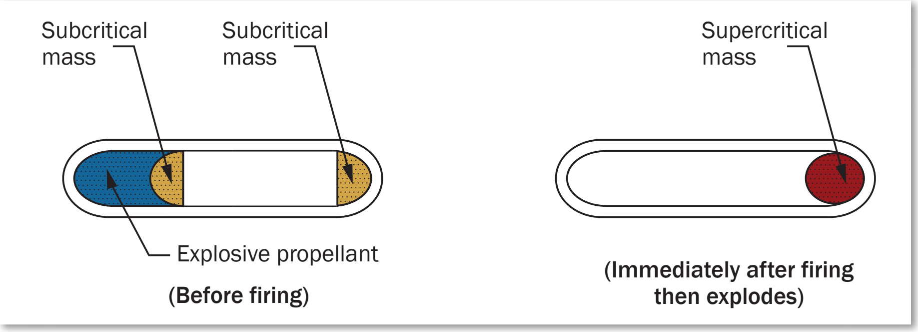

Figure 13.6 Unclassified Illustration of a GA Weapon
(Source: Joint DOE/DoD Topical Classification Guide for Nuclear Assembly Systems (TCG-NAS-2), March 1997)

Implosion Weapon

Implosion weapons (Figure 13.7) use the method of imploding one subcritical fissile component to achieve greater density and a supercritical mass. This compression is achieved by using high explosives surrounding a subcritical sphere of fissile material to drive the fissile material inward. The increased density achieves supercriticality due to the fissile nuclei being closer together, increasing the probability that any given neutron causes a subsequent fission event. In general, the implosion design is more technically complex than the GA design and more efficient.

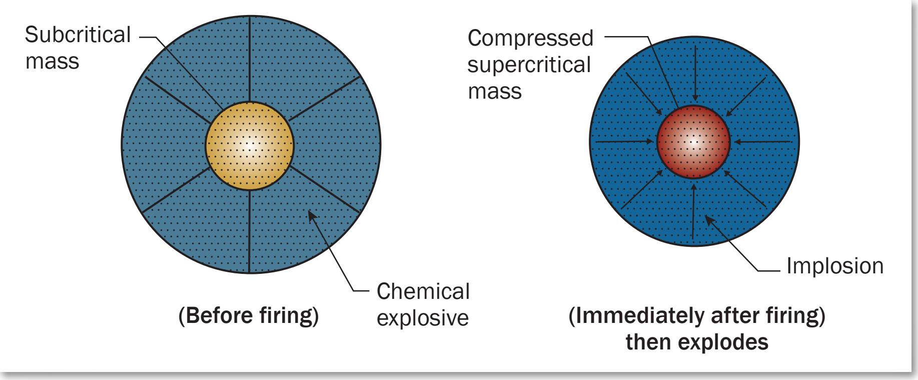

Figure 13.7 Unclassified Illustration of an Implosion Weapon
(Source: TCG-NAS-2, March 1997)

Boosted Weapons

A boosted weapon increases the efficiency and yield for a weapon of the same volume and weight when a small amount of fusionable material, such as deuterium or tritium gas, is placed inside the core of a fission device. The immediate fireball, produced by the supercritical mass, has a temperature of tens of millions of degrees and creates enough heat and pressure to cause the nuclei of the light atoms to fuse together. In this environment, a small amount of fusion gas, measured in grams, can produce a huge number of fusion events. Generally, for each fusion event, there is one high-energy neutron produced. These high-energy neutrons then interact with the fissile material, before the weapon breaks apart in the nuclear detonation, to cause additional fission events that would not occur if the fusion gas were not present. This approach to increasing yield is called "boosting" and is used in most modern nuclear weapons to meet yield requirements within size and weight limits. In general, the boosted weapon design is more technically complex than the implosion design and also more efficient.

Staged Weapons

A staged weapon (Figure 13.8) normally uses a boosted primary stage and a secondary stage to produce a significantly increased yield. In the first stage, a

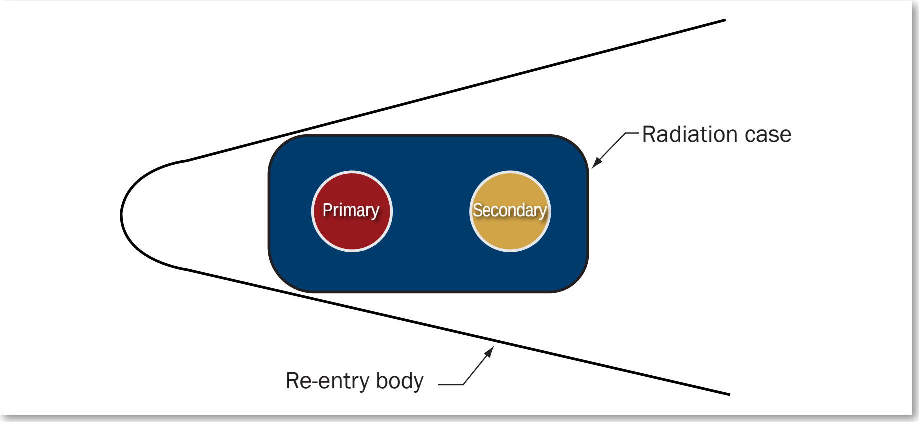

Figure 13.8 Unclassified Illustration of a Staged Weapon
(Source: TCG-NAS-2, March 1997)

boosted fission device releases the energy of a boosted weapon, which includes a large number of X-rays. The X-rays transfer energy to the secondary stage, causing fusionable material in the secondary to undergo fusion, which releases large numbers of high-energy neutrons. These neutrons, in turn, interact with fissionable material in the secondary to cause a huge number of fission events, thereby significantly increasing the yield of the whole weapon. The two-stage weapon design is more technically complex than any other weapon design. For a given size, it can produce a much larger yield than any other design.

EFFECTS OF NUCLEAR DETONATIONS

A nuclear detonation produces effects overwhelmingly more significant than those produced by a conventional explosive, even if the nuclear yield is relatively low. A typical nuclear detonation[4] produces energy that, weight for weight, is millions of times more powerful than that produced by a conventional explosion. It also produces an immediate large, hot nuclear fireball (mushroom cloud), thermal radiation, prompt nuclear radiation, air blast wave, residual nuclear radiation, electromagnetic pulse (EMP), interference with communications signals, and, if the fireball interacts with the terrain, ground shock. Figure 13.9 depicts the overarching energy distribution for a typical nuclear detonation.

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[4] For the purposes of this chapter, a typical nuclear detonation is one that occurs on the Earth's surface or at a HOB low enough for the primary effects to cause damage to surface targets. Detonations that are exoatmospheric, high altitude, or deeply buried underground have different effects.

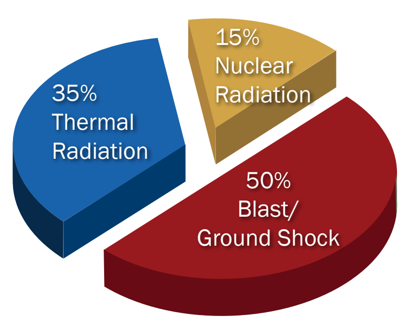

Figure 13.9 Energy Distribution for a Typical Nuclear Detonation

GROUND ZERO

Nuclear detonations can occur on, below, or above the Earth's surface. Ground zero (GZ) is the point on the Earth's surface closest to the detonation. The effects of a nuclear detonation can destroy structures and systems and can injure or kill exposed personnel at great distances from GZ. Figure 13.10 shows Hiroshima after the nuclear weapon detonation on August 6, 1945.

Figure 13.10 Hiroshima After the Nuclear Detonation

Nuclear detonation effects for people or objects close to GZ are devastating. However, the distances that effects can travel away from GZ are limited.

OVERALL EFFECTS

The yield of the weapon, measured in equivalent tons of TNT, is one of the most important factors in determining the level of casualties and damage. Other factors include the type and density of target elements near GZ, height of burst (HOB), terrain, or objects in the area that could interfere with various effects moving away from GZ as well as the weather patterns in the target area.

If effectively employed,[5] any one nuclear weapon should defeat any one military target. However, a few nuclear weapons with relatively low yields, such as the yields of any nation's first generation of nuclear weapons, would not defeat a large military force, such as the allied force in the first Gulf War. A single, low-yield nuclear weapon employed in a major metropolitan area would produce total devastation in an area large enough to produce tens of thousands or even hundreds of thousands of fatalities. Yet, it would not destroy the entire major metropolitan area. The survival of thousands of people who are seriously injured or exposed to a moderate level of nuclear radiation would depend on the response of various federal, state, and local government agencies and non-governmental organizations.

Casualty and Damage Distances for Populated Areas

A very low-yield, 1-kiloton (kt) detonation produces severe damage effects approximately one quarter of a mile from GZ. Within the severe damage zone, almost all buildings would collapse and 99 percent of persons become fatalities quickly. Moderate damage would extend approximately one half mile and would include structural damage to buildings, many prompt fatalities, severe injuries, overturned cars and trucks, component damage to electronic devices, downed cellphone towers, and induced radiation at ground level that could remain hazardous for several days. Light damage would extend out approximately 1.5 miles and include some prompt fatalities, some persons with severe injuries, and the effects on infrastructure as stated for medium damage. Some fatalities or injuries may occur beyond the light damage zone.

A low-yield, 10-kt detonation can produce severe damage effects approximately one half mile from GZ. Moderate damage can extend approximately one mile and light damage can extend to approximately three miles.

A high-yield, strategic 1-megaton (MT) detonation[6] can produce severe damage effects slightly beyond two miles from GZ. Moderate damage extends out beyond four miles and light damage occurs beyond 12 miles.

Nuclear Fireball

A typical nuclear weapon detonation can produce a huge number of X-rays, which heat the air around the detonation to extremely high temperatures, causing the heated air to expand and form a large fireball within a small fraction

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[5] Proper employment includes using the required yield at the required location with an effective HOB (e.g., a high-altitude detonation would not destroy a building or a bridge). Examples of single military targets include one or a group of structures in a relatively small area, special contents within a structure (e.g., biological agents), a missile silo or launcher position, a military unit (e.g., a single military ship, an air squadron, or even a ground-force battalion), a communications site, and a command post.

[6] A 1-MT detonation releases the energy equivalent to one million tons of TNT.

of a second. The size of the immediate fireball is a function of yield and the surrounding environment. Figure 13.11 shows the size of the immediate fireball for selected yields and environments.

Yield	Air Burst		Underground Burst	
	Radius	Diameter	Radius	Diameter
1 MT	560 m	1,120 m	315 m	630 m
10 kt	65 m	130 m	36 m	72 m
1 kt	30 m	60 m	17 m	34 m

Figure 13.11 Approximate Immediate Fireball Size

The immediate fireball is tens of millions of degrees (i.e., as hot as the interior of the sun). Inside the fireball, the temperature and pressure cause a complete disintegration of molecules and atoms. Current targeting procedures do not consider the fireball to be one of the primary weapon effects, but a nuclear fireball can be used to incinerate chemical or biological agents.

Thermal Radiation

Thermal radiation is electromagnetic radiation in the visible light spectrum that can be sensed as heat and light. Thermal radiation is maximized with a low-air burst and the optimum HOB increases with yield. Thermal radiation can ignite wood-frame buildings, vegetation, and other combustible materials at significant distances from GZ. It can also cause burns to exposed skin directly or indirectly, if clothing ignites or the individual is caught in a fire ignited by the heat. Anything that casts a shadow or reduces light, including buildings, trees, dust from the blast wave, heavy rain, and dense fog, provides some protection against thermal burns or the ignition of objects.

Flash blindness, or dazzle, is a temporary loss of vision caused when eyes are overwhelmed with intense thermal light. On a clear night, dazzle may last for up to 30 minutes and may affect people at distances beyond 10 miles. On a clear day, dazzle can affect people at distances beyond those for first degree burns, albeit it lasts for a shorter period of time. Because thermal radiation can be scattered and reflected in the air, flash blindness can occur regardless of whether an individual is looking toward the detonation. At distances where it can produce a first degree burn, thermal radiation is intense enough to penetrate through the back of the skull to overwhelm the eyes. Retinal burns can occur at great distances for individuals looking directly at the fireball at the moment of the nuclear detonation. Normally, retinal burns cause a permanent blindness to a small portion of the eye in the center of the normal field of vision. Figure 13.12 shows types of burns and approximate maximum distances for selected yields.[7]

			Approximate Distances (km)		
Degree	**Affected Area**	**Description & Symptoms**	**1 kt**	**10 kt**	**1 MT**
3rd	Tissue under skin	Charred skin; Extreme pain	0.7	1.7	11.1
2nd	All layers of skin	Blisters; Severe pain	0.9	2.3	13.7
1st	Outer layers of skin	Red/darker skin; Moderate pain	1.0	2.8	19.0

Figure 13.12 Thermal Radiation Burns

Because thermal radiation can start fires and cause burns at such great distances, if a nuclear weapon is employed against a populated area on a clear day, with an air burst at approximately the optimum HOB, it is likely the thermal effects would account for more casualties than any other effect. With a surface burst or if rain or fog are in the area, the thermal radiation effects would be reduced.

The effects of thermal radiation can be reduced with protective enclosures, thermal protective coatings, and the use of non-flammable clothing, tools, and equipment. Thermal protective coatings include materials that swell when exposed to flame, thus absorbing the heat rather than allowing it to penetrate through the material, and ablative paints, which act like a melting heat shield. Materials like stainless steel, as opposed to temperature-sensitive metals like aluminum, are used to protect against thermal radiation. In order to reduce the amount of absorbed energy, light colors and reflective paints are also used. For effective thermal hardening, the use of combustible materials is minimized. Finally, to mitigate the effects of thermal radiation, it is important to protect items prone to melting, such as rubber gaskets, O-rings, and seals.

Air Blast

In the case of surface and low-air bursts, the fireball expands, immediately pushing air away from the point of the detonation, causing a dense wall of air to travel at great speed away from the detonation. Initially, this blast wave moves at several times the speed of sound, but quickly slows to a point at which the leading edge of the blast wave is traveling at the speed of sound and continues at

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[7] The distances in Figure 13.12 are based on scenarios in which the weather is clear, there are no obstacles to attenuate thermal radiation, and the weapon is detonated as a low-air burst at the optimum HOB to maximize the thermal effect.

this speed as it moves farther away from GZ. Shortly after breaking away from the fireball, the wall of air reaches its maximum density of overpressure, or over the nominal air pressure.[8] As the blast wave travels away from this point, the wall of air becomes wider, loses density, and the overpressure continues to decrease.

At significant distances from GZ, overpressure can have a crushing effect on objects as they are engulfed by the blast wave. In addition to overpressure, the blast wave has an associated wind speed as it passes any object. This can be quantified as dynamic pressure that can move, rather than crush, objects. The blast wave has a positive phase and a negative phase for both overpressure and dynamic pressure.

As the blast wave hits a target object, the positive overpressure initially produces a crushing effect. If the overpressure is great enough, it can cause instant fatality to an exposed person. Less overpressure can collapse the lungs and, at lower levels, can rupture the ear drums. Overpressure can implode a building. Immediately after the positive overpressure has begun to affect the object, dynamic pressure exerts a force that can move people or objects laterally at high speed, causing injury or damage. Dynamic pressure can also strip a building from its foundation, blowing it to pieces.

As the positive phase of the blast wave passes an object, it is followed by a vacuum effect (i.e., the negative pressure caused by the lack of air in the space behind the blast wave). This is the beginning of the negative phase of dynamic pressure. The vacuum effect, or negative overpressure, can cause a building to explode, especially if the positive phase has increased the air pressure inside the building by forcing air in through broken windows. The vacuum effect then causes the winds in the trailing portion of the blast wave to be pulled back into the vacuum. This produces a strong wind moving back toward GZ. While the negative phase of the blast wave is not as strong as the positive phase, it may move objects back toward ground zero, especially if trees or buildings are severely weakened by the positive phase. Figure 13.13 shows the overpressure in pounds per square inch (psi) and the approximate distances associated with various types of structural damage.[9]

If the detonation occurs at ground level, the expanding fireball pushes into the air in all directions, creating an ever-expanding hemispherical blast wave, called the

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[8] At a short distance beyond the radius of the immediate fireball, the blast wave would reach a density pressure of thousands of pounds per square inch.

[9] The distances in Figure 13.13 are based on an optimum HOB to maximize the blast effect and the existence of no significant terrain that would stop the blast wave (e.g., the side of a mountain). For surface bursts, the distances shown are reduced by approximately 30 to 35 percent for the higher overpressures and by 40 to 50 percent for 1 psi.

		Approximate Distances (km)		
Approx. Overpressure	**Description**	**1 kt**	**10 kt**	**1 MT**
7 - 9 psi	Concrete building collapse	0.5	1.1	5.1
6 psi	Shatter concrete walls	0.6	1.3	6.1
4 psi	Wood-frame building collapse	0.8	1.8	8.1
2 psi	Shatter wood siding panels	1.3	2.9	13.2
1 psi	Shatter windows	2.2	4.7	21.6

Figure 13.13 Air-Blast Damage to Structures

incident wave. As the blast wave travels away, its density continues to decrease. After some significant distance, it loses destructive potential and becomes a mere gust of wind. Yet, if the detonation is a low-air burst, a portion of the blast wave travels toward the ground and is then reflected off the ground. This reflected wave travels up and out in all directions, reinforcing the incident wave traveling along the ground. Because of this, air blast is maximized with a low-air burst rather than a surface burst.

If the terrain is composed of a surface that absorbs more thermal radiation than grass or soil, the thermal radiation leads to a greater than normal heating of that surface. The surface produces heat before the arrival of the blast wave. This creates a "non-ideal" condition that causes the blast wave to become distorted when it reaches the heated surface, resulting in an abnormal reduction in the blast wave density and psi. Extremely cold weather (minus 50° Fahrenheit or colder) can lead to increased air-blast damage distances. If a surface burst occurs in a populated area or if there is rain and/or fog at the time of burst, the blast effect would probably account for more casualties than any other effect.

Structures and equipment can be reinforced to become less vulnerable to air blast. Nevertheless, any structure or piece of equipment is destroyed if it is close enough to the detonation. High priority facilities that must survive a close nuclear strike are usually constructed underground and reinforced with strong materials, making them much harder to defeat.

Individuals who sense a blinding white flash and intense heat coming from one direction should immediately fall to the ground and cover their heads with their arms. This provides the highest probability the air blast passes overhead, without moving them laterally, and debris in the blast wave does not cause impact or puncture injuries. Exposed individuals who are very close to the detonation have no chance of survival. At distances at which a wood-frame building can survive, however, exposed individuals significantly increase their chance of survival if they are on the ground when the blast wave arrives and remain on the ground until after the negative phase blast wave has moved back toward ground zero.

GROUND SHOCK

Given surface or near-surface detonations, the fireball's expansion and interaction with the ground causes a significant shock wave to move into the ground in all directions. This causes an underground fracture or "rupture" zone. The intensity and significance of the shock wave and the fracture zone decrease with distance from the detonation. A surface burst produces significantly more ground shock than a near-surface burst in which the fireball barely touches the ground.

Underground structures, especially ones deep underground, are not vulnerable to the direct primary effects of a low-air burst. However, the shock produced by a surface burst may damage or destroy an underground target, depending on the yield of the detonation, soil or rock type, depth of the target, and its structure. It is possible for a surface detonation to fail to crush a deep underground structure but have an effective shock wave that crushes or buries entrance or exit routes and destroys connecting communications lines. This could cause the target to be "cut-off" and render it, at least temporarily, incapable of performing its intended function. Normally, a surface burst or shallow sub-surface burst is used to attack deeply buried targets. As a rule of thumb, a 1-kt surface detonation can destroy an underground facility as deep as a few tens of meters. A 1-MT surface detonation can destroy the same target as deep as a few hundred meters.

Deeply buried underground targets can be attacked through the employment of an earth-penetrating warhead to produce a shallow sub-surface burst. Only a few meters of penetration into the earth is required to achieve a "coupling" effect, in which most of the energy that would have gone up into the air with a surface burst is trapped by the material near the surface and reflected downward to reinforce the original shock wave. This reinforced shock wave is significantly stronger and can destroy deep underground targets at distances usually two to five times deeper than those destroyed through the employment of a surface burst.[10] Ground shock is the governing effect for damage estimation against any underground target.

Underground facilities and structures can be buried deeper to reduce vulnerability to damage from a surface or shallow sub-surface detonation. Facilities and equipment can be built with structural reinforcement or other designs to decrease their vulnerability to ground shock. For functional survivability, entrance and exit

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[10] The amount of increased depth of damage is primarily a function of the yield and the soil or rock type.

routes as well as communications lines connected to ground-level equipment can be hardened or made redundant.

SURFACE CRATER

In the case of near-surface, surface, and shallow sub-surface bursts, the fireball's interaction with the ground causes it to engulf much of the soil and rock within its radius and remove the material as it moves upward. This removal of material results in the formation of a crater. A near-surface burst would produce a small, shallow crater. The crater from a surface burst, with the same yield, is larger and deeper, while the crater size is maximized with a shallow sub-surface burst at the optimum depth.[11] The size of the crater is a function of the yield of the detonation, depth of burial, and type of soil or rock.

For deeply buried detonations, such as those created with underground nuclear explosive testing, the expanding fireball creates a spherical volume of hot radioactive gases. As the radioactive gas cools and contracts, the spherical volume of space becomes an empty cavity with a vacuum effect. The weight of the heavy earth above the cavity and the vacuum effect within the cavity cause a downward pressure for the earth to fall in the cavity. This can occur unpredictably at any time from minutes to months after the detonation. When it occurs, the cylindrical mass of earth collapsing down into the cavity forms a crater on the surface, called a subsidence crater (see Figure 13.14).

Figure 13.14 Subsidence Craters at Yucca Flats, Nevada National Security Site

A crater produced by a recent detonation near

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[11] For a 1-kt detonation, the maximum crater size would have a burial depth between 32 and 52 meters, depending on the type of soil or rock.

the ground surface is probably radioactive. Individuals required to enter or cross such a crater could be exposed to significant levels of ionizing radiation, possibly enough to cause casualties or fatalities. If a deep underground detonation has not yet formed the subsidence crater, it is very dangerous to enter the area on the surface directly above the detonation.

Normally, the wartime employment of nuclear weapons would not use crater formation to attack targets. Though at the height of the Cold War, NATO forces had contingency plans to use craters from nuclear detonations to channel, contain, or block enemy ground forces. The size of the crater and its radioactivity for the first several days produces an obstacle extremely difficult, if not impossible, for a military unit to cross.

A crater by itself does not present a hazard to people or equipment, unless an individual tries to drive or climb into the crater. In the case of deep underground detonations, the rule is to keep away from the area where the subsidence crater could be formed until after the collapse occurs.

UNDERWATER SHOCK

An underwater nuclear detonation generates a shock wave in a manner similar to that in which a blast wave is formed in the air. The expanding fireball pushes water away from the point of detonation, creating a rapidly moving dense wall of water. In the deep ocean, this underwater shock wave moves out in all directions, gradually losing its intensity. In shallow water, it can be distorted by surface and bottom reflections. Shallow bottom interactions may reinforce the shock effect.

If the yield is large enough and the depth of detonation is shallow enough, the shock wave ruptures the water's surface. This can produce a large surface wave that moves away in all directions. It may also produce a "spray dome" of radioactive water above the surface.

If a submarine is close enough to the detonation, the underwater shock wave is strong enough to rapidly move the vessel. This near-instantaneous movement could force the ship against the surrounding water with a force beyond its design capability, causing a structural rupture of the vessel. The damage to the submarine is a function of weapon yield, depth of detonation, depth of the water under the detonation, bottom conditions, and the distance and orientation of the submarine. People inside the submarine are at risk if the boat's structure fails. Even if the submarine structure remains intact, the lateral movement may cause injuries or fatalities to those inside the submarine.

Surface ships may be vulnerable to the underwater shock wave striking the hulls of the ships. If the detonation produces a significant surface wave, it can damage surface ships at greater distances. If ships move into the radioactive spray dome, the dome could present a radioactive hazard to people on the ship.

Both surface ships and submarines can be designed to be less vulnerable to the effects of underwater nuclear detonations. Yet, any ship or submarine can be damaged or destroyed if it is close enough to a nuclear detonation.

INITIAL NUCLEAR RADIATION

Nuclear radiation is ionizing radiation emitted by nuclear activity consisting of neutrons, alpha and beta particles, and electromagnetic energy in the form of gamma rays.[12] Gamma rays are high-energy photons of electromagnetic radiation with frequencies higher than visible light or ultraviolet rays.[13] Gamma rays and neutrons are produced from fission events. Alpha and beta particles and gamma rays are produced by the radioactive decay of fission fragments. Alpha and beta particles are absorbed by atoms and molecules in the air at short distances and are insignificant compared with other effects. Gamma rays and neutrons travel great distances through the air in a general direction away from ground zero.[14]

Because neutrons are produced almost exclusively by fission events, they are produced in a fraction of a second, and no significant number of neutrons is produced after that. Conversely, gamma rays are produced by the decay of radioactive materials and are produced for years after the detonation. Initially, these radioactive materials are in the fireball. For surface and low-air bursts, the fireball rises quickly and, within approximately one minute, is at an altitude high enough that none of the gamma radiation produced inside the fireball has any impact to people or equipment on the ground. For this reason, initial nuclear radiation is defined as the nuclear radiation produced within one minute post-detonation. Initial nuclear radiation is also called *prompt nuclear radiation*.

The huge number of gamma rays and neutrons produced by a surface, near-surface, or low-air burst may cause casualties or fatalities to people at significant distances. The unit of measurement for radiation exposure is the centigray (cGy).[15] The 450 cGy exposure dose level is considered to be the lethal dose for

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[12] Ionizing radiation is defined as electromagnetic radiation (gamma rays or X-rays) or particulate radiation (e.g., alpha particles, beta particles, neutrons) capable of producing ions directly or indirectly in its passage through or interaction with matter.

[13] A photon is a unit of electromagnetic radiation consisting of pure energy and zero mass. The spectrum of photons include AM and FM radio waves, radarwaves, microwaves, infrared waves, visible light, ultraviolet waves, X-rays, and gamma or cosmic rays.

[14] Both gamma rays and neutrons are scattered and reflected by atoms in the air, causing each gamma ray and neutron to travel a "zig-zag" path moving generally away from the detonation. Some neutrons and photons may be reflected so many times that, at a significant distance from GZ, travel back toward ground zero.

[15] cGy represents the amount of energy deposited by ionizing radiation in a unit mass of material and is expressed in units of joules per kilogram (J/kg).

50 percent of the population (LD50) with medical assistance. People who survive at this dose level would have a significantly increased risk of contracting mid-term and long-term cancers. Figure 13.15 shows selected levels of exposure, the associated near-term effects on humans, and the distances by yield.[16]

		Approximate Distances (km)		
Level of Exposure	**Description**	**1 kt**	**10 kt**	**1 MT**
3,000 cGy	Prompt casualty; death within days	0.5	0.9	2.1
650 cGy	Delayed casualty; ~95% death in wks	0.7	1.2	2.4
450 cGy	Performance impaired; ~50% death	0.8	1.3	2.6
150 cGy	Threshold symptoms	1.0	1.5	2.8

Figure 13.15 Near-Term Effects of Initial Nuclear Radiation

Low levels of exposure can increase an individual's risk for contracting long-term cancers. For example, in healthy male adults ages 20 to 40, an exposure of 100 cGy increases this risk by approximately 10 to 15 percent and lethal cancer by approximately 6 to 8 percent.[17]

The ground absorbs more gamma rays and neutrons than the air. Almost half of the initial nuclear radiation resulting from a surface burst is quickly absorbed by the earth. In the aftermath of a low-air burst, half of the nuclear radiation travels in a downward direction. Much of that radiation is scattered and reflected by atoms in the air, adding to the amount of radiation traveling away from GZ. Because of this, initial nuclear radiation is maximized with a low-air burst.

Initial nuclear radiation effects can be predicted with reasonable accuracy. In this case, initial nuclear radiation is considered with air blast to determine the governing effect. Initial nuclear radiation is always considered for safety (if safety of populated areas or friendly troop personnel is a factor) and safety distances are calculated based on a "worst-case" assumption (i.e., there is a maximum initial radiation effect and objects in the target area will not shield or attenuate the radiation).

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[16] For the purposes of this chapter, all radiation doses are assumed to be acute (total radiation received within approximately 24 hours) and whole-body exposure. Exposures over a longer period of time (chronic), or exposures to an extremity (rather than to the whole body) could have less effect on a person's health.

[17] Calculated from data in National Research Council, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2* (Washington, D.C.: The National Academies Press, 2006), https://doi.org/10.17226/11340.

Individuals can do very little to protect themselves against initial nuclear radiation after a detonation has occurred because initial radiation is emitted and absorbed in less than one minute. DoD has developed an oral chemical prophylactic to reduce the effects of ionizing radiation exposure; however, the drug does not reduce the hazard to zero. Just as with most of the other effects, it is fatal if an individual is very close to the detonation.

Initial nuclear radiation can also damage the electrical components in certain equipment. Equipment can be hardened to make electronic components less vulnerable to initial nuclear radiation. Generally, structures are not vulnerable to initial nuclear radiation.

RESIDUAL NUCLEAR RADIATION

Residual nuclear radiation consists of alpha and beta particles as well as gamma rays emitted from radioactive nuclei. There are types of residual nuclear radiation that result from a typical detonation. Residual radiation also results from a deep underground detonation, but the radiation remains underground unless radioactive gases vent from the fireball or residual radiation escapes by another means. An exoatmospheric detonation creates a cloud in orbit that could remain significantly radioactive for many months.

Induced Radiation on the Ground

Induced radiation on the ground is radioactivity caused by neutron absorption. With a detonation near the ground, neutrons are captured by light metals in the soil or rock near the ground surface.[18] These atoms become radioactive isotopes capable of emitting, among other things, gamma radiation. The induced radiation is generally created in a circular pattern that is most intense at GZ immediately after the detonation. The intensity decreases over time and with distance from GZ. In normal soil, it takes approximately five to seven days for induced radiation to decay to a safe level. In a populated area, the induced radiation could extend beyond building collapse, especially with a low-yield detonation. It is important for first responders to be trained to understand induced radiation and be aware of the radioactive hazard. Many first responders today have radiation detectors for this purpose.

Induced Radiation in the Air

Induced radiation in the air is caused by the production of carbon-14 by nitrogen absorbing neutrons. Carbon-14 atoms can remain suspended in the air, are beta particle emitters, and have a long half-life (5,715 years). During the 1950s and 1960s, when four nuclear nations conducted aboveground nuclear testing, a two

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[18] Neutrons induced into typical soil are captured primarily by sodium, manganese, silicon, and aluminum atoms.

to 3 percent increase occurred in total carbon-14 levels worldwide. Gradually, the carbon-14 is returning to pre-testing levels. There are no known casualties attributed to the increase, but any increase in carbon-14 levels could be an additional risk.

Fallout

Fallout is the release of small radioactive particles that drop from the fireball to the ground. In most technical jargon, fallout is defined as the fission fragments from the nuclear detonation. The fireball contains other types of radioactive particles as well that fall to the ground and contribute to the total radioactive hazard. These include the radioactive fissile material that did not undergo fission, as no weapon fissions 100 percent of the fissile material, and material from warhead components induced with neutrons that have become radioactive. Residual gamma radiation is colorless, odorless, and tasteless and cannot be detected with the five senses unless an extremely high level of radiation exists.

If the detonation is a true air burst in which the fireball does not interact with the ground or any significant structure, the size and heat of the fireball causes it to retain almost all of the weapon debris, usually one or at most a few tons of material, as it moves upward in altitude and downwind. In this case, very few particles fall to the ground at any moment and no significant radioactive hot-spot on the ground is caused by the fallout. The fireball rises to become a long-term radioactive cloud. The cloud travels with the upper atmospheric winds and circles the hemisphere several times, over a period of months, before it dissipates completely. Most of the radioactive particles decay to stable isotopes before falling to the ground. The particles that reach the ground are distributed around the hemisphere at the latitudes of the cloud travel route. Even though there would be no location receiving a hazardous amount of fallout radiation, certain locations on the other side of the hemisphere could receive more fallout, which is measurable with radiation detectors, than the area near the detonation. This phenomenon is called *worldwide fallout*.

If the fireball interacts with the ground or any significant structure (e.g., a large bridge or a building), the fireball has different properties. In addition to the three types of radioactive material, the fireball would also include radioactive material from the ground or structure induced with neutrons. The amount of material in the fireball would be much greater than the amount with an air burst. For a true surface burst, a 1-kt detonation would extract thousands of tons of earth up into the fireball, although only a small portion would be radioactive. This material would disintegrate and mix with the radioactive particles. As large and hot as the fireball is (1-kt detonation produces a fireball almost 200 feet in diameter and tens of millions of degrees), it has no potential to carry thousands of tons of material. Thus, as the fireball rises, it begins to release a significant amount of radioactive dust, which falls to the ground and produces a radioactive fallout pattern around GZ and in areas downwind. The intensity of radioactivity in this fallout area would be hazardous for weeks. This is called *early fallout*, caused primarily by a surface-burst detonation regardless of the weapon design. Early fallout would be a concern in the case of employment of a nuclear threat device during a terrorist attack.

Normally, fallout should not be a hazardous problem for a detonation that is a true air burst. Yet, if rain and/or snow occurs in the target area, radioactive particles could be "washed-out" of the fireball, creating a hazardous area of early fallout. If a detonation is a surface or near-surface burst, early fallout would be a significant radiation hazard around GZ and downwind.

Generally, a deep underground detonation presents no residual radiation hazard to people or objects on the surface. If there is an accidental venting or some other unintended escape of radioactivity, however, it could become a radioactive hazard to people in the affected area. The residual nuclear cloud from an exoatmospheric detonation could damage electronic components in some satellites over a period of time, usually months or years, depending on how close a satellite gets to the radioactive cloud, the frequency of the satellite passing near the cloud, and its exposure time and whether it is hardened against nuclear radiation.

There are four actions that provide protection against residual radiation. First, personnel with a response mission should enter the area with at least one radiation detector, and all personnel should employ personal protective equipment (PPE).[19] While the PPE does not stop the penetration of gamma rays, it will prevent the responder personnel from breathing any airborne radioactive particles. Second, personnel should only be exposed to radioactivity for the minimum time possible to accomplish a given task. Third, personnel should remain at a safe distance from radioactive areas. Finally, personnel should use shielding when possible to further reduce the amount of radiation received. It is essential for first responder personnel to follow the PPE principles of time, distance, and shielding.

BIOLOGICAL/MEDICAL EFFECTS OF IONIZING RADIATION

Ionizing radiation is any particle or photon that produces an ionizing event (i.e., strip an electron away from an atom), including alpha and beta particles, gamma and cosmic rays, and X-rays. Ionizing events cause biological damage to humans and other mammals. The greater the exposure dose, the greater the biological problems caused by the ionizing radiation. At medium and high levels of

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[19] PPE for first responders includes a sealed suit and self-contained breathing equipment with a supply of oxygen.

exposure, there are near-term consequences, including impaired performance that can cause casualties and death. Figure 13.16 lists the types of biological damage associated with ionizing events.

Ionized Objects	Resulting Problem
Ionized DNA molecules	Abnormal cell reproduction
Ionized water molecules	Creates hydrogen peroxide (H2O2)
Ionized cell membrane	Cell death
Ionized central nervous system molecules	Loss of muscle control
Ionized brain molecules	Loss of thought process & muscle control

Figure 13.16 Biological Damage from Ionization

At low levels of exposure, ionizing radiation does not cause any near-term medical problems. However, at the 75 cGy level, approximately 5 percent of healthy adults experience mild threshold symptoms (i.e., transient mild headaches and mild nausea). At the 100 cGy level, approximately 10 to 15 percent of healthy adults experience threshold symptoms and a smaller percentage experience some vomiting. Low levels of ionizing radiation exposure also result in a higher probability of contracting mid- and long-term cancers. Figure 13.17 shows increased risk in healthy adults of contracting cancer after ionizing radiation exposure, by gender.

Level of Ionizing Radiation Exposure	Approximate Increased Risk of Cancer (percent)			
	Healthy Males, age 20-40		Healthy Females, age 20-40	
	Lethal	All Cancers	Lethal	All Cancers
100 cGy	6 - 8	10 - 15	7 - 12	13 - 25
50 cGy	2 - 3	4 - 6	3 - 5	5 - 10
25 cGy	1 - 2	2 - 3	1 - 2	2 - 5
10 cGy	< 1	1	1	1 - 2
1 cGy	< 1	< 1	< 1	< 1

Figure 13.17 Increased Cancer Risk at Low Levels of Exposure to Ionizing Radiation

Protection from ionizing radiation can be achieved through shielding. Most materials shield from radiation, but some materials need to be present in significant amounts to reduce the penetrating radiation by half. Figure 13.18 illustrates the widths required for selected types of material to stop half the gamma radiation, called "half-thickness," and to stop 90 percent of the radiation, called "tenth-value thickness."

Material	Half-Thickness	Tenth-Value Thickness
Steel / Iron	1.0	3.3
Concrete	3.3	11.0
Earth	4.8	16.0
Water	7.2	24.0
Wood	11.4	38.0

[values in inches]

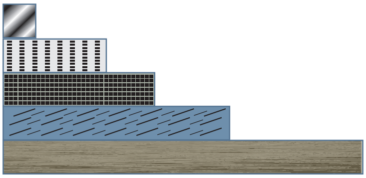

Figure 13.18 Radiation Shielding

ELECTROMAGNETIC PULSE

EMP is a very short duration pulse of low-frequency, or long-wavelength, electromagnetic radiation (EMR).

The source for all nuclear-generated EMP begins with the prompt nuclear radiation from the weapon which consists of neutrons, gamma rays, and X-rays. The most significant EMP effects are HEMP, for high-altitude EMP, SREMP, for source region EMP, and SGEMP, for system generated EMP. All forms of EMP require a symmetry-breaking condition or environmental disturbance in order for EMP to be generated—a requirement that is met in practice for all nuclear detonations but to varying degrees depending on HOB.

Detonations at altitudes above about 20 km are considered high-altitude bursts and give rise to high-altitude EMP, or HEMP. HEMP is the name for the effect that manifests itself on the ground due to radiated electromagnetic fields from EMP. High to exoatmospheric bursts also give rise to SGEMP which effects satellites and space-based systems. Surface and low-altitude bursts below about 5 km produce SREMP, while detonations ranging from about 5 km to 20 km altitude fall into a region of atmospheric and environmental conditions capable or generating a mix of HEMP and SREMP, but at weaker levels.

The symmetry-breaking mechanism responsible for generating HEMP is the Earth's geomagnetic field, without which no radiated EMP fields would escape the source region due to radial symmetry. The *source region,*[20] also known as the

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[20] For high-altitude bursts, the source region is typically at altitudes of 15-40 km as this is the region where the atmosphere begins to be dense enough to produce significant Compton scattering. In the case of low-altitude and surface bursts, the source region (region of appreciable atmosphere) surrounds the detonation. Here the gammas begin to undergo Compton scattering immediately, unlike the high-altitude gammas which, depending upon their HOB, may traverse tens of kilometers before impinging upon the upper limits of the source region.

deposition region or conversion layer, is the region where the prompt gamma photons interact with air molecules primarily through the process of Compton scattering in which they scatter from electrons—deemed Compton electrons. The EMP[21] is created as the Compton electrons, traveling at close to the speed of light, accelerate and spiral along the Earth's magnetic field lines, creating transient electric fields and currents responsible for the electromagnetic pulse. The EMP, created with frequencies between about 100 KHz and 1 GHz, travels efficiently through the atmosphere. Because the detonation is high above the Earth's surface, the HEMP effect on the ground can cover large sweeping areas as well as affect targets or assets in flight such as planes and reentry vehicles. The large electric fields millivolt/meter (mV/m) associated with these EMP waves can have devastating consequences on electrical equipment that is not protected.

For surface or low-altitude detonations the symmetry-breaking mechanism that gives rise to SREMP is the non-uniformity of the air-ground boundary. The ground acts both as a radiation absorber and an electrical conductor. A target or asset on the ground close to GZ for a surface or low-altitude detonation will experience much greater electromagnetic fields than from a high-altitude detonation with the same weapon; however, the radiated fields from a surface or low altitude detonation affect a much smaller footprint on the ground and dissipate quickly with range from GZ.

For mid-altitude bursts, about 5 to 20 km, the effects of HEMP begin to taper off but still contribute depending on how much of the source region the prompt gammas actually travel through. Because the burst is lower in altitude, the footprint of the HEMP on the ground will also be smaller than that covered by a high-altitude burst. At mid-altitudes, the effect of SREMP begins to manifest the lower the HOB and, thus, it too contributes to the total electromagnetic field strength generated on the ground or experienced by assets in flight (planes and RVs).

Low energy X-rays from high-altitude detonations can give rise to SGEMP on satellites and space-based assets thorough the photoelectric effect by which the low energy X-rays are absorbed by the asset's surface materials and then liberate free electrons.[22] These liberated electrons move both inside and outside

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[21] The EMP signal from high-altitude detonations is broken down into three components: E1, the early time signal generated by prompt gammas; E2, the intermediate time signal generated by scattered gammas and neutrons; and E3, the late time signal generated by the effects caused from blast and heave of the Earth's atmosphere (as opposed to Compton Scattering). The long-wavelength, lower frequency E3 component is responsible for damage to transmission lines and long-underground conductors whereas the short-wavelength, higher frequency E1 component has the strongest electromagnetic fields and is responsible for electrical system/component upset and damage.

[22] SGEMP is driven by low-energy X-ray prompt radiation, whereas TREE is driven by the gamma and neutron prompt radiation.

the space-based asset creating currents and inducing conductivity in dielectrics. The transient electron currents generated in this process create electromagnetic fields which can couple to nearby components that are part of the space-based asset. SGEMP energy can ultimately deposit in onboard electronic devices, causing upset (interruption, data loss) or damage from electrical overstress to unprotected electronics.

TRANSIENT RADIATION EFFECTS ON ELECTRONICS

Transient radiation effects on electronics (TREE) is damage to electronic components exposed to initial nuclear radiation gamma rays and neutrons. Gamma rays and neutrons moving away from GZ can affect electronic components and associated circuitry by penetrating deep into materials and electronic devices. Gamma rays can induce stray currents of electrons that generate electromagnetic fields similar to EMP. Neutrons can collide with atoms in key electronic materials causing damage to the crystal (chemical) structure and changing electrical properties. All electronics are vulnerable to TREE but smaller, solid-state electronics such as transistors and integrated circuits are the most vulnerable. Although initial nuclear radiation passes through material and equipment in a matter of seconds, the damage is usually permanent.

In the case of a high-altitude or exoatmospheric burst, prompt gamma rays and neutrons can reach satellites or other space systems. If these systems receive large doses of this initial nuclear radiation, their electrical components can be damaged or destroyed. If a nuclear detonation is a low-yield surface or low-air burst, the prompt gamma rays and neutrons could be intense enough to damage or destroy electronic components at distances beyond those affected by air blast. Because electronic equipment can be hardened against the effects of TREE, it is not considered in damage estimation.

Equipment designed to be protected against TREE is called “rad-hardened.” Generally, special shielding designs can be effective, but TREE protection may include using shielded containers with a mix of heavy shielding for gamma rays and certain light materials to absorb neutrons. Just as with EMP hardening, it is always less expensive and more effective to design rad-hardening protection into the system during design and development.

BLACKOUT

Blackout is the interference with radio and radar waves resulting from an ionized region of the atmosphere. Nuclear detonations in the atmosphere generate a flow of gamma rays and X-rays moving away from the detonation. These photons produce a large number of ionizing events in the atoms and molecules in the air, creating a large region of ions with more positively charged atoms closer to the detonation, which can interfere with communications transmissions. Blackout does not cause damage or injuries directly. However, the interference with communications or radar operations could cause accidents indirectly, for example, the loss of air traffic control (due to either loss of radar capability or the loss of communications).

A high-altitude or exoatmospheric detonation produces a large ionized region of the upper atmosphere that could be as large as thousands of kilometers in diameter. This ionized region could interfere with communications signals to and from satellites and with AM radio transmissions relying on atmospheric reflection. Under normal circumstances, this ionized region interference continues for a period of time, up to several hours, after the detonation. The ionized region can affect different frequencies out to different distances and for different periods of time.

A surface or low-air burst produces a smaller ionized region of the lower atmosphere that could be as large as tens of kilometers in diameter. These bursts could interfere with Very High Frequency (VHF) and Ultra High Frequency (UHF) communications signals and radar waves that rely on line-of-sight transmissions. Normally, this low altitude ionized region interference would continue for a period of time, up to a few tens of minutes, after the detonation. There is no direct protection against the blackout effect.

First Thermonuclear Test, Ivy Mike (10.4 MT)

CHAPTER 14

HISTORY OF NUCLEAR EXPLOSIVE TESTING

OVERVIEW

From 1945 to 1992, the United States conducted both nuclear explosive and non-nuclear testing. Since 1992, the United States has not conducted nuclear explosive testing. Instead, the United States has developed and relied upon certifying the continued safety, security, and effectiveness of nuclear weapons as well as evaluating the effects of nuclear weapons on systems without the use of nuclear explosive testing. Uncertainties and challenges associated with these approaches may make it necessary in the future to resume some level of nuclear explosive testing to certify the aging nuclear stockpile. The requirement to resume nuclear explosive testing is assessed on an annual basis by the directors of the national security laboratories and the Commander of U.S. Strategic Command (USSTRATCOM). These assessments are reported to Congress and the President.

U.S. NUCLEAR TESTING PROGRAM

The U.S. nuclear testing program began with the *Trinity* test on July 16, 1945, at a location approximately 55 miles northwest of Alamogordo, New Mexico, now called the *Trinity Site*. The test confirmed that the implosion design weapon used in the *Fat Man* atomic bomb would function to produce a nuclear detonation and also gave the Manhattan Project scientists their first look at the effects of a nuclear detonation.

The United States conducted five additional nuclear tests between 1946 and 1948. By 1951, the United States had increased the ability to produce nuclear devices for testing and conducted 16 nuclear tests that year. Between 1951 and 1958, the United States conducted 188 nuclear tests. Increasing the knowledge and data associated with nuclear physics and weapon design was the main purpose of most of these tests. Some tests were designed to develop nuclear weapons effects data while a few were safety experiments. These tests were a mixture of underground, aboveground, high-altitude, underwater, and above-water detonations.

In 1958, the United States instituted a self-imposed moratorium on nuclear tests. On October 31, 1958, the United States entered into a unilateral testing moratorium announced by President Eisenhower with the understanding that the former Soviet Union also would refrain from conducting tests. The Soviet Union resumed testing in September 1961 with a series of the largest number of tests ever conducted.

On September 15, 1961, the United States resumed testing at the Nevada Test Site (NTS) on a year-round basis and conducted an average of approximately 27 tests per year over the next three decades. These included 24 joint tests with the United Kingdom;[1] 35 tests for peaceful purposes as part of the Plowshare program;[2] seven to increase the capability to detect, identify, and locate nuclear tests as part of the *Vela Uniform*[3] program; four to study nuclear material dispersal in possible accident scenarios; and post-fielding tests of specific weapons. By 1992, the United States had conducted a total of 1,054 nuclear tests. In 1992, Congress passed legislation that prohibited the United States from

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[1] The United States and the United Kingdom were preparing to conduct a 25th test when President George H. W. Bush announced a moratorium on underground nuclear testing in 1992. Until that point, the nuclear relationship between the United States and the United Kingdom, as defined by the *1958 Mutual Defense Agreement*, allowed for the conduct of joint tests between the two nations. This was helpful to the United Kingdom—especially following the atmospheric testing moratorium of 1958—because the UK did not have the same access to land that could be used for underground nuclear testing as the United States and the Soviet Union. Following the 1992 testing moratorium, the United Kingdom formally undertook to end nuclear testing in 1995 and they ratified the *Comprehensive Nuclear-Test-Ban Treaty* in April 1998. See *Chapter 10: International Programs*, for a more detailed discussion of the nuclear relationship between the United States and the United Kingdom.

[2] The Plowshare program was primarily intended to evaluate the use of nuclear detonations for constructive purposes (e.g., to produce craters for the rapid and effective creation of canals).

[3] *Vela Uniform* was an element of Project Vela undertaken by DoD to develop and implement methods to monitor compliance with the *1963 Partial Test Ban Treaty* focused on monitoring seismic signals in order to detect underground and underwater nuclear testing. *Vela Uniform* performed seven underground nuclear tests in the continental U.S. and Alaska.

conducting an underground nuclear test and led to the current policy restriction on nuclear explosive testing.

EARLY YEARS OF U.S. NUCLEAR TESTING

The first six nuclear tests represented the infancy stage of the U.S. nuclear testing program. The first test at the Trinity Site in New Mexico provided the confidence required for an identical weapon to be employed at Nagasaki. The second and third tests, both in 1946, used identical *Fat Man* design devices to evaluate the effects of airdrop and underwater detonations in the vicinity of Bikini Island, located in the Pacific. The next three tests were conducted in 1948 on towers on the Enewetak Atoll in the Pacific, testing three different weapon designs. These first six tests began with no previous data and, by today's standards, had very crude test measurement equipment and computational capabilities. Because of this, only limited amounts of scientific data were generated by each of these events.

The 188 nuclear tests conducted between 1951 and 1958 included 20 detonations above one megaton (MT), one detonation between 500 kilotons (kt) and one MT, 13 detonations between 150 and 500 kt, and 17 tests that produced zero or near-zero-yields, primarily as safety experiments. Many of these tests produced aboveground detonations, which were routine at the time. The locations for these tests included the NTS and Nellis Air Force Range in Nevada, Enewetak Atoll, Bikini Island, and the Pacific Ocean. Some of the highest yield detonations were produced by test devices far too large to be used as deliverable weapons. For example, the *Mike* device, which produced a 10.4 MT detonation on November 1, 1952, at Enewetak, was almost seven feet in diameter, 20 feet long, and weighed 82 tons. On February 28, 1954, the *Bravo* test on Bikini Island produced a surface burst detonation of approximately 15 MT, the highest yield ever produced by the United States. The *Bravo* device was a two-stage design in a weapon-size device, using enriched lithium as fusion fuel in the secondary stage. Figure 14.1 shows the Bravo fireball shortly after detonation.

During this period, as the base of scientific data grew and as sensor technology, test measurement, and diagnostic equipment became more sophisticated and more capable, the amount of data and scientific information gained from each test increased. The initial computer codes, used to model fissile material compression, fission events, and the like, were based on two-dimensional models. These computer models became more capable as the scientific database expanded and computing technology evolved.

TRANSITION TO UNDERGROUND NUCLEAR TESTING

Between October 31, 1958, and September 14, 1961, the United States conducted no nuclear tests because of a self-imposed testing moratorium. The United States resumed nuclear testing on September 15, 1961, and conducted

Figure 14.1 Bravo Fireball

100 tests over the next 14 months to include underground, underwater, and aboveground detonations. These tests included nine detonations above one MT, eight detonations between 500 kt and one MT, and four detonations between 150 and 500 kt. The locations for these tests included the NTS, the vicinity of Christmas Island in the East Indian Ocean, the Pacific Ocean, Johnston Island in the Pacific, and Carlsbad, New Mexico. The last four tests of this group were conducted during a nine-day period between October 27 and November 4, 1962. These were the last U.S. nuclear tests that produced aboveground or surface burst detonations.

In compliance with the 1963 Limited Test Ban Treaty (LTBT), all subsequent U.S. nuclear test detonations were conducted deep underground. Initially, some thought this restriction would have a negative impact on the program to develop accurate data on the effects of nuclear weapons. The Atomic Energy Commission (AEC) and the Defense Atomic Support Agency (DASA)[4] responded with innovative ways to minimize the impact of this restriction. Through the use of long and deep horizontal tunnels, and with the development of specialized sensors and diagnostic equipment to meet the need, the effects testing program continued successfully.

In the 30 years between November 9, 1962, and September 23, 1992, the United States conducted 760 deep underground nuclear tests (UGT).[5] The locations for these tests included the NTS, Nellis Air Force Range in Nevada, and the vicinities of Fallon, Nevada; Hattiesburg, Mississippi; Amchitka, Alaska;

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[4] While the AEC was a forerunner organization to the current NNSA, the DASA served as a precursor to the current Defense Threat Reduction Agency (DTRA).

[5] Four of these were surface experiments, without a nuclear detonation, to study plutonium scattering.

Farmington, New Mexico; Grand Valley, Colorado; and Rifle, Colorado.[6] The tests during the period between November 1962 and April 1976 included four detonations above one MT, 14 detonations between 500 kt and one MT, and 88 detonations between 150 and 500 kt.[7] Of the 1,054 total U.S. nuclear tests, 63 had simultaneous detonations of two or more devices while 23 others had zero or near-zero yield.

Generally, a device for a weapons-related UGT (for physics research, to refine a warhead design in engineering development, or for a post-fielding test) was constructed at one of the two design laboratories (LANL or LLNL), as shown in Figure 14.2, and transported to the test site and positioned down a deep vertical shaft in one of the NTS test areas. Informally, this type of test was called a "vertical test." Typically, a large instrumentation package would be lowered into the shaft and positioned relatively close to the device with electrical wires running back to aboveground recording instruments. The vertical shaft was covered with earth and structural support was added to prevent the weight of the earth from crushing the instrumentation package or the device. This closed the direct opening to the surface and precluded the fireball from pushing hot radioactive gases up the shaft into the atmosphere. When the detonation occurred, the hundreds or thousands of down-hole instruments momentarily transmitted data but were almost immediately consumed in the fireball.

Figure 14.2 LANL Rack Assembly and Alignment Complex (RAAC)

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[6] After May 17, 1973, all U.S. nuclear tests were conducted at the NTS.
[7] 81 of the 90 tests are listed in the unclassified record with a yield between 20 and 200 kt.

The preparation for a vertical UGT took months and included drilling the vertical shaft and preparation of the instrumentation package, which was constructed vertically, usually within 100 meters of the shaft. The instrumentation package was typically 40 to 80 feet high, several feet in diameter, and surrounded by a temporary wooden structure. The structure would have levels, approximately seven to eight feet apart, and a temporary elevator to take technicians to the various floors to place and prepare the instruments. The test device would be lowered into the shaft, followed by the cylindrical instrument package. After the test, the ground above the detonation would often collapse into the cavity left by the cooling fireball, forming a subsidence crater on the surface directly over the test location.[8] See Figure 14.3 for a photograph of a preparation site for an underground nuclear test.

Figure 14.3 Underground Nuclear Test Preparation

Generally, a UGT device for an effects test was positioned in a long, horizontal tunnel deep in the side of one of the mountains in the Yucca Mountain Range, located at the north end of the NTS. Informally, this type of test was called a "horizontal test." The tunnels were relatively large, usually more than 30 to 40 feet across, and ran several miles into the side of the mountain. Typically, the tunnel had a small-scale railroad track running from the entrance to the deepest part of the main tunnel, which included a train to support the logistics

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[8] The collapse that caused the subsidence crater could occur at any time, from minutes to months, after the detonation, making the time of the collapse unpredictable.

movement of workers and equipment. The main tunnel would have many long branches, called "side-drifts," each of which could support a UGT. Instruments were positioned at various distances from the device and a huge blast door was constructed to permit the instantaneous effects of nuclear and thermal radiation, X-rays, and electromagnetic pulse to travel to instruments at greater distances but to close prior to the arrival of the blast wave. After the detonation, instruments outside the blast door would be recovered and the side-drift would be closed and sealed with a large volume of earth.

For both vertical and horizontal UGTs, the device would be prepared in a laboratory environment and transported to the test site, usually only a few days prior to the test date. On the test date, the NTS operations center would continuously monitor wind direction and speed to determine where any airborne radioactive particles would travel in the unlikely event of a "venting" incident.[9] If the wind conditions could blow venting gases to a populated area, the test was delayed until the wind conditions changed. Frequently, UGTs were delayed hours or days.

In 1974, the Threshold Test Ban Treaty (TTBT) was signed by the United States. The treaty would not be ratified until 1990 but, in 1976, the United States announced it would observe the treaty pending ratification. The treaty limited all future tests to a maximum yield of 150 kt. This presented a unique problem because, at the time, each of the three legs of the nuclear triad required new warheads with yields exceeding 150 kt and this compelled the weapons design community to make two major changes to nuclear weapons development.

First, new warhead designs would now be limited to using tested and proven secondary stage components, which provide most of the yield in high-yield weapons. The rationale for this change was that if previous testing had already determined the output required from the primary stage to ignite or drive the secondary and if testing had also determined the output of the secondary, then all that would be needed was a test to determine if the new primary would produce a yield large enough to drive the secondary. Of the 1,054 U.S. nuclear tests, at least 82 had yields that exceeded 150 kt. Another 79 may have had yields exceeding 150 kt but are listed in unclassified source documents only as being between 20 to 200 kt. Many of these tests provided the data for scientists to determine the required information (e.g., ignition threshold, yield output)

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[9] Venting incidents occurred very few times during the history of U.S. underground nuclear testing. Venting occurs when a vertical UGT shaft is close enough to an unknown deep underground cave system that leads to the surface and permits the expanding fireball to push hot radioactive gases through the underground cave system to the surface and into the air. Instruments to determine geology thousands of feet underground were not precise enough to detect all possible underground caves or cavities. Venting can also occur if the blast door for a horizontal UGT is not strong enough to contain the blast wave.

to certify several different secondary stage designs, which would produce yields greater than 150 kt. See Figure 14.4 for a summary of U.S. nuclear tests by yield.

Time Period	Yield					
	Zero or Near-Zero	> 0 to 150 kt	Possible > 150 kt	> 150 to 500 kt	> 500 kt to 1 MT	> 1 MT
1945–1948	0	6	0	0	0	0
1951–1958	17	137	0	13	1	20
1961–11/04/62 *	0	79	0	4	8	9
11/9/62–03/17/76 **	5	391	79	9	14	4
5/76–1992	1	257	0	0	0	0
Total:	**23**	**870**	**79**	**26**	**23**	**33**

* Last U.S. aboveground or surface detonation.
** Last U.S. detonation above 150 kt.

Grand Total: 1,054 Nuclear Tests

Figure 14.4 U.S. Nuclear Tests by Yield

Second, in order to test any new warhead with a yield greater than 150 kt, the warhead would have to be reconfigured to ensure it would not produce a yield in excess of 150 kt. Thus, new strategic warheads capable of yields greater than 150 kt would not have the benefit of a nuclear test in the full-yield configuration.

By the 1980s, the U.S. nuclear testing program had evolved into a structure that categorized tests as physics research, effects, warhead development engineering, and post-fielding tests. Physics research tests contributed to the scientific knowledge and technical data associated with general weapons design principles. The effects tests contributed to the base of nuclear effects data and to testing the vulnerability of key weapons and systems to the effects of nuclear detonations. See *Chapter 9: Nuclear Survivability and Effects Testing* for more information.

Development tests were used to test or refine key aspects of specific designs to increase yield output or to improve certain nuclear detonation safety features. Post-fielding tests were conducted to provide stockpile confidence and ensure safety. For each warhead-type, a stockpile confidence test (SCT) was conducted between 6 and 12 months after fielding. This was intended to check the yield to ensure any final refinements in the design added after the last development test and any imperfections that may have resulted from the mass-production process did not corrupt the designed yield. Post-fielding tests were also used to confirm or repair safety or yield problems when non-nuclear testing, other surveillance, or computer simulation detected possible problems, especially unique abnormalities with the fissile components. If a problem was confirmed and a significant modification applied, a series of nuclear tests could be used to validate the modification to ensure that fixing one problem did not create a new issue.

TRANSITION TO 3-D CODES

By the early 1980s, the United States had conducted more than 970 nuclear tests, most of which had the basic purpose of increasing the scientific data associated with weapon design or refining specific designs. The national security laboratories had acquired the most capable computers of the time and were expanding the computer codes to analyze, for example, fissile material compression and fission events in a three-dimensional (3-D) model. By the mid-1980s, use of 3-D codes had become routine. The 3-D codes provided more accurate estimates of what would be achieved with new designs or what might happen, for nuclear detonation safety considerations, in an abnormal environment.

With the 3-D codes, the national security laboratories evaluated a broader range of abnormal environments for fielded warhead-types (e.g., the simultaneous impact of two high-velocity fragmentation pieces). This led to safety experiments and improvements that might not have otherwise occurred.[10] The increased computational modeling capability with the 3-D codes also helped scientists to refine the near-term nuclear testing program to include tests that would enhance the base of scientific knowledge and data. Each year, the results of the nuclear testing program increased U.S. computational modeling capabilities.

END OF UNDERGROUND NUCLEAR TESTING

Throughout the 20th century, most nations that developed nuclear weapons tested them to obtain information about how the weapons worked as well as how the weapons behaved under various conditions and how personnel, structures, and equipment behaved when subjected to nuclear explosions. In 1963, three of the four nuclear states (the United States, the United Kingdom, and the then Soviet Union) and many non-nuclear states signed the Limited Test Ban Treaty, pledging to refrain from testing nuclear weapons in the atmosphere, underwater, or in outer space. The Treaty, however, permitted underground nuclear testing. France continued atmospheric testing until 1974 and China continued until 1980. Then, in 1992, the United States voluntarily suspended its program of nuclear testing. Public Law (Pub. L.) 102-377, *Fiscal Year 1993 Energy and Water Development Appropriations Act,* the legislation that halted U.S. nuclear testing, had several key elements. The law included a provision for 15 additional nuclear

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[10] For example, an interim fix for one of the Army warheads was fielding a "horse blanket" to be draped over the container to provide fragmentation/projectile shielding for transportation and storage; the ultimate fix put the shielding inside the container.

tests to be conducted by the end of September 1996 for the primary purpose of modifying weapons in the established stockpile to include three modern safety features.[11] However, with a limit of 15 tests within less than four years and without any real advance notice of the requirement, there was no technically credible way, at the time, to certify design modifications that would incorporate any of the desired safety features into existing warhead-types.[12] Therefore, the decision was made to forgo the 15 additional tests permitted under the new law and no other tests were conducted.

The nuclear test prohibition impacted the stockpile management process in several significant ways. First, the legislation was too restrictive to achieve the objective of improving the safety of those already-fielded warhead-types. Second, the moratorium on underground nuclear testing also resulted in suspending production of weapons being developed with new, untested designs. These changes resulted in a shift toward a second era for the U.S. nuclear weapons program: the modernization and production cycle, in which newer-design warheads replaced older warheads, was supplanted by a new strategy of indefinitely retaining existing warheads without nuclear testing and with no plans for weapon replacement. Third, the underground nuclear testing moratorium created an immediate concern for many senior stockpile managers that any weapon-type that developed a nuclear component problem might have to be retired because nuclear tests could no longer be used to define the specific problem and confirm the correcting modification was acceptable. There was a concern that without nuclear testing, there was a possibility that one weapon-type after another would be retired because of an inability to fully diagnose and correct emerging problems, which might eventually lead to unintended, unilateral disarmament by the United States. This fear has not been realized in the years since 1992. However, as the legacy Cold War stockpile continues to be deployed, age-related issues, including those related to nuclear components, are an increasing concern. Eventually, all of the weapons in the legacy stockpile will need to be replaced by new warheads whose designs place a premium on yield margin so that they can be certified without the benefit of nuclear explosive testing. This is the third U.S. nuclear era. See *Chapter 1: The U.S. Nuclear Deterrent: Past, Present, and Future* for a more detailed description.

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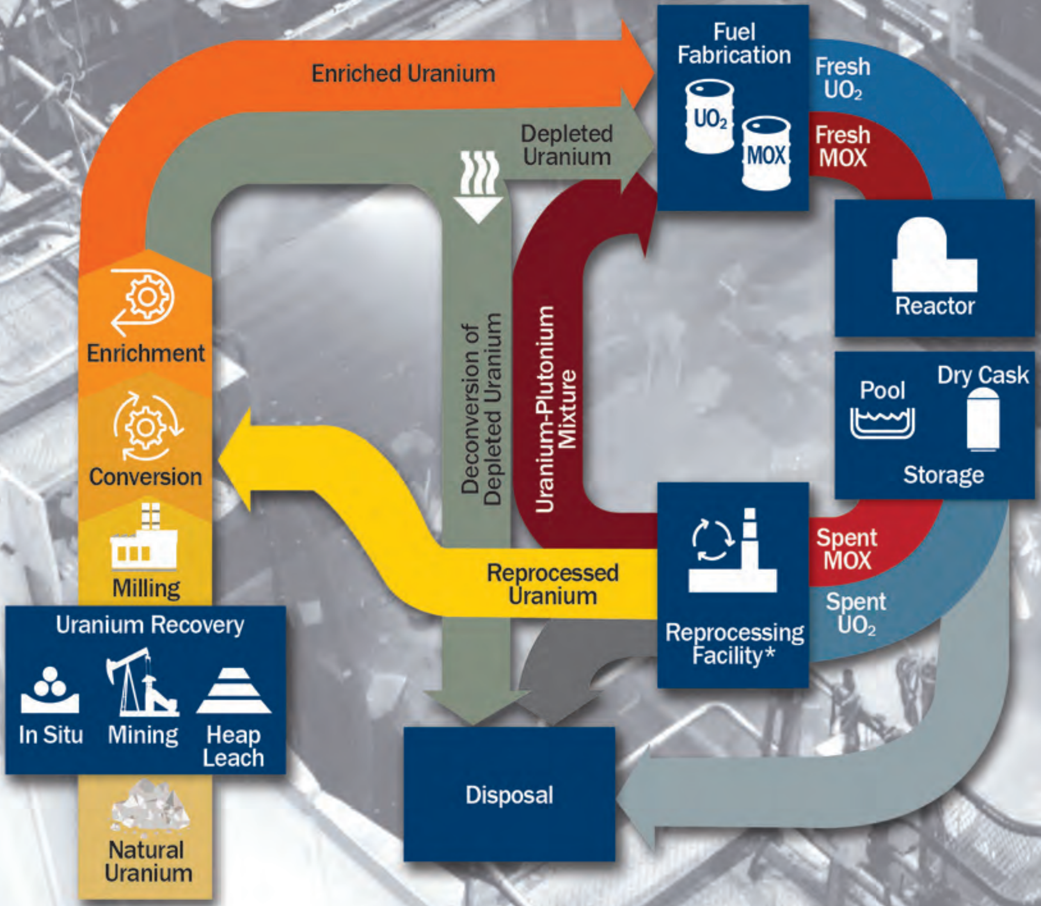
[11] Pub. L. 102-377 specified three desired safety features for all U.S. nuclear weapons: enhanced nuclear detonation safety (ENDS), insensitive high explosive (IHE), and a fire-resistant pit (FRP).

[12] At the time the legislation was passed in 1992, scientists estimated that each modification to any given type of warhead would require at least five successful nuclear tests, all of which had to be done sequentially; one test was necessary to confirm that the modification did not corrupt the wartime yield, and four tests were needed to confirm nuclear detonation safety for four different peacetime abnormal environments.


NEVADA TEST SITE
TESTING OF DEVICES FOR DEFENSE AND FOR PEACEFUL USES OF NUCLEAR EXPLOSIVES IS CONDUCTED HERE. THE NATION'S PRINCIPAL NUCLEAR EXPLOSIVES TESTING LABORATORY IS LOCATED WITHIN THIS 1,350 SQUARE MILE, GEOLOGICALLY COMPLEX, AREA IN THE ISOLATED VALLEYS OF JACKASS, YUCCA, AND FRENCHMAN FLATS. SELECTED AS ON-CONTINENT TEST SITE IN 1950, THE FIRST TEST TOOK PLACE ON FRENCHMAN FLAT IN JANUARY, 1951.
ARCHEOLOGICAL STUDIES OF THE NTS AREA HAVE REVEALED CONTINUOUS OCCUPATION BY PREHISTORIC MAN FROM ABOUT 9,500 YEARS AGO. SEVERAL PREHISTORIC CULTURES ARE REPRESENTED. THE LAST ABORIGINAL GROUP TO OCCUPY THE SITE WAS THE SOUTHERN PAIUTE WHO FORAGED PLANT FOODS IN SEASON AND OCCUPIED THE AREA UNTIL THE COMING OF THE PIONEERS.

THE NUCLEAR FUEL CYCLE



** The United States does not produce spent nuclear fuel, including mixed-oxide (MOX) fuel.*

Chapter 15

Nuclear Fuel Cycle and Proliferation

Overview

There is a close relationship between the technology and infrastructure necessary for a nation to produce nuclear energy for peaceful purposes and those necessary to produce nuclear weapons. History shows that most proliferating nations rely on their own nuclear weapons development programs to produce the essential components for a nuclear weapon. Some nations prefer to advertise their intent to develop nuclear weapons. Other nations prefer to hide their proliferation activities until they have produced usable weapons. Analyzing a proliferant nation's weapons development program and its ability to produce nuclear weapons capabilities depends on understanding the nuclear fuel cycle and how it relates to the major activities required to produce a nuclear weapon. This chapter describes the steps a proliferating nation would need to take, either overtly or covertly, and to develop a nuclear weapons program and covers subjects including: nuclear fuel-cycle requirements; the basic principles of nuclear engineering; and the process to develop, produce, and weaponize a nuclear energy program.

Nuclear Weapons Development Program

Any proliferating nation that desires to successfully develop a nuclear weapon must engage in two basic essential activities: 1) a process to produce fissile material and from that a fissile component, and 2) a process to develop and produce all of the required non-fissile (non-nuclear) components required to produce a nuclear weapon. Figure 15.1 shows four basic paths to produce fissile material and then a fissile component. It also lists the required[1] major non-fissile components that must be developed and produced in a process called weaponization.

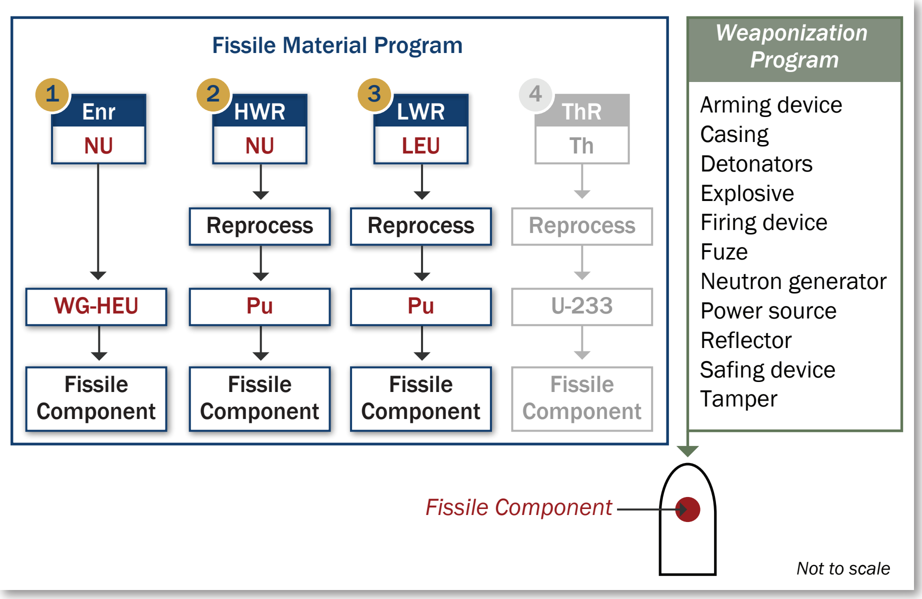


Figure 15.1 Paths to Attain a Nuclear Weapons Development Program

The first path to a fissile component is to use an enrichment process with natural uranium (NU) as the basic material to be transformed into fissile material, shown as Path 1 in Figure 15.1. The enrichment process produces weapons-grade highly enriched uranium (WG-HEU) as the fissile material, which is put through a fabrication process to create a fissile component. A second possible path is to run a sufficiently large heavy-water reactor (HWR) with natural uranium as the reactor's nuclear fuel. The reactor's operation process converts a small portion of the nuclear fuel to the fissile material plutonium (Pu). The spent fuel is reprocessed to extract the fissile plutonium from the other materials in the

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[1] Most of the weaponization components listed are essential for any of the four basic nuclear weapon designs. Some may be required for one design, but not another. Others may be desired but not essential to produce a nuclear detonation, depending on the design.

spent fuel. The extracted plutonium is put through a fabrication process to create a fissile component (Path 2). A third possible path is to run a sufficiently large light-water reactor (LWR) with low-enriched uranium (LEU) as the reactor's nuclear fuel.[2] The reactor converts a small portion of the nuclear fuel to the fissile material plutonium. The spent fuel is reprocessed to extract the fissile plutonium from the other materials in the spent fuel, and the plutonium is fabricated into a fissile component (Path 3). A fourth possible path uses a thorium-fueled reactor producing uranium-233 as the fissile material (Path 4). This process is rarely used because thorium (Th) as a nuclear fuel is less efficient than either natural uranium in a heavy-water reactor or low-enriched uranium in a light-water reactor. Additionally, the uranium-233 produced is less efficient as a fissile material than plutonium. For these reasons, Path 4 in Figure 15.1 is shown grayed-out.

Because there are three practical paths to produce fissile material, there is no single path or single activity that is mandatory for a nuclear weapons program, including nuclear testing, which makes detecting illicit proliferation more difficult. Further details about these first three paths to a fissile component, each of the major components produced in weaponization, and the issue of nuclear testing are described later in this chapter.

NUCLEAR FUEL CYCLE AND FISSILE MATERIAL

Fissile material is a necessary element of any nuclear weapon; therefore, a nation attempting to achieve a nuclear weapons capability must decide how to obtain fissile material. In most cases, proliferating nations prefer to produce their own fissile material as a by-product of nuclear energy production rather than rely on a foreign supplier. The process required to obtain nuclear fuel for use in a nuclear reactor is called the "nuclear fuel cycle," and normally refers to the requirements for reactors used as power plants to generate electrical power, generally referred to as *power reactors*. The process is almost identical for reactors that serve to produce fissile material for nuclear weapons, generally referred to as *production reactors*. Most production reactors serve both functions, i.e., to produce fissile material for a weapons program and to generate electricity, again making detection more difficult if a nation wants to obscure its intent to proliferate.

Figure 15.2 shows the process to enrich uranium and produce WG-HEU, one common type of fissile material. Steps A through F represent a proliferating nation's path to WG-HEU with no outside foreign assistance to obtain fissile materials. In Step F, the enrichment process must enrich uranium beyond LEU and non-weapons-grade highly enriched uranium (HEU). It also shows the

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[2] It is possible to use natural uranium in a graphite-moderated light-water reactor to produce plutonium and generate electricity. Very few of the world's total nuclear rectors are in this category.

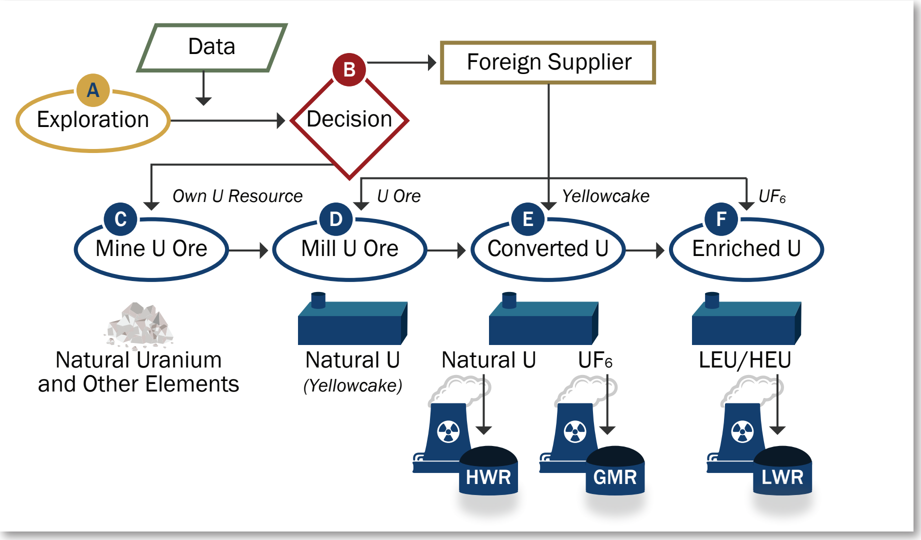

Figure 15.2 Nuclear Fuel Cycle: Producing WG-HEU

paths to produce plutonium, the other most common fissile material, using natural uranium in heavy-water or graphite-moderated reactors under Step E or using LEU in light-water reactors under Step F.

If the decision in Step B is to use a foreign source for uranium ore, natural uranium, or converted uranium, the path can go from Step B to either Step D, E, or F accordingly. It is also possible that the proliferating nation procures uranium at any level of enrichment from a foreign source. History shows that proliferating nations rarely, if ever, procure from a foreign source any significant amount of HEU or WG-HEU for their nuclear weapons.

EXPLORATION

Exploration is the first phase of any new nuclear fuel cycle. Step A in Figure 15.2 shows the process of beginning exploration and obtaining data through research and assessment about nuclear physics, engineering, economic costs, manufacturing requirements, safe handling and transport requirements, and potential foreign suppliers. Step B is the decision to choose a path to obtaining fissile material—produce fissile material indigenously or purchase and import uranium ore, or uranium already extracted from ore (usually in the form of yellowcake), or converted uranium (usually uranium hexafluoride).

MINING

Step C in Figure 15.2 depicts the mining process for uranium ore. Conventional mining removes ore from the earth, which is processed above ground to extract the desired minerals, such as uranium. In situ mining, also called leach mining, processes the ore while still in the ground by dissolving the ore in-place and extracting only the desired minerals. The leach solution which contains the desired minerals is pumped to the surface and the minerals are separated above ground in a subsequent process. In situ is usually more cost-effective than conventional mining because there is much less movement, handling, and disposal of wasted ore tonnage (sometimes called tailings), and it is more environmentally friendly because there is much less destruction of the natural surface of the terrain and less waste for disposal.

MILLING

In Step D, the uranium ore is transported to a milling facility to separate the natural uranium from all other minerals. This usually involves grinding the ore to a specified particle size and extracting the uranium using a chemical leaching process. The extracted uranium is usually in the form of a yellow, dry, coarse powder with a distinct odor, called yellowcake. Typically, yellowcake consists of mostly tri-uranium oxide (U_3O_8),[3] and other uranium oxides such as uranium dioxide (UO_2) and uranium trioxide (UO_3).

CONVERSION

In Step E, the yellowcake uranium is transported to a conversion facility to further modify the chemical form of the uranium. This is required because the intended use of the uranium is for either manufacturing the uranium into a fuel pellet for a reactor that will use natural uranium, or to be put into a process to enrich the uranium. Either process requires that the uranium be in a different chemical form. The most common conversion is to uranium hexafluoride (UF_6), which is suitable for use in most reactors and also suitable to enter an enrichment process. The uranium may be converted to uranium dioxide (UO_2), which is the preferred form for some less-common reactors, such as the Canadian CANDU reactors.[4]

FUEL PELLET FABRICATION

Certain types of less-common reactors, such as heavy-water or graphite-moderated reactors, are designed to use natural uranium without enrichment. In these cases, the natural uranium can be converted into the fuel pellet form required,

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[3] The common name is tri-uranium oxide, but the technically correct term in chemistry is tri-uranium octaoxide.

[4] CANDU (Canadian deuterium uranium) reactors are pressurized, heavy-water reactors using uranium as the fissionable fuel and heavy water as a neutron moderator (i.e., to slow down the neutrons and increase the fission cross-section, which is the probability that the neutron will interact with a heavy nucleus and cause a fission event). The term deuterium is used because heavy-water molecules contain deuterium atoms (the second isotope of hydrogen, which has one proton and one neutron in the nucleus) rather than the common form of hydrogen, which is called protium, and has one proton but zero neutrons.

and can be used in the reactor without enrichment as shown at the bottom of Step E. These reactors can be used as power reactors to generate electricity, or as production reactors to produce plutonium for nuclear weapons.

ISOTOPES OF URANIUM

Natural uranium consists of three isotopes shown in Figure 15.3. Of these three isotopes, only U-235 is fissile.

Isotope	Percent
Uranium-238	99.2745
Uranium-235	0.7200
Uranium-234	0.0055

Figure 15.3 Natural Uranium Isotopes and Percentages

URANIUM ENRICHMENT

Uranium enrichment is the process of isotope separation increasing the percentage of uranium-235 atoms in any given amount of uranium and decreasing the percentage of the sum of all other isotopes. Uranium enrichment does not create fissile atoms, but rather removes most of the non-fissile U-238 atoms, leaving a larger percentage of the fissile U-235 atoms in a much smaller quantity of uranium.

In Figure 15.4, Step A shows natural uranium moved to an enrichment apparatus. The gray area represents the atoms of the non-fissile isotopes and the black dots represent the atoms of the fissile uranium-235, which is only 0.72 percent of the total as shown in Figure 15.3 above. In Step B the uranium is subjected to a force or process applied by the apparatus. This causes the uranium atoms to separate in a manner that causes more of the heavier atoms to go one way and more of the lighter atoms to go in a different direction. This results in one portion of the uranium having a lower percentage of U-235 atoms, called depleted uranium, as shown in Step C at the top of the apparatus. The other portion of the uranium is enriched, i.e., having a higher percentage of U-235 atoms, as illustrated at the bottom of the apparatus.

All three steps in Figure 15.4 occur sequentially in one apparatus, which is called a *stage* when it is a part of a series of enrichment devices. At each stage, the separation process causes only a slight difference in the percentages of U-235 between the depleted and enriched portions. For most enrichment methods, this difference is usually only a small fraction of 1 percent.

The right portion of Figure 15.4 shows a list of different methods of creating the force or process to cause isotope separation. The current gold-standard of uranium enrichment is gas centrifuge technology. However, there are several

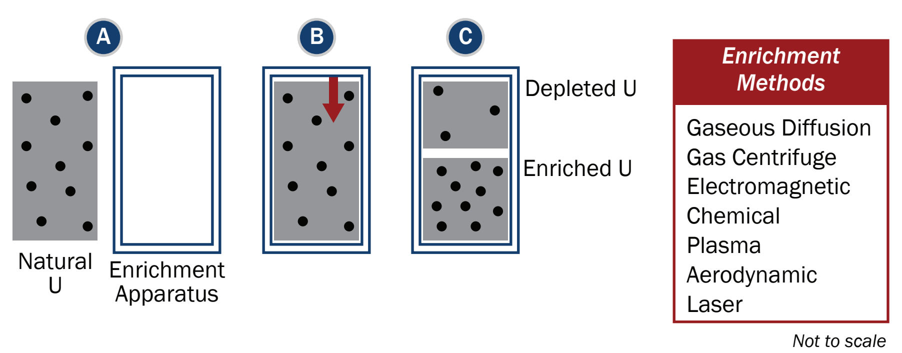

Figure 15.4 Enrichment Process in a Single Stage

feasible and practical alternative methods that have either been implemented for commercial or weapons programs or that have been demonstrated at smaller scales for isotope separation. A proliferating nation may attempt to pursue a less widely used enrichment method.

In order to enrich uranium to a level where the percentage of U-235 is increased significantly, many enrichment stages are required. Multiple apparatuses are configured in a series, called a *cascade*, where each stage enriches the uranium to a higher level. The flow of uranium going through stages for higher levels of enrichment is referred to as moving *downstream*. Depleted uranium moving to earlier stages is called moving *upstream*. Figure 15.5 depicts a cascade of three enrichment stages.

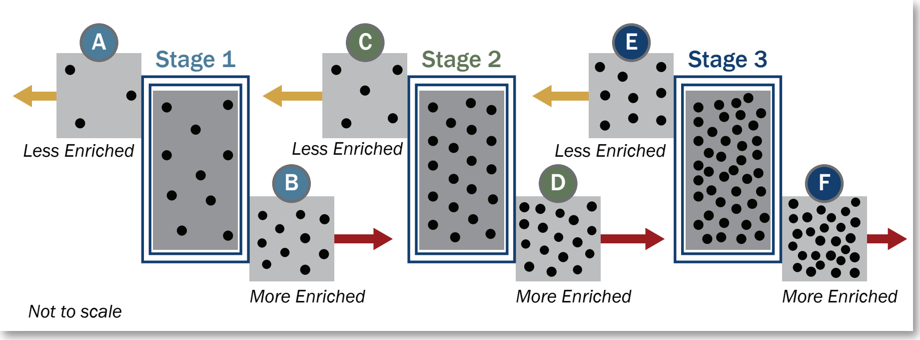

Figure 15.5 Cascade of Three Enrichment Stages

In Stage 1, natural uranium undergoes isotope separation with the depleted uranium (A) sent upstream to the previous stage.[5] The enriched uranium (B)

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[5] Most enrichment cascades that begin with natural uranium use stages upstream from the entry stage because those stages will process many U-235 atoms and return them to the downstream stages. This provides greater efficiency for the overall system.

moves downstream to Stage 2. Uranium returning from Stage 2 (C) to Stage 1 has the same level of enrichment as the uranium processed in Stage 1. The apparatus at Stage 2 receives uranium enriched at Stage 1 (B) moving downstream and uranium depleted at Stage 3 (E) moving upstream. The Stage 2 apparatus combines the incoming uranium, separates the isotopes, and passes the more enriched downstream and the less enriched upstream.[6] The apparatus at each stage performs the same functions, but at each successive stage going downstream, the level of enrichment is slightly higher. The level of uranium enrichment is defined as the percentage of U-235 atoms in the uranium, e.g., 3 percent enriched uranium contains 3 percent U-235 atoms of the total uranium atoms.

Depleted Uranium

Depleted uranium (DU) is uranium containing less than 0.72 percent U-235 atoms. DU is a by-product of an enrichment process where the primary product is enriched uranium and the DU is the by-product depleted of U-235 atoms. DU has many uses, e.g., serving as a heavy substitute component instead of a fissile component in nuclear weapons flight tests (that cannot use "live" nuclear weapons), being used as a heavy, dense material in conventional weapons relying on kinetic energy, or for certain types of scientific research, etc. Figure 15.6 shows the categories of uranium enrichment levels.

Category	Percent
Depleted Uranium (DU)	Less than 0.72 percent U-235
Natural Uranium (NU)	0.72 percent U-235
Low-Enriched Uranium (LEU)	> 0.72 < 20.00 percent U-235
Highly Enriched Uranium (HEU)	20.00 to 89.99 percent U-235
Weapons-Grade HEU (WG-HEU)	= / > 90.00 percent U-235

Figure 15.6 Categories of Uranium Enrichment

Low-Enriched Uranium

LEU is uranium enriched to any level above natural uranium, but less than 20 percent enrichment. Low-enriched uranium may serve several purposes, including use in medical or other scientific research, as fuel for nuclear reactors (usually light-water reactors), or feed material for higher levels of enrichment. Normally, it takes hundreds of stages to enrich natural uranium to the level required for light-water reactors (usually between 3 and 5 percent LEU). The exact number of stages required depends on the exact level of enrichment

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[6] By technical definition, depleted uranium has a lower percentage of U-235 than natural uranium. In common discussion, at each stage, the portion with the smaller percentage of U-235 is referred to as depleted. However, after Stage 1, these portions of uranium should be called "less-enriched" because they have a higher percentage of U-235 than natural uranium, not lower.

required, the method of enrichment used by the enrichment apparatus, and the "operational efficiency of the design of the apparatus. LEU has such a small percentage of fissile U-235 atoms that it cannot serve as the fissile material in a nuclear weapon.

Highly Enriched Uranium

HEU is uranium enriched to at least 20 percent, but less than 90 percent. HEU may be used in medical or other scientific research, or for industrial purposes. Usually, it requires many hundreds or even more than one thousand stages to reach 20 percent enrichment. HEU normally cannot serve as the fissile material in a nuclear weapon. HEU enriched to the highest levels of the category could be usable, but would be much less efficient than weapons-grade HEU.

Weapons-Grade Highly Enriched Uranium

WG-HEU is uranium enriched to 90 percent or higher. WG-HEU may serve as the fissile material in a nuclear weapon. It may also be used in small naval propulsion reactors or in breeder reactors. It would be rare to find a valid justification for using WG-HEU in medical or other scientific research, or for industrial purposes, even if only in trace amounts.

Figure 15.7 illustrates the results of the enrichment process. Step A represents a large amount of natural uranium entering the process. Step B shows that approximately half way through the process, the level of enrichment has reached 50 percent, with approximately half of the non-fissile U-238 atoms removed, but the amount of uranium has decreased significantly. Step C depicts the stage at which the enrichment has reached 90 percent. Approximately 90 percent of the U-238 atoms have been removed, and the small amount of remaining uranium is 90 percent fissile U-235 atoms. In a typical enrichment process with average efficiency, it may take one ton or more of natural uranium input to enrich one kilogram (kg) (approximately 2.2 pounds) of 90 percent enriched WG-HEU.

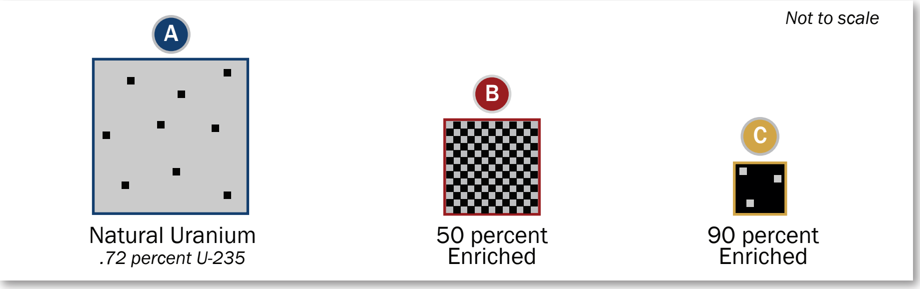

Figure 15.7 Enrichment Process Results

WG-HEU may be used as the fuel for research reactors and is typically used as the fuel for propulsion reactors. Several nations' intelligence agencies and international organizations like the International Atomic Energy Agency (IAEA) track various aspects of research and propulsion reactor fuel. Some of the aspects that are evaluated are accounting for material, security of the material in storage and transit, safe handling, and any indicators that the fissile fuel could be for sale on the international black market. Additionally, there are ongoing efforts to develop technical solutions allowing for the replacement of WG-HEU fuel with LEU fuel. Thus far, no terrorist organization has come into possession of propulsion reactor fuel and assembled it into a nuclear weapon, although the international community must continue monitoring for that possibility.

ENRICHMENT FACTORS

The process to enrich natural uranium in a large enough quantity to produce sufficient WG-HEU for even a small number of nuclear weapons would require several resources, including:

- a modern industrial facility to accommodate the several acres required for the thousands of enrichment devices (one at each stage) laid out in one extremely long cascade, or more likely, several shorter cascades of a few hundred enrichment devices in each cascade. Space would be required for technicians to have access to each device for routine maintenance, repair, or replacement with reserve "float" enrichment devices;
- a huge amount of electrical energy to power each of the enrichment devices and all of the other activities of a modern manufacturing plant—which may be more electricity on a continuous basis than required to support a large city;
- security to prevent sabotage or theft of valuable materials or equipment. If a proliferating nation is attempting to hide their nuclear weapons program from sophisticated foreign intelligence sources, it may require extraordinary and expensive additional measures, such as constructing facilities underground and disguising the activities in and around each facility;
- persons with the required technical knowledge and skills; and
- funding to procure or build the facility, hire a work force of skilled and semi-skilled technicians, purchase or produce the required electrical energy, provide the required security, and provide the necessary support activities.

NUCLEAR REACTORS

Most nuclear reactors are structures as large or larger than a small house, containing radioactive nuclear fuel configured to achieve a controlled, sustained chain reaction of fission events. The normal basic reactor design has the nuclear fuel in small cylindrical pellets, arranged in a line called a *fuel rod*. Many fuel rods are grouped into large three-dimensional fuel rod assemblies, which are further grouped into a three-dimensional "pile" that is the reactor core. The core will have neutron-absorbing control rods, a cooling/heat transfer system, and an interactive electrical control system. There are several ways of categorizing nuclear reactors; the most basic way is by purpose/intended function, in which case there are four basic categories of nuclear reactors: research, propulsion, power, and production.

Research Reactors

Research reactors are nuclear reactors intended for scientific or medical research. They are usually very small compared with other categories of reactors. They may have a configuration similar to most other reactors, or they may have unique configurations that do not resemble a standard nuclear reactor.[7] Research reactors are small enough that any fissile material produced would be in such small quantities that it would not be enough for a fissile component in a nuclear weapon.

Propulsion Reactors

Propulsion reactors are nuclear reactors that are intended to provide the power for ship propulsion and other power needs to operate the ship. They are usually larger than research reactors, but much smaller than power reactors. They are almost always of a basic design that uses a pile arrangement as the reactor core, and the nuclear fuel is usually uranium enriched to 90 percent or more.

Power Reactors

Power reactors are nuclear reactors that are intended solely for the production of electrical energy. They are usually very large reactors with a basic design that uses a pile arrangement as the reactor core. Most of the more than 400 operational reactors worldwide are power reactors, and they all produce significant amounts of fissile plutonium.[8] The material accountability, security, safety, and political control of power reactors are a concern.

Production Reactors

If a nuclear reactor is intended to produce electrical energy and also to produce fissile material for nuclear weapons, it is categorized as a production reactor. They are usually relatively large in order to produce significant quantities of

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[7] Some research reactors do not use nuclear fuel configured in a pile, e.g., a neutron flux reactor may consist of two separated subcritical fissile components that operate by using gravity to slide one component past the other creating a brief moment of supercriticality and a large flux of neutrons produced by the supercritical fission events. This type of reactor uses but does not produce fissile material.

[8] In the 1990s, the U.S. nuclear reactor community evaluated a "triple-play" reactor design that would consume fissile material without producing any other fissile material, produce electrical energy, and produce tritium needed for nuclear weapons programs. The then-Secretary of Energy terminated the program before a comprehensive evaluation of the advantages and disadvantages was completed.

fissile materials. Within the category of production reactors, most are light-water reactors, but a significant number are heavy-water reactors. A few have been thorium-fueled reactors.

Light-Water Reactors. LWRs use LEU (usually between 3 and 5 percent enriched) as nuclear fuel in the reactor core and natural water (light water) to moderate (slow down) neutrons for increased fission efficiency. Thermal (slow) neutrons have a higher probability of producing fission events and producing a more efficient chain reaction than using unmoderated faster neutrons to produce subsequent fission events. The light water is also used to cool the reactor core, and usually to transfer heat to drive a turbine and generator to produce electricity.

Within the reactor core of LEU fuel, 95 percent or more of the uranium atoms are non-fissile U-238 atoms. As the reactor operates, some of these U-238 atoms absorb or capture a neutron. When this occurs, it becomes a U-239 atom with one more neutron than the U-238. U-239 has a short half-life of only 23.47 minutes. When the U-239 atom decays, it emits a beta particle from the nucleus, which in effect changes one neutron to a proton. With one more proton and one less neutron it becomes neptunium-239 (Np-239). Np-239 has a relatively short half-life of 2.355 days. When the Np-239 atom decays, it also emits a beta particle from the nucleus, and becomes plutonium-239 (Pu-239).

Figure 15.8 illustrates how this process of U-238 atoms capturing neutrons and transmuting to neptunium, then to plutonium, is continually ongoing while the reactor is operational.

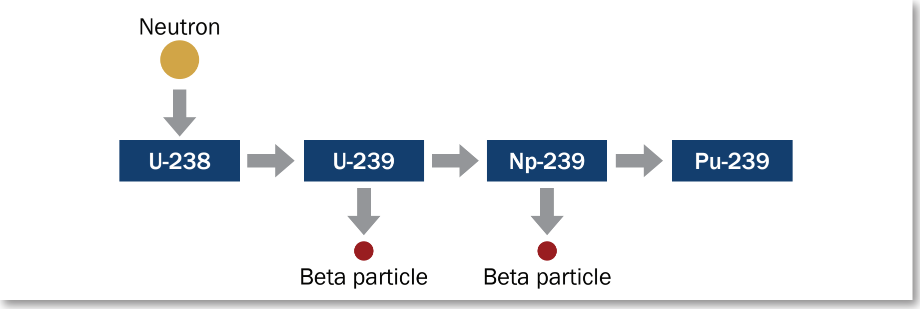

Figure 15.8 U-238 Neutron Capture and Transmutation to Plutonium

LWR Production Factors. The process to operate a light-water production reactor to produce plutonium in sufficient quantities for a nuclear weapons program would require associated infrastructure and resources, to include:

- a modern industrial capability to design, construct, and operate a large nuclear reactor. Normally the acreage required would be less than that required to enrich uranium to weapons grade;

- procurement or production of LEU enriched to the required level for the reactor design;
- a significant water source to provide water to be passed through the core serving as the moderator, coolant, and to drive a turbine. Most large reactors pass through tens of millions to a billion gallons of water per day.
- persons with the required technical knowledge and skills;
- security to prevent sabotage or theft of valuable materials or equipment. If a proliferating nation is attempting to hide their nuclear weapons program from sophisticated foreign intelligence sources, it may require extraordinary and expensive additional measures, such as constructing facilities underground and disguising the activities in and around each facility; and
- significant funding to procure or build the reactor, produce or procure LEU, maintain a highly skilled workforce, provide the security, and provide all the necessary support activities. While the capital investment required is significant, and may be as much as the investment required for an enrichment program, unlike the enrichment program, the reactor will generate electricity that could help offset the total cost of the nuclear weapons program.

PLUTONIUM

Plutonium-239 is the most efficient of all the fissile isotopes producible in large quantities. It has a relatively long half-life of 24,100 years and a low incidence of spontaneous fission.[9] Therefore, it is the preferred fissile isotope for most proliferating nations. As the Pu-239 begins to increase in quantity in the reactor core, two things happen that interfere with a steady build-up of plutonium. First, because it is so efficient as a fissile material, most of the Pu-239 atoms will fission when struck with a neutron. These Pu-239 fission events add to the reactor's operation and output, but it hampers the build-up of large quantities of Pu-239, which occurs slowly over a period of many months or years.

Second, some of the Pu-239 atoms that do not fission will capture neutrons and become heavier isotopes of plutonium. These heavier isotopes are disadvantageous as fissile material. Pu-240 is not a fissile isotope and cannot contribute to a multiplying chain reaction of fission events in a nuclear weapon. More importantly, Pu-240 has a much higher incidence of spontaneous fission

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[9] All known fissile isotopes that can be produced in significant quantities are subject to some low level of spontaneous fission. This is a concern because the spontaneous fission events reduce the number of fissile atoms, and the neutrons produced can cause subsequent fission events and further loss of fissile atoms.

than the fissile isotopes, thereby making it an impurity to the overall plutonium as a fissile material.

Some of the Pu-240 atoms will capture neutrons and become Pu-241 atoms. Pu-241 is a fissile isotope with a low incidence of spontaneous fission, but it has a short half-life of 14.4 years and will decay with higher frequency than longer half-life isotopes. When Pu-241 atoms decay, they emit beta particles and strong gamma radiation. The gamma rays have the potential to interact with surrounding material and cause the material to increase in temperature, making it less desirable for use in a weapon. This heating effect can cause high explosive (HE) compounds (necessary to implode the fissile material to cause a sustained chain reaction) to change their molecular arrangement and become less efficient for symmetrical implosion, reducing the weapon's efficiency and yield, and the heat could make the HE unstable and unsafe. Some of the Pu-241 atoms will capture neutrons causing an increase in plutonium isotopes heavier than Pu-241, but these isotopes have less effect on the overall characteristics of the plutonium as a fissile material.

Unlike uranium enrichment, the production of plutonium in reactors has the opposite effect. In uranium enrichment, only a small percentage of the uranium reaches high levels of enrichment, but the more enriched it is, the more it approaches weapons grade. The production of plutonium in reactors has a continuing increase in the amount of plutonium, but a continuing decrease in the quality of isotope distribution.

At the beginning of reactor operations, there is no plutonium in the nuclear fuel. As the reactor continues operations the amount of plutonium increases, but the quality of the plutonium decreases as it becomes hotter with increased heavy isotopes above Pu-239. As the amount of plutonium builds up, it becomes less pure as a fissile material, and is hotter in both temperature and in the amount of hazardous gamma radiation emitted.

Weapons-Grade Plutonium

As the amount of plutonium is increasing in the reactor core, it has very little of the undesirable heavier isotopes. It is considered weapons-grade plutonium (WG-Pu) as long as the percentage of heavier isotopes is not greater than 7 percent and the percentage of Pu-239 is at least 93 percent. This quality of plutonium is the most fissile efficient of all isotopes that can be produced in sufficient quantities for a nuclear weapon, and its radiation emissions are low enough for safe handling for short periods of time.

Unlike uranium, the common terminology for plutonium does not use the level of purity, but instead uses the level of undesirable isotopes to distinguish levels of plutonium. For example, very pure plutonium that has only 3 percent heavier isotopes would be referred to as "3 percent plutonium," not 97 percent. Figure 15.9 shows the categories of plutonium.

Category	Percent
Weapons-Grade Pu (WG-Pu)	= / < 7 percent Pu-240, 241, etc. (= / > 93 percent Pu-239)
Reactor-Rrade Pu (RG-Pu)	> 7 < 15 percent Pu-240, 241, etc. (< 93 > 85 percent Pu-239)

Figure 15.9 Categories of Plutonium

Reactor-Grade Plutonium

When the heavier isotopes build-up to more than 7 percent, the plutonium is considered to be reactor-grade plutonium (RG-Pu). At that point it remains a fissile material and can be used in a nuclear weapon. However, as it approaches higher levels of reactor grade (probably between 9 and 14 percent plutonium depending on the weapon design, peacetime configuration, and the nation's health risk standards for radiation workers, if any) it is too radioactive to handle safely and too hot to be next to a high explosive component.

Light-water reactors vary in their efficiency producing fissile plutonium due to several factors including the design of the reactor, the level of enrichment of the LEU reactor fuel, and especially the managed operations of the reactor. The longer the reactor operates before replacing the spent fuel, the hotter the plutonium will become.

High-Level Waste

With long reactor operational cycles, the heavier isotopes of plutonium build up in the reactor, and eventually will exceed 15 percent and become high-level waste, i.e., having a high-level of radioactivity, which makes it radioactive waste. It would be hot enough in radiation emissions that it would be unsafe for humans to handle and would be hot enough in temperature that it would be unsafe to put it next to or near a high explosive component. High-level waste plutonium is not safe to be used in nuclear weapons. However, high-level waste is often processed as spent fuel to extract fissile uranium and plutonium to be used as nuclear fuel for power reactors. Plutonium is considered to be high-level waste when the percentage of heavier isotopes reaches 15 percent.

Light-water reactors are less efficient than heavy-water reactors at producing weapons-grade plutonium. Because of that fact, there have been assertions made that light-water reactors are "proliferation resistant" and cannot produce fissile material. This is false and will be discussed at the end of the section on heavy-water reactors.

HEAVY-WATER REACTORS

HWRs use natural uranium as nuclear fuel in the reactor core and specially produced heavy water to moderate (slow down) neutrons for increased fission efficiency and usually to cool the core. The heated heavy water may also be used to drive a turbine for electricity generation. Heavy-water reactors are more efficient at producing weapons-grade plutonium than light-water reactors.

Heavy Water

Heavy water is natural water (usually seawater) that has been processed to remove all salt and other minerals as well as the ^{1}H protium atoms from the water molecules, which are replaced with ^{2}H deuterium atoms (also shown in science literature as ^{2}D). Figure 15.10 illustrates the nuclei particles for light-water and heavy-water molecules. When used in a reactor, heavy water, containing two more neutrons than light/natural water, will have a higher probability of being struck by neutrons and slowing their velocity, and will be more efficient for producing fission events in the chain reaction. Because the heavy-water reactor uses natural uranium for the same size reactor, the nuclear fuel contains more U-238 atoms, which are the fertile isotopes that transmute to form Pu-239.

As shown in Figure 15.10, a light-water molecule (natural water) consists of one oxygen atom and two hydrogen atoms. The hydrogen atoms are approximately 99.9844 percent ^{1}H protium atoms (the first isotope of hydrogen with a nucleus of one proton and zero neutrons). In the symbol ^{1}H, the 1 indicates only one particle in the nucleus, i.e., the proton. The other 0.0156 percent of hydrogen atoms in natural water are ^{2}H deuterium atoms that have one proton and one neutron in the nucleus. For every one million hydrogen atoms in naturally occurring seawater, only 156 are ^{2}H deuterium atoms.

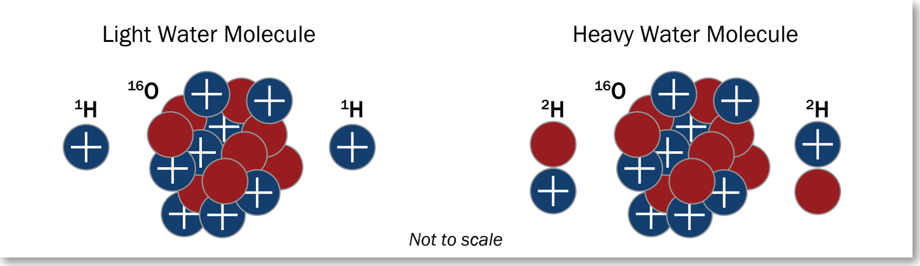

Figure 15.10 Nuclei of Atoms: Light- and Heavy-Water Molecules

The process to produce heavy water uses a cascade of devices (usually using either distillation or electrolysis) to separate heavy from light molecules in a manner similar to the process to enrich uranium. Often the heavy water is referred to as enriched water. Most heavy-water reactors require the water to be enriched to levels between 99.7 and 99.97 percent. This is a resource-intensive process and, in some cases, can be almost as expensive as enriching uranium to LEU levels.

HWR Production Factors

The process to operate a heavy-water production reactor to produce plutonium in large enough quantities for a nuclear weapons program would require several resources similar to a light-water production reactor, including a modern industrial capability, skilled personnel, enhanced security, and funding. The significant differences are that the heavy-water reactor requires the production or procurement of heavy water, not LEU. In most cases the heavy water would serve as a coolant eliminating the need for a significant water source at the reactor site.

As the heavy-water reactor operates, it will have a similar conversion of U-238 to plutonium as in the light-water reactor discussed above. It will also have a similar build-up of the undesirable heavier isotopes as shown in Figure 15.9.

HWR VS LWR FOR PLUTONIUM PRODUCTION

Because HWRs moderate neutrons more efficiently and have a larger percentage of U-238 atoms in the uranium fuel, they are more efficient for producing weapons-grade plutonium than LWRs. However, some people misunderstand and misrepresent the capabilities of the less-efficient LWRs. Assertions that light-water reactors are "proliferation resistant" and cannot produce fissile material are false. While an LWR may take longer to produce a given amount of weapons-grade plutonium, it can produce enough fissile weapons-grade plutonium for a weapons program. The efficiency and capacity varies with different reactor designs and operations. The shorter the operational cycle (before extracting the spent fuel and replacing it with new nuclear fuel) the less plutonium produced, but the plutonium will be more pure with a lower percentage of the undesirable heavier isotopes. The same size HWR can produce 50 percent more nuclear weapons in a decade. The LWR produces fewer—but not zero.

SUMMARY OF FISSILE COMPONENT FEASIBILITY

For use as fissile material, uranium must be enriched to near 90 percent, i.e., weapons grade. Figure 15.11 shows that the WG-HEU will have a long shelf-life, usually many decades. Enrichment at lower levels, less than weapons grade, will not function as fissile material to produce a nuclear detonation in a weapon-size device, illustrated in the second column. The third column represents weapons-grade plutonium as a good fissile material with a long shelf life. The fourth column shows reactor-grade plutonium usable as a fissile material in a nuclear weapon, but with a shorter shelf life.

If the RG-Pu is 7.1 percent Pu or 7.2 percent Pu—just above the definitional threshold beyond weapons grade—it would still have a shelf life of decades, but

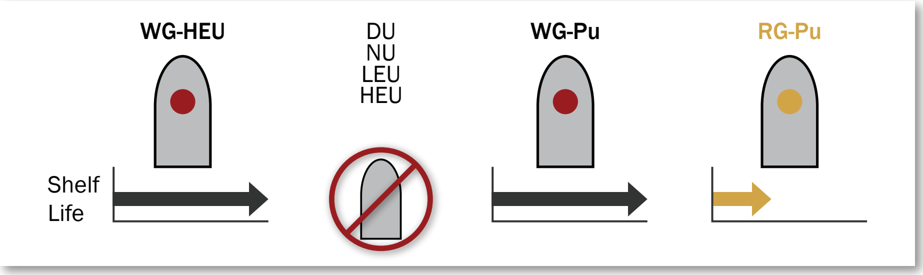

Figure 15.11 Fissile Component Feasibility and Shelf Life

less than WG-Pu. However, if RG-Pu is at a much higher level, e.g., 11 percent or 12 percent, it would have a significantly reduced shelf life. At 15 percent it becomes dangerous in proximity to a high explosive component for even a short period of time.

REPROCESSING

After fissile plutonium is produced in the reactor core as a part of the process of reactor operation, it is mixed with a variety of radioactive spent fuel. Reprocessing is the activity to extract the plutonium from the remainder of the spent fuel.[10] Normally, this is accomplished using a chemical process. Because the spent fuel includes some of the original natural uranium or LEU, it would also be extracted for its monetary value as a by-product of the weapons program.

The process of enriching natural uranium to WG-HEU levels requires a reconversion to return it to its metal form. This is the reverse process of the activity used to create the UF6 for the enrichment process. There is no universal term for this activity, but it is not referred to as reprocessing.

Compared with other key activities in the overall nuclear weapons development program, neither plutonium reprocessing nor uranium reconversion are difficult or very expensive.

FISSILE COMPONENT FABRICATION

After fissile material is produced, it must be formed into a component with the required size and shape. The process of component fabrication is different between uranium and plutonium.

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[10] In a power reactor program, the primary purpose of reprocessing would include extracting both uranium and plutonium to be used as mixed oxide as nuclear fuel for future reactor use.

URANIUM FISSILE COMPONENT FABRICATION

If the fissile material is either WG-HEU (one of the most commonly used fissile materials) or U-233 (produced in a thorium-fueled reactor but rarely used, if ever),[11] the uranium is relatively easy to return from the gaseous form to uranium used in manufacturing to fabricate a hard, heavy metal component that retains its size and shape at ambient temperatures[12] with normal handling. Normally, this would be one of the least difficult activities of a nuclear weapons program.

PLUTONIUM FISSILE COMPONENT FABRICATION

If the fissile material is plutonium, regardless of the reactor type used to produce it, the plutonium has among the most unique chemical properties of all known elements. At a minimum, plutonium has two different component fabrication challenges. First, plutonium has six different chemical phases at normal pressures. This means that a given amount of plutonium can have different densities depending on its chemical phase. Density is one of the essential factors affecting criticality. Most nations with nuclear weapons treat the detailed information about plutonium phases as classified and do not share it with other nations.

A second challenge is that pure plutonium in its most common phases does not readily retain normal heavy metal characteristics. It must be chemically stabilized by mixing some other material with the plutonium to form a plutonium compound that will allow the plutonium to be fabricated into a heavy metal component that will hold its size and shape. This can require research and experimentation to find an adequate stabilizing agent and a process in which to apply it. The types of materials used and the processes to stabilize plutonium normally are not shared with other nations.

WEAPONIZATION

Weaponization includes all of the activities required to research, develop, test, evaluate, produce, and maintain nuclear weapons components, including those that will interface with weapon system delivery vehicles, other than the production of fissile materials and the fissile component. There are at least ten non-fissile components that are either essential or beneficial in a nuclear weapon.

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[11] Some organizations promoting the use of thorium-fueled reactors have made assertions that the spent fuel has either no fissile material or fissile material that is less fissile than plutonium, and not appropriate for a nuclear weapon. This is inaccurate. The uranium-233 produced in a thorium-fueled rector is more efficient than HEU and is easier to fabricate into a nuclear component than plutonium.

[12] Ambient temperatures for nuclear weapons and components are the temperatures in the expected temperature range spectrum for normal activities including handling, storage, transport, and employment.

ARMING DEVICE

An arming device is an essential component that, at the proper time or proper condition, will change the weapon from a safe condition to a condition ready for firing, explosion, or detonation. Any prudent design of a nuclear or other weapon will include an arming device. This will preclude arbitrary initiation of the lethal force of the weapon that could be triggered by impact, temperature change, a nearby lightning strike, or stray electromagnetic radiation (e.g., radiation transmitted by hand-held electrical devices and relayed by cell towers). Conventional munitions use arming devices based on set-back during launch, setting an internal timer, barometric pressure, or other means as the impetus to arming. An arming component is neither technologically difficult nor expensive relative to other aspects of a nuclear weapons program.

CASING

The casing is an essential component that is the outside of any munition or weapon; it contains all the other components. It may be as simple as a single cast iron container or as complex as two or more components made of titanium or other compounds that screw or bolt together. The casing is neither relatively expensive nor technically difficult.

DETONATORS

Detonators are small, essential components containing explosive material intended to produce a detonation wave to ignite a high explosive compound. In some nuclear weapon designs there may be a single detonator to initiate the high explosive. Detonators are also used in conventional weapons. They are relatively inexpensive, very reliable, and readily available to almost any nation with conventional weapons.

EXPLOSIVE

An explosive compound is an essential component that will either move a subcritical component into another subcritical component or compress a subcritical component to cause a supercritical mass in a nuclear weapon. If used as a propellant, there are many such compounds in conventional weapons useful for nuclear weapons. To create an inward exploding compound that is near-perfectly symmetrical would be one of the more difficult elements of a nuclear weapons program to achieve/acquire. The time it would take to perfect an inward exploding compound is likely more of an obstacle than the cost.

FIRING DEVICE

In a nuclear weapon, a firing device is an essential component that either converts or stores and releases electrical or chemical energy to detonate the system. A crude firing device from a conventional weapon could work, but most nations would try to produce a more sophisticated firing device that would have extremely high reliability. This would be moderately difficult to achieve compared with other components, but is relatively low cost.

FUZE

A fuze is an essential component that provides a signal to the firing device at the proper time to fire the weapon. A fuze from a conventional weapon could suffice, but refinement of the conventional fuze for use in a nuclear weapon would be necessary to ensure high reliability. This would be moderately difficult to achieve and in the moderate cost range.

NEUTRON GENERATOR

A neutron generator is an essential component that produces a flux of neutrons at the precise moment when the fissile material reaches its designed supercriticality. There is no comparable component in conventional weapons. Neutron generators are used in industry for geological neutron-sounding, for example, but they are almost always large devices. It would be very difficult to take a commercial design and miniaturize it to meet the limited allocation for volume/space and weight in a nuclear weapon. This component would be very difficult and moderately expensive compared with other components to develop or acquire. Neutron generators would most likely use short-life radioactive material, and be a limited-life component (LLC) requiring periodic replacement.

POWER SOURCE

A power source is a component that stores and releases energy to power the warhead's imbedded electrical components and sub-components such as the arming device, firing device, the fuze, and possibly a safing component. The power source may be as simple as a good commercial battery or it could be a specially designed and produced, one-of-a-kind item using unique electrical parameters for security. Unless the power source uses nuclear isotopes, such as PU-238 in a radioisotopic thermoelectric generator (RTG), it will be a LLC requiring periodic replacement.

REFLECTOR

A reflector is a component that reflects neutrons back into the supercritical mass at the moment of detonation. This returns escaping neutrons into the fissile material to increase the design efficiency. A nuclear weapon can work without a neutron reflector, but it would be very inefficient (meaning it would require more fissile material). Designing and producing a reflector component would not be technically difficult or costly.

SAFING DEVICE

A safing device is a component that may provide increased safety. Safing devices are not essential for a first-generation weapon; it is unnecessary in order to produce a nuclear detonation and it would require significant space and weight. The most important function of a safing device is to preclude the weapon from unintended detonation. Other safety functions could be to prevent fissile material from scattering in an accident or to reduce ionizing radiation hazards to weapon handlers. The most sophisticated safing devices could require significant space and weight, and would be very difficult to design and moderately costly to produce.

TAMPER

A tamper is a component that will tamp or restrict the explosive component from releasing its energy in all directions. This adds efficiency to the weapon design. It may also assist in holding the supercritical mass together longer, adding to weapon design efficiency. Many basic designs combine the functions of the tamper, reflector, and casing into one component, which would have little technical difficulty or cost.

SECURITY DEVICE

A security device is a component that locks the warhead in the safe mode until unlocked with a security code. This prevents unauthorized nuclear weapon employment or detonation. A security device built into the warhead is optional, and many nations, including the United States, first fielded nuclear weapons without security devices. A security device could be as simple and crude as a mechanically-operated padlock (which could be overcome by a heavy-duty bolt cutter) or as sophisticated as electrical components embedded in the warhead requiring a multi-digit code to unlock and limited to only two or three unsuccessful attempts before permanently locking. Most proliferating nations will bypass a security feature that would take valuable space and weight, and could reduce the warhead availability/reliability if the security device were to malfunction, denying authorized use.

SPECIAL HANDLING EQUIPMENT

Special handling equipment must be designed and produced to allow personnel to handle a warhead which could weigh several tons, i.e., warhead equipment for lifting, repositioning, transporting, and disassembling. Special tools would be required for warhead maintenance, removing, and replacing LLCs (e.g., power source, neutron generator, or boosting gas). The special handling equipment is relatively easy to design and produce, and not costly.

DELIVERY SYSTEM INTERFACE

Nuclear warheads are designed and produced to interface with the intended weapon delivery system (e.g., manned aircraft, ballistic missile, submarines). The interface includes physical attachment, electrical compatibility, preclusion of mutual interference, and a practical solution for physically joining the warhead with the delivery system.

- *Casing* – The casing must be designed to mate with the delivery system in a practical manner. If the warhead weighs two tons and it must be screw-attached to a missile, it would be impossible for a team of handlers to lift the warhead and screw it onto the missile without the proper handling equipment.
- *Electrical Components* – The arming, fuzing, and firing components must be electrically compatible with the delivery system. Voltage, electrical coded signals, and even the plugs and electric receptacles must be designed for compatibility.

It is possible to design different adaptation kits/devices that do all interface requirements between a warhead and two or more different delivery systems, using one type of adaptation kit for each type of delivery system. A single given type of warhead could be compatible with several types of aircraft and several types of missiles with the use of well-designed adaptation kits.

BASIC NUCLEAR WARHEAD DESIGN TYPES

The first nuclear warhead designs resided in *Little Boy*, a uranium gun-type fission bomb, and *Fat Man*, a plutonium implosion-type fission bomb. A fission weapon is a nuclear weapon because the primary energy release comes from the nuclei of fissile atoms. Fusion weapons are called hydrogen bombs or H-bombs because isotopes of hydrogen are used to achieve fusion events that increase the yield of the detonation. Fusion weapons are also called thermonuclear weapons because high temperatures and pressure are required for the fusion reactions to occur.[13]

Figure 15.12 describes the basic types of nuclear weapon designs detailed in *Chapter 13: Basic Nuclear Physics and Weapons Effects*.

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[13] The term *thermonuclear* is also sometimes used to refer to a two-stage nuclear weapon.

Weapon Type	Key Characteristics
Gun Assembly (GA) Weapon	• Propellant drives one subcritical mass into another subcritical mass, forming one supercritical mass and nuclear detonation • Less technically complex than other designs, but less efficient
Implosion Weapon	• Compression/implosion of one subcritical fissile component to achieve greater density and supercritical mass • More technically complex than gun assembly type and more efficient
Boosted Weapon	• Fusionable material (e.g., deuterium, tritium) placed inside core of fission device, producing large number of fusion events, thereby increasing yield • More technically complex than GA or implosion design and more efficient
Staged Weapon	• Boosted primary stage and secondary stage to produce significantly increased yield • Most technically complex; produces larger yields than other designs

Figure 15.12 Basic Types of Nuclear Weapons

NUCLEAR WEAPON DESIGN FACTORS

There are many considerations that affect the decision to select a specific nuclear weapon design and its size and weight.

Weapon Size

Generally, the smaller the size (volume, dimensions, and weight) of the warhead, the more challenging it is to design to function properly to produce a nuclear detonation, and the harder it is to achieve a higher yield. As illustrated in Figure 15.13, for a given level of technical knowledge and capability, a very large size nuclear weapon will have less technical difficulty and can produce a very high yield. A very small nuclear weapon will have significantly increased technical difficulty and will produce a much lower yield.

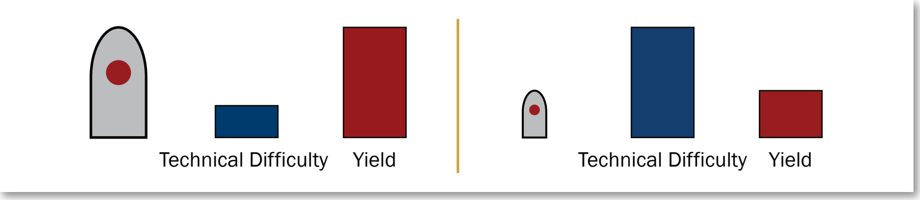

Figure 15.13 Size, Technical Difficulty, and Yield

Because the boosted and two-staged designs are significantly more difficult than the gun assembly or implosion design, they are not practical candidates for any nation's first generation nuclear weapon. There is no evidence that any nuclear-capable nation was able to produce either of these as their first workable warhead.

Up to this time, nations that have pursued a nuclear weapons capability have been motivated to design warheads to be small enough to be delivered using missiles or high-performance jet aircraft.[14] This is probably because, unlike the situation in the early 1940s, today most nations (and even some non-state actors) possess some type of air defense, which render non-stealth, large cargo, or passenger aircraft ineffective at penetrating to potential adversary targets. Therefore, it is highly likely that the first generation weapons developed by proliferating nations would be low-yield weapons, typically between one and 10 kilotons (kt).[15]

While the United States pursued both the GA and the implosion designs in the Manhattan Project, other nations that have become nuclear-capable (with one exception), have focused on the implosion design for several reasons. First, the GA design is the least efficient design for producing yield per amount of fissile material. Second, the GA design has inherent operational disadvantages that are not associated with the other designs. Third, Pu is susceptible to predetonation in a GA design, requiring HEU for the GA weapon; however, HEU is extremely expensive because of the cost of the enrichment process. Figure 15.14 compares warhead types for a given size where the left side compares yield and the right side compares technical difficulty.

The right side of Figure 15.14 includes a column showing the relative difficulty for a developing nation to design and manufacture one million automobiles; even a gun assembly weapon would be more difficult. The relative cost could be similar to the technical difficulty, with the easiest and least expensive nuclear weapons program more costly than producing a million autos, which would be in the billions of U.S. dollars.

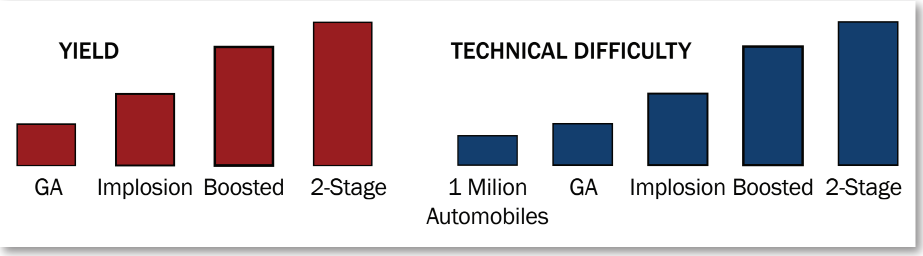

Figure 15.14 Warhead-Type Comparison: Yield and Technical Difficulty
(Notional Comparison)

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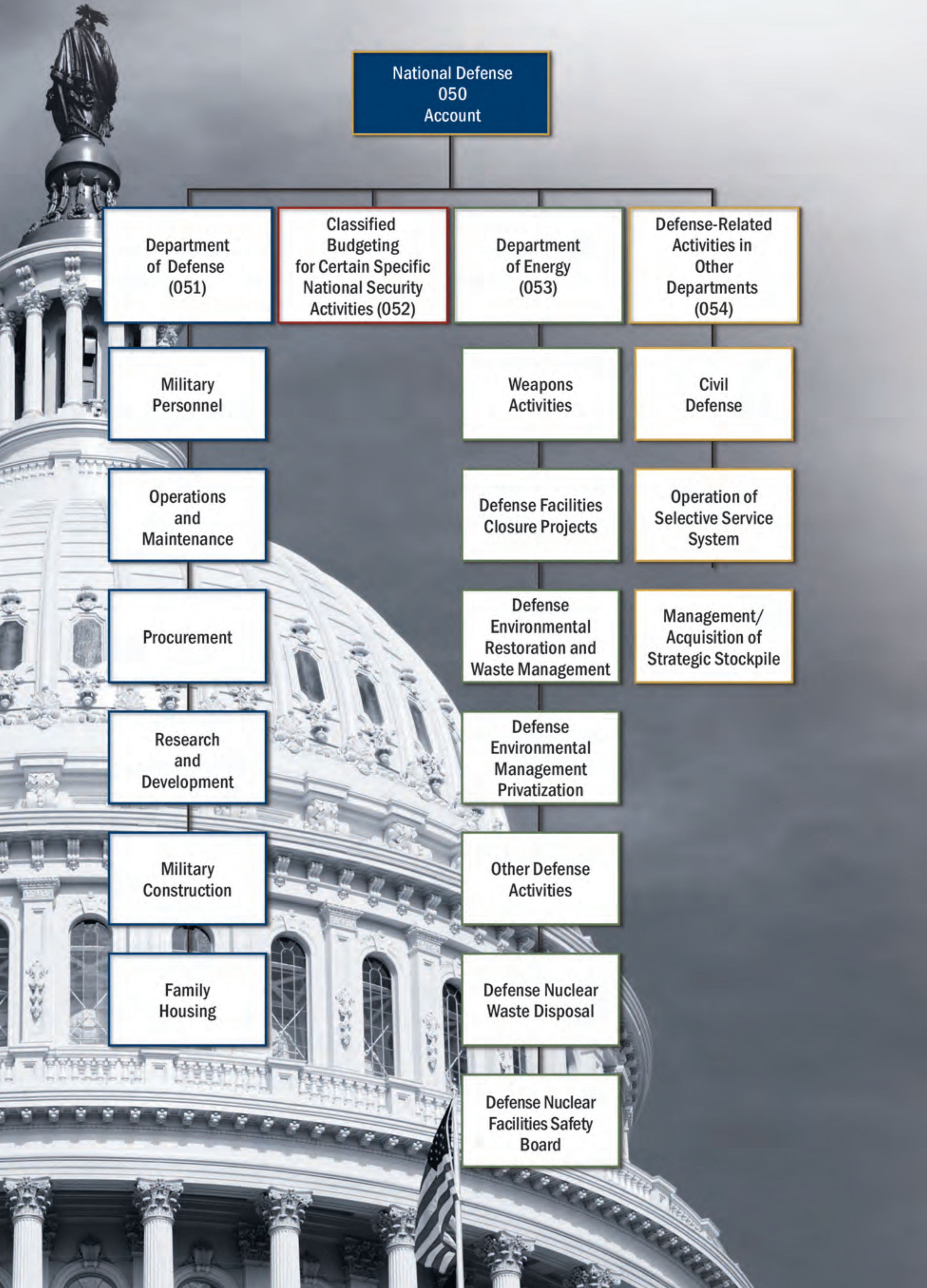
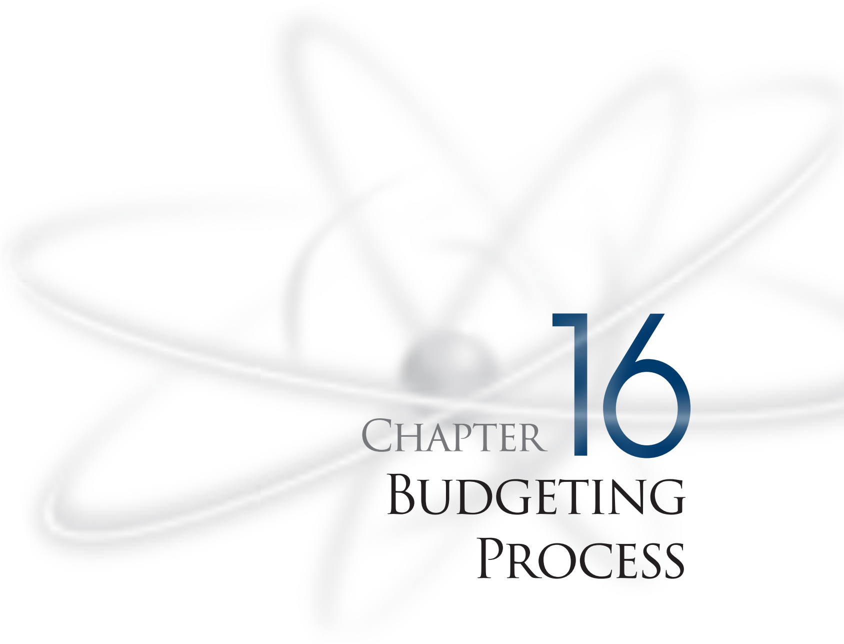
[14] Typically, the maximum weight for a warhead to be compatible with a high-performance jet aircraft would be approximately 1,000 to 1,500 kg (2,200–3,300 pounds), and approximately 750 to 1,000 kg (1,650–2,200 pounds) for the typical missile being proliferated, e.g., NODONG or SCUD-variant missiles.

[15] The *Fat Man* and *Little Boy* weapons had respective yields of 21 and 15 kt but were approximately 10,000 pounds each, and had dimensions much larger than today's modern warheads.


National Defense 050 Account
Department of Defense (051)
Classified Budgeting for Certain Specific National Security Activities (052)
Department of Energy (053)
Defense-Related Activities in Other Departments (054)
Military Personnel
Operations and Maintenance
Procurement
Research and Development
Military Construction
Family Housing
Weapons Activities
Defense Facilities Closure Projects
Defense Environmental Restoration and Waste Management
Defense Environmental Management Privatization
Other Defense Activities
Defense Nuclear Waste Disposal
Defense Nuclear Facilities Safety Board
Civil Defense
Operation of Selective Service System
Management/ Acquisition of Strategic Stockpile



Chapter 16

Budgeting Process

Overview

The budget system of the United States government provides the means for the President and Congress to decide how much money to spend, what to spend it on, and how to raise the money needed. Through the budget system, the allocation of resources among federal agencies across the competing missions and functions is determined. The budget system focuses primarily on dollars, but it also allocates other resources, such as federal employment positions.

Within the federal budget system, the acquisition and funding of nuclear weapons systems is a complex process involving multiple organizations in the executive and legislative branches of the federal government.

Federal Budget

The process for creating the federal budget is set forth in the *Congressional Budget and Impoundment Control Act of 1974*. The Act has been amended several times, but the 1974 legislation remains the basic blueprint for budget procedures. Significant amendments to the original law include measures such as the *Balanced Budget and Emergency Deficit Control Act of 1985* (commonly known as "Gramm-Rudman-Hollings") and the *Budget Enforcement Act of 1990*.

The federal budget is divided into 20 functional and subfunctional categories so that all budget authority and outlays can be presented according to the national needs being addressed. National needs are grouped in 17 broad areas to provide a coherent and comprehensive basis for analyzing and understanding the budget. Three additional categories do not address specific national needs, but are included to cover the entire budget. A final category is used for accounts that involve two or more major functions. Each functional and subfunctional category is assigned a numerical identification code. The National Defense budget function is identified by the numerical identification code "050." This account is divided into sub-accounts: 051 for DoD national security funding; 052 for classified budgeting for certain specific national security activities; 053 for Department of Energy (DOE)/National Nuclear Security Administration (NNSA) defense programs; and 054 for defense-related activities in other departments.

The federal budget provides a plan to prioritize and fund government activities. The President, the White House Office of Management and Budget (OMB), and various federal departments and agencies have major roles in developing the *Budget of the United States Government*, which is often called the "President's Budget."

PRESIDENT'S BUDGET

OMB is the principal executive branch oversight agency for the federal budget. It consolidates the budget proposal for the President after consulting with senior advisors, cabinet officials, and agency heads. OMB also apportions funds to the federal agencies after Congress completes the budget process and the President signs the various appropriations bills into law.

Initial development of the President's Budget begins with preliminary discussions between OMB and the departments (including DoD and DOE). OMB issues policy direction and planning guidance to the agencies for the upcoming budget request.

The DoD, DOE, and other agencies submit their budget requests to OMB on the first Monday after Labor Day of the year prior to the start of the fiscal year covered by the budget request. In the fall, OMB representatives review these budget requests, hold hearings with the agencies, and review the economic outlook, as well as revenue estimates in order to prepare issues for review by the OMB Director. The Director of OMB briefs the President and senior advisors on proposed budget policies and revenue estimates and recommends a complete set of budget proposals based on a review of all requests.

The President makes decisions on broad policies so that, in late November, OMB sends the budget decisions back to the departments and agencies on their budget requests in a process called "passback." The passback includes decisions concerning funding levels, program policy changes, and personnel ceilings; the agencies may appeal any decisions with which they disagree. If OMB and an agency cannot reach agreement, the issue may be taken to the Secretaries of the Departments and the President.

The President's budget request (PBR) to Congress is the first step in the annual Congressional appropriations cycle. The annual PBR is a political and policy document indicative of the goals of the Administration for the coming year. The President submits the PBR to Congress by the first Monday in February.[1] The PBR consists of several volumes delineating the President's financial proposals with recommended priorities for the allocation of resources by the federal government.

CONGRESSIONAL BUDGET RESOLUTION

Congress considers the PBR and either approves, modifies, or rejects. Congress can change funding levels, eliminate programs, or add programs not requested by the President. Congress can also add or eliminate taxes and other sources of receipts, or can make other changes that affect the amount of receipts collected.

Initial House and Senate budget committee hearings are held during the month of January leading up to the submission of the President's Budget during the first week of February. During February, the Congressional Budget Office publishes its annual report on the President's Budget, and the House and Senate budget committees develop their versions of a budget resolution. Ideally, these Resolutions are brought to the House and Senate floors for markup[2] at the end of February and adopted by early April. Leading budget committee members from both chambers then develop a conference report on the budget representing a consensus agreement on the legislation between House and Senate negotiators. This conference report is the blueprint for broad spending and tax decisions that will be made during the remainder of the year. Ideally, the conference report on the budget is adopted by April 15.

The budget resolution is not formally a law. It is a Concurrent Resolution, which does not require the President's signature. The aggregate levels of revenues, budget authority, outlays, and the committee allocations in the budget resolution are guidelines and targets against which subsequent fiscal legislation such as appropriation acts and authorizing legislation is measured.

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[1] The President also submits a mid-session review of the budget to Congress in July. Also called a supplementary budget summary, the document includes updated presidential policy budget estimates, summary updates to the information in the budget submission, and budget-year baseline estimates.

[2] "Markup" refers to the process by which congressional committees and subcommittees debate, amend, and rewrite proposed legislation.

AUTHORIZATION

Authorization acts provide the legislative authority to establish or maintain a federal government program or agency. Authorizations define the scope and provide the recommended maximum funding levels to the Appropriations Committees for the various programs.

Authorizing committees have discretion regarding the legislative changes they recommend. These committees, moreover, are not bound by program changes that are recommended or assumed by the budget committees. They are required, however, to recommend legislation addressing budget authority[3] and outlays[4] for each fiscal year.

Authorizing legislation may originate in either Chamber and may be considered at any time during the year. The authorizing committees and subcommittees hold hearings to review agency programs and policies. It is possible, though rare, for an Agency to operate without an authorization, but it cannot function without an appropriation.

The House and Senate Armed Services Committees provide annual legislative authorization for the federal government programs associated with national defense. The House and Senate Armed Services Committees and the seven standing subcommittees are responsible for the development of the annual *National Defense Authorization Act* (NDAA).[5] Between January and April, the House and Senate Armed Services Committees hold hearings to determine the defense authorization levels. The Subcommittees on Strategic Forces have jurisdiction over strategic forces and DOE national security programs. House markup of the authorization act occurs between April and May; the Senate markup follows. The two houses meet in conference after completion of their markup; the authorization bill is then finalized and forwarded to the President for signature so that it can be passed into public law by the new fiscal year.

APPROPRIATIONS

Appropriation acts set the terms and conditions for the use of federal funds. The congressional Appropriations Committees provide budget authority and outlays through 12 general appropriations areas. The Appropriations Subcommittees, which correspond to each of the 12 general appropriations areas, initially recommend the level at which programs within their jurisdiction will

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[3] "Budget Authority" refers to the authority to incur legally binding obligations of the government.

[4] "Outlays" refer to the liquidation of the government's obligations, generally representing cash payments.

[5] The NDAA serves two purposes: it establishes, continues, or modifies existing defense programs, and it provides guidance for defense appropriators, all of which allows Congress to appropriate funds for defense programs. The NDAA also authorizes funding for defense-related activities at NNSA and other agencies.

receive appropriations. The House and Senate Energy and Water Development Subcommittees have jurisdiction over NNSA nuclear weapons funding (e.g., nuclear warheads and supporting activities), and the House and Senate Defense Subcommittees have jurisdiction over DoD nuclear weapons funding (e.g., delivery systems).

The House and Senate Appropriations Committees and Subcommittees hold hearings from the end of January through mid-May each year. If the budget committees have not finalized a conference report on the budget before May 15, the Appropriations Committee may begin markup of appropriations legislation. All appropriations subcommittees are required to pass respective Appropriations Bills on or before June 10 each year and then forward them to the full Appropriations Committees for further consideration before sending the bill to the full House and Senate for consideration. The House targets June 30 as a completion date for Appropriations Bills, but debate can continue within the legislative bodies until the July/August timeframe. After the bodies pass their respective Appropriations Bills, House and Senate representatives meet to develop a conference report on appropriations.

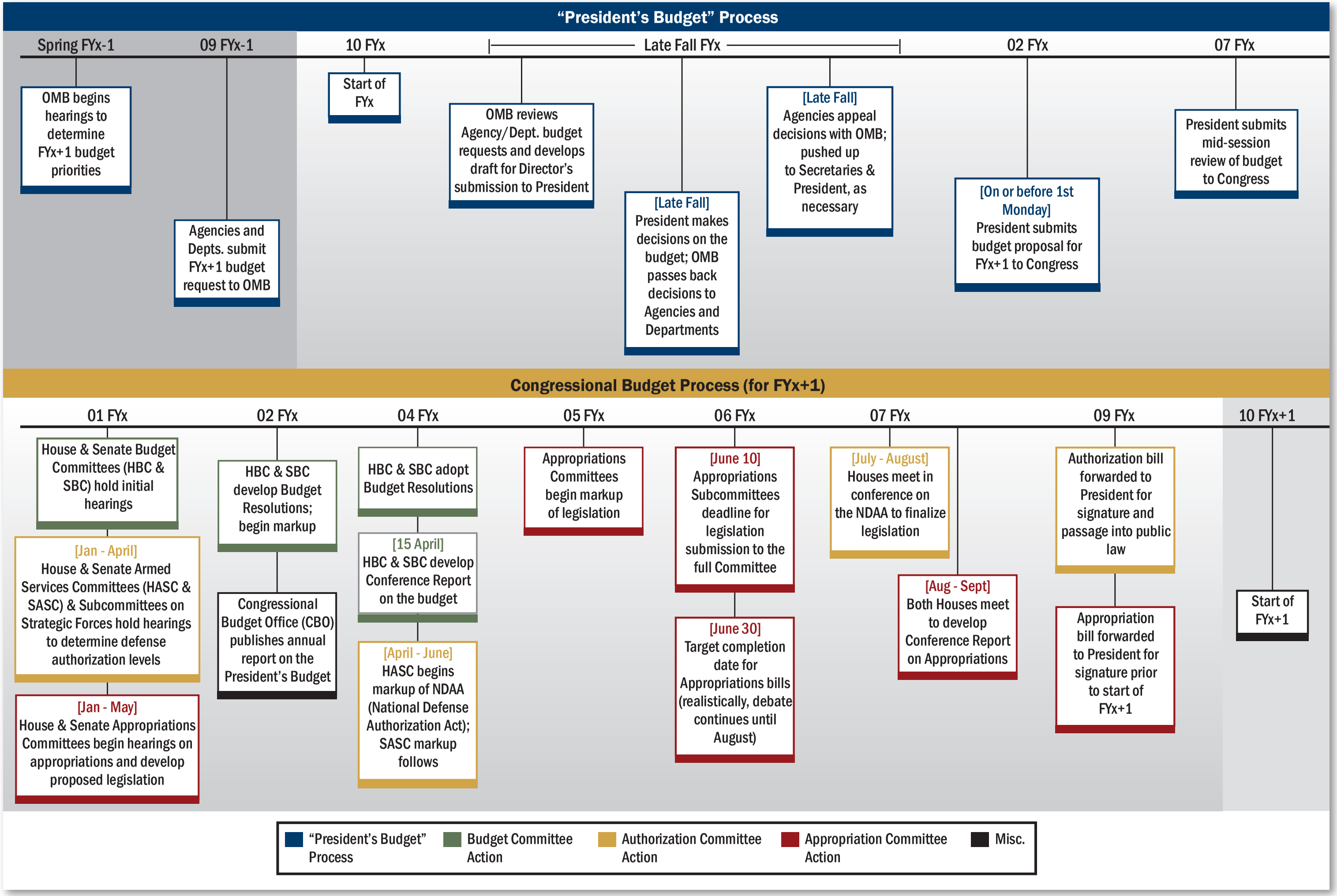
When the House and Senate members approve the final legislation it is forwarded to the President. The President has ten days to approve or veto the bill. If the bill is signed, the bill and the conference report form the legal basis for an agency's use of funds. If the bill is vetoed, Congress may either override the veto with a two-thirds affirmative vote in each Chamber, or it may modify the bill and send it back to the President for signature or veto. Figure 16.1 illustrates the congressional budget process for nuclear weapons-related programs.

Continuing Resolution

If Congress and the President have not completed action on the regular appropriation acts by the start of the fiscal year (October 1), action must be taken to ensure that departments and federal agencies and programs continue to function. Enacted as a joint resolution, a continuing resolution (CR) is an interim appropriation act that sets forth a specified level of funding for an agency for the full year, up to a specified date, or until regular appropriations are enacted. Spending may be set at any level, but if it is enacted to cover the entire fiscal year, the resolution will usually specify amounts provided for each appropriation account.

A CR has an expiration date at which time it must be extended by additional congressional action if no Appropriation Bill has been enacted. Unlike the Congressional Budget Resolution (CBR), the President must sign all CRs into law.

Figure 16.1 Congressional Budget Process for Nuclear Weapons-Related Programs



DoD and NNSA Role in the Budget Process

DoD and NNSA have processes in place to plan, program, and budget resources for inclusion in the President's Budget. The DoD process is known as the Planning, Programming, Budgeting, and Execution (PPBE) process. The NNSA process is called the Planning, Programming and Budgeting, and Evaluation (PPBE) process.

Department of Defense PPBE

For DoD, planning includes the definition and examination of alternate strategies as well as various analyses of conditions, threats and technologies, and economic assessments. The Defense Planning Guidance (DPG) forms the basis of the planning portion of the DoD PPBE process. The DPG contains guidance concerning the key planning and programming priorities to execute the *National Military Strategy* and other documents produced by the Joint Staff. The DPG provides guidance and fiscal constraints to the Military Departments, U.S. Special Operations Command (USSOCOM), and the defense agencies for the development of the DoD Program Objective Memorandum (POM).

Programming includes the definition and analysis of alternative forces, weapons, and support systems, as well as the associated multi-year resource implications and option evaluations. The POM is the DoD document that expresses the fiscally constrained total program requirements for the years covered in the DPG. The POM is sent to the Office of the Secretary of Defense (OSD) in the spring of even-numbered years for the fiscal year two calendar years in advance. So, for example, in the spring of 2020 POMs are being built for FY2022. The POM also describes the rationale for proposed changes to the U.S. Force as reflected in the Future Years Defense Program (FYDP), which is the official database of all major Force Programs established by the military. The composite POM is reviewed by the Joint Staff, OSD, and OMB, where issues and alternatives are developed. Some issues are elevated to the Defense Resources Board (DRB) where decisions are finalized and recorded in Program Decision Memoranda (PDM) in early August.

Budgeting includes the formulation, justification, execution, and control of the funds necessary to support DoD and its missions. Each Military Department, USSOCOM, and the appropriate defense agency develops its own Budget Estimate Submission (BES) based on data in the POM and the PDM. The BES includes data from the prior year, the current year, and two additional budget years. The budget estimates are forwarded to the OSD Comptroller where joint OSD and OMB hearings are held to review the submissions in order to ensure that the requests are properly priced, program schedules are appropriate, and estimates are consistent with the objectives of the Secretary of Defense.

Once each Military Department and Defense Agency has submitted its POM and/or BES to OSD, OSD releases its databases for review to the entire Department. Any organization that wants to identify a potential issue with resource choices of another organization may then write a formal Issue Paper highlighting the perceived problem, discrepancy, or alternate viewpoint.

Program Budget Decisions (PBDs) are used to document approval of the estimates for inclusion in the President's Budget. Each PBD consists of a discussion of the subject area, issues, and a series of alternatives as laid out in the issue papers. The Deputy Secretary of Defense selects an alternative or directs a new one, and the signed PBD is then released. An appeal can be made to the PBD through a reclamation process that follows the same channels as the PBD. The Deputy Secretary of Defense makes all final decisions. Once final budget decisions are made, the DoD budget becomes part of the President's Budget that is submitted to Congress. After congressional approval of the budget and signature by the President, OMB apportions the funds to DoD for execution.

DoD Distribution of Funds

Appropriations are the most common method of providing budget authority (BA) to DoD, which results in immediate or future outlays. Most Defense BA is provided by Congress in the form of enacted appropriations, or appropriations bills in which a definite amount of money is set aside to pay incurred or anticipated expenditures.

After funds, or budget authority, are appropriated to DoD by Congress, OMB apportions budget authority to the DoD Comptroller. The Comptroller is then responsible for distributing the funds to the Military Department and agency comptrollers who then distribute budget authority at the local level. As the budget authority flows through DoD comptrollers, a small percentage of the funds may be withheld for contingency purposes; these funds are unofficially referred to as *taxes* or *withholds*.

The DoD budget is organized into separate budget titles that include approximately 75 appropriations. Each budget title is unique because resources are requested and applied for different purposes under different legal and regulatory constraints and for different time periods. Major DoD appropriations categories include:

- Research, Development, Test, and Evaluation (RDT&E);
- Procurement;
- Shipbuilding and Conversion, Navy (SCN);
- Operations and Maintenance (O&M);

- Military Personnel (MILPERS);
- Military Construction (MILCON); and
- Other related agencies

Each appropriation has a legal time limit, or "life" within which funds can be obligated, or legally reserved to make a future payment of money (e.g., one-, two-, or three-year) appropriations.

Four appropriations categories directly relevant to nuclear weapons funding are RDT&E, Procurement, O&M, and other related agencies:

- *RDT&E funds* support modernization through basic and applied research, fabrication of technology-demonstrated devices, and development and testing of prototypes and full-scale preproduction hardware. RDT&E work is performed by government laboratories and facilities, contractors, universities, and nonprofit organizations. RDT&E funds are considered two-year appropriations.
- *Procurement funds* support the acquisition of aircraft, ships, combat vehicles, and all capital equipment. The Procurement budget resources contribute to achieving DoD goals of maintaining readiness and sustainability, transforming the force for new missions, and reforming processes and organizations. Procurement funds are three-year appropriations; an exception is SCN, whose procurement funding life is extended to five years.
- *O&M funding* finances the cost of operating and maintaining the Armed Forces with the exception of military personnel pay, allowances, and travel costs. Included in the funding are amounts for training and operation costs, civilian pay, contract services to maintain equipment and facilities, fuel supplies, and repair parts. O&M funding is categorized as one-year appropriations.
- *DoD also supports several other national agencies* (such as NNSA) and includes their requirements in the President's Budget submission to Congress. The amount of funding for these efforts is negotiated with the other agencies and OMB (via the 050 account).

As discussed above, appropriations have life cycles during which they can incur new obligations. An appropriation whose period of availability for incurring new obligations has expired is not closed; instead it is in an "expired account." For five years after the time the appropriation expires, both the obligated and unobligated balances of that appropriation are available to make expenditures on existing obligations and adjustments to existing obligations. At the end of the five-year expiration period, the appropriation is closed and the funds can no longer be used. Figure 16.2 illustrates obligations and outlays periods.

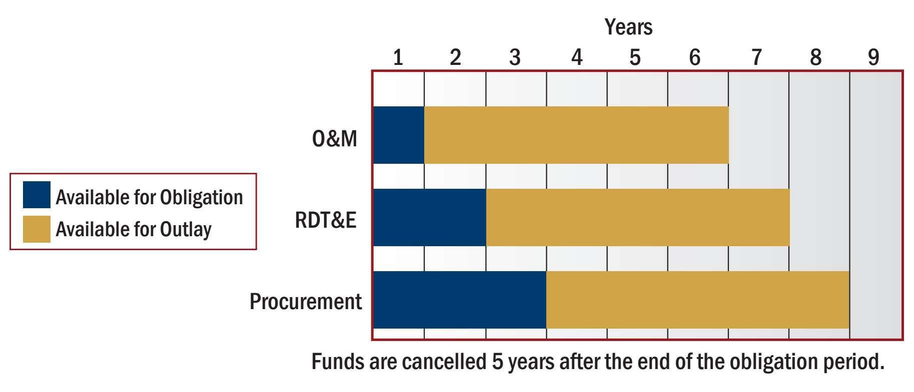


Figure 16.2 Obligation and Outlay Periods

NATIONAL NUCLEAR SECURITY ADMINISTRATION PPBE

NNSA is responsible for enhancing national security through the military application of nuclear science by maintaining and enhancing the safety, security, and effectiveness of the U.S. nuclear weapons stockpile without nuclear explosive testing; reducing the global danger from weapons of mass destruction; providing the U.S. Navy with safe and effective nuclear propulsion; and responding to nuclear and radiological emergencies in the United States and abroad. These programs are carried out at a nationwide complex of Government-Owned, Contractor-Operated (GOCO) laboratories, production plants, and testing sites, which employ about 2,000 federal employees and over 30,000 management and operating contractors.

The NNSA PPBE process is a continuous cycle for: establishing goals; developing, prioritizing, funding, and executing programs; and evaluating performance results to provide feedback for future planning. At NNSA, planning and programming are primarily a Headquarters function. Execution and evaluation of the programs are accomplished by the field elements (e.g., laboratories, production plants, and testing sites).

The *NNSA Enterprise Strategic Vision*, cascading from the *DOE Strategic Plan*, provides the framework for top to bottom linkages in PPBE activities. It also establishes the mission, vision, and issues, in addition to providing the goals, strategies, and strategic indicators for the five NNSA program elements. Each of the five program elements has a single goal in the Strategic Plan. These program elements are: Defense Programs; Defense Nuclear Nonproliferation; Naval Reactors; Infrastructure and Security; and Management and Administration. Multi-Year Plans are developed between Headquarters program managers and the field elements. The Program Plans are the primary documents used to make key programming decisions and to develop the NNSA budget. Strategic Guidance is provided annually to start the annual planning and programming processes.

Programming is a Headquarters-driven process to develop, prioritize, and integrate the five NNSA programs. The process begins with the Strategic Guidance, the current Future-Years Nuclear Security Program (FYNSP), and a Program and Fiscal Guidance Document. These enable the Headquarters elements to update baseline programs and projects as well as to explore and prioritize excursions from the baseline. Programming is conducted with fiscal awareness and concludes with a Program Decision Memorandum that records decisions for presentation to DOE and OMB. In the budgeting phase, planning and programming are brought into a fiscally constrained environment.

Budget execution and evaluation are carried out by the management and operating contractors at NNSA sites with oversight from federal program and site managers.

Nuclear weapons acquisition in the NNSA complex is part of a highly integrated workload for the science-based stewardship of the nuclear weapons stockpile. Planning and budget information for weapons system acquisition is contained in Selected Acquisition Reports that are included in all phases of the PPBE process and available to decision makers.

DOD ACQUISITION POLICY

PROCESS FLOW

Figure 16.3 depicts the high-level process flow for authoritative direction concerning the nuclear deterrent. Presidential guidance, as promulgated through national security documents such as Nuclear Posture Reviews, National Security Strategies, and National Defense Strategies, informs planning documents that DoD Combatant Commanders (CCDRs) use in the development of operational plans for U.S. nuclear forces. In turn, these planning documents include requirements for capabilities and forces. Established requirements create a demand for resources to ensure the required capabilities are available to support CCDRs. Resource requirements are consolidated and sent to the President for approval and submission into budget requests.

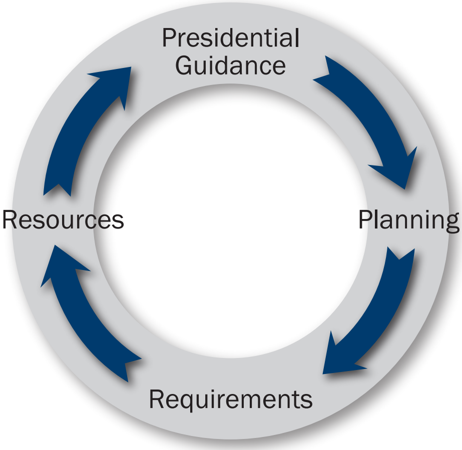


Figure 16.3 High-Level Process Flow

Nuclear policy and strategy guidance originate from presidential direction. Each president has his own naming convention for these direction documents; in the recent past, presidents have used the phrase National Security Directives (NSDs), Presidential Decision Directives (PDDs), National Security Presidential Directives (NSPDs), and Presidential Policy Directives (PPDs). Currently the phrase National Security Presidential Memorandum (NSPM) is used. While the names may differ, the intent is the same—to provide national-level guidance on U.S. national security issues such as those related to the nuclear deterrent.

After guidance is promulgated by the President, the Secretary of Defense reviews and refines departmental guidance to ensure consistency before issuing it to the Chairman of the Joint Chiefs of Staff (CJCS). These documents include the defense planning/programming guidance, nuclear-related DoD directives, and DoD instructions.

Based on detailed guidance and general planning by CCDRs, nuclear requirements are developed by the CCDRs, the Military Departments, and the Joint Staff.

The continuous cycle of guidance, planning, requirements, and resources rely on the current operational plans developed by U.S. Strategic Command (USSTRATCOM) as a basis for the requirements analysis process. If necessary, requirements are modified based on the most recent detailed guidance. If a required capability does not exist, the Military Departments begin the acquisition process to provide the capability. If the required capability is a delivery platform, the Military Departments use the Joint Capabilities Integration and Development System (JCIDS) process.

The Joint Capabilities Integration and Development System

JCIDS was established by the CJCS and the Joint Requirements Oversight Council (JROC) to identify, assess, and prioritize joint military capability needs. The JCIDS process is governed by CJCS Instruction 5123.01H, *Charter of the JROC and Implementation of the JCIDS*. Additional procedural guidance is provided in a related document, *Manual for the Operation of the JCIDS*. The scope includes major acquisitions or modifications, such as nuclear launch platforms (e.g., ballistic missile submarines) and delivery vehicles (e.g., long-range standoff (LRSO)). The Military Departments retain the responsibility for developing and acquiring the appropriate capability. JCIDS is an intra-DoD system of the Military Departments and agencies and not applicable to outside agencies, such as NNSA. The Vice Chairman of the Joint Chiefs of Staff (VCJCS) leads the JROC in the JCIDS process. JCIDS "closes the loop" between the CJCS, CCDRs, and Military Departments in the development of system requirements.

DoDD 5000.01, *The Defense Acquisition System*, and DoDI 5000.02, *Operation of the Defense Acquisition System*, govern the acquisition management process through which DoD provides effective, affordable, and timely systems to the users. Commonly referred to as "The 5000 Process," this system is managed by the Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)) as the primary process for transforming validated capability requirements into materiel capability solutions. Capability requirement documents created through the JCIDS provide the critical link between validated capability requirements and the acquisition of materiel capability solutions through the five major 5000 process phases: 1) materiel solution analysis; 2) technology maturation and risk reduction; 3) engineering and manufacturing development; 4) production and deployment; and 5) operations and support.

All phases inform further refinement of capability requirements for proposals to the appropriate validation authority, and the generation of additional or refined capability requirement documents that will reenter the JCIDS process for staffing and validation. Figure 16.4 highlights the key components comprising the JCIDS process.

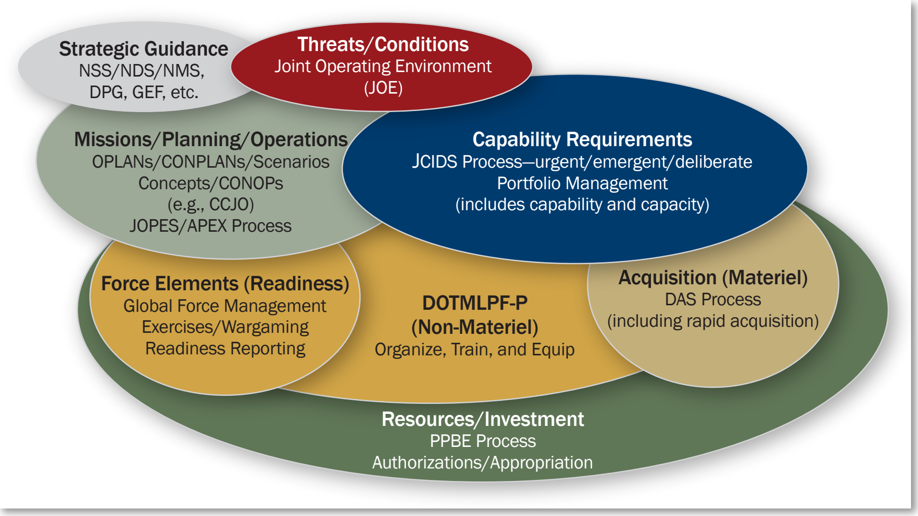
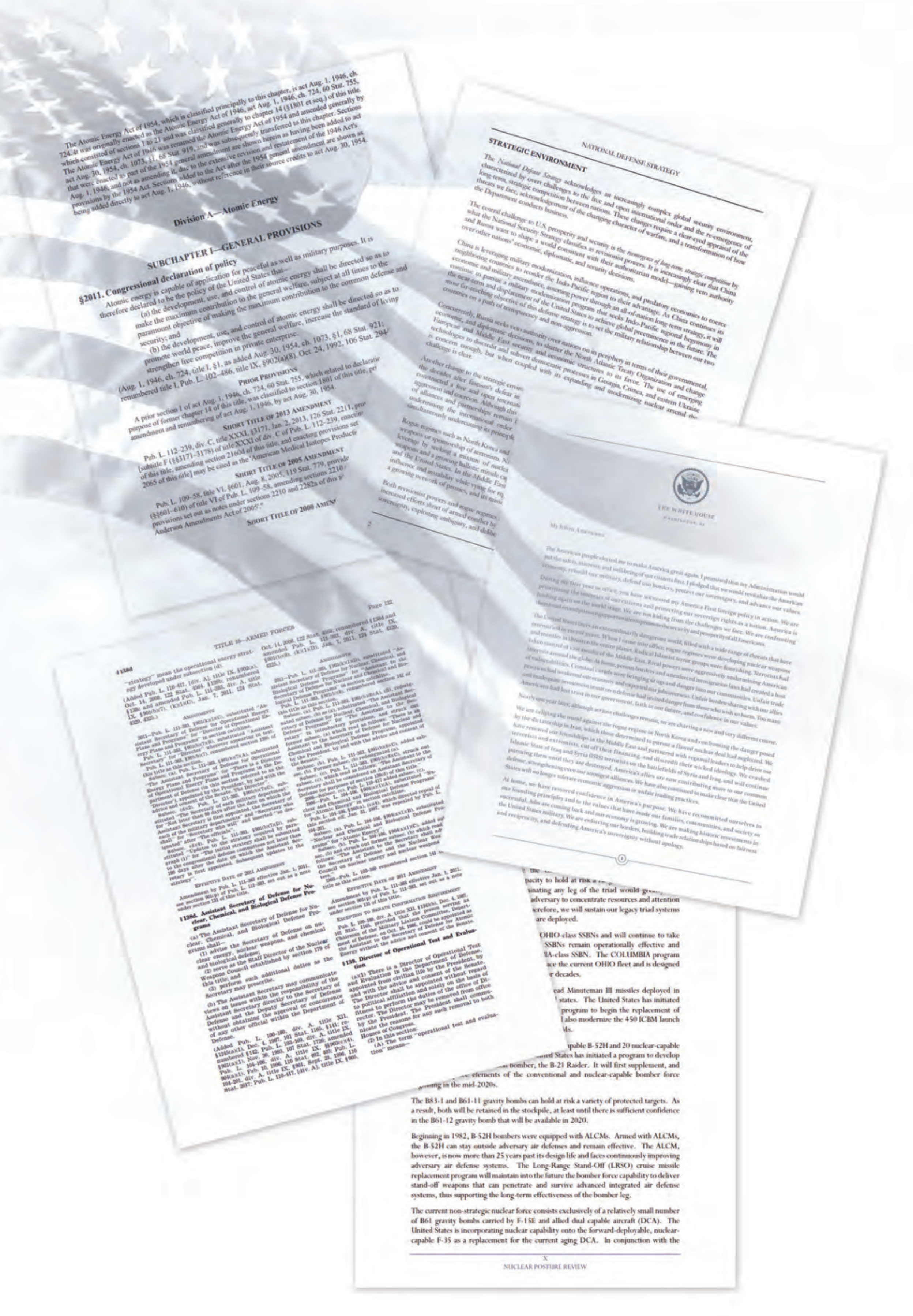


Figure 16.4 JCIDS Process
(Source: CJCSI 5123.01H, 31 August 2018)



The Atomic Energy Act of 1954, which is classified principally to this chapter, is act Aug. 1, 1946, ch. 724. It was originally enacted as the Atomic Energy Act of 1946, act Aug. 1, 1946, ch. 724, 60 Stat. 755, which consisted of sections 1 to 21 and was classified generally to chapter 14 (§1801 et seq.) of this title. The Atomic Energy Act of 1946 was renamed the Atomic Energy Act of 1954 and amended generally by act Aug. 30, 1954, ch. 1073, §1, 68 Stat. 919, and was subsequently transferred to this chapter. Sections that were enacted as part of the 1954 general amendment are shown herein as having been added to act Aug. 1, 1946, and not as amending it, due to the extensive revision and restatement of the 1946 Act's provisions by the 1954 Act. Sections added to the Act after the 1954 general amendment are shown as being added directly to act Aug. 1, 1946, without reference in their source credits to act Aug. 30, 1954.

Division A—Atomic Energy

SUBCHAPTER I—GENERAL PROVISIONS

§2011. Congressional declaration of policy

Atomic energy is capable of application for peaceful as well as military purposes. It is therefore declared to be the policy of the United States that—

(a) the development, use, and control of atomic energy shall be directed so as to make the maximum contribution to the general welfare, subject at all times to the paramount objective of making the maximum contribution to the common defense and security; and

(b) the development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living strengthen free competition in private enterprise.

(Aug. 1, 1946, ch. 724, title I, §1, as added Aug. 30, 1954, ch. 1073, §1, 68 Stat. 921; renumbered title I, Pub. L. 102–486, title IX, §902(a)(8), Oct. 24, 1992, 106 Stat. 294

PRIOR PROVISIONS

A prior section 1 of act Aug. 1, 1946, ch. 724, 60 Stat. 755, which related to declarati
purpose of former chapter 14 of this title, was classified to section 1801 of this title, pr
amendment and renumbering of act Aug. 1, 1946, by act Aug. 30, 1954.

SHORT TITLE OF 2013 AMENDMENT

Pub. L. 112–239, div. C, title XXXI, §3171, Jan. 2, 2013, 126 Stat. 2211, pro
[subtitle F (§§3171–3178) of title XXXI of div. C of Pub. L. 112–239, enactin
of this title, amending section 2160d of this title, and enacting provisions set
2065 of this title] may be cited as the 'American Medical Isotopes Productio

SHORT TITLE OF 2005 AMENDMENT

Pub. L. 109–58, title VI, §601, Aug. 8, 2005, 119 Stat. 779, provide
(§§601–610) of title VI of Pub. L. 109–58, amending sections 2210
provisions set out as notes under sections 2210 and 2282a of this ti
Anderson Amendments Act of 2005'."

SHORT TITLE OF 2000 AMEN

NATIONAL DEFENSE STRATEGY

STRATEGIC ENVIRONMENT

The *National Defense Strategy* acknowledges an increasingly complex global security environment, characterized by overt challenges to the free and open international order and the re-emergence of long-term, strategic competition between nations. These changes require a clear-eyed appraisal of the threats we face, acknowledgement of the changing character of warfare, and a transformation of how the Department conducts business.

The central challenge to U.S. prosperity and security is the *reemergence of long-term, strategic competition* by what the National Security Strategy classifies as revisionist powers. It is increasingly clear that China and Russia want to shape a world consistent with their authoritarian model—gaining veto authority over other nations' economic, diplomatic, and security decisions.

China is leveraging military modernization, influence operations, and predatory economics to coerce neighboring countries to reorder the Indo-Pacific region to their advantage. As China continues its economic and military ascendance, asserting power through an all-of-nation long-term strategy, it will continue to pursue a military modernization program that seeks Indo-Pacific regional hegemony in the near-term and displacement of the United States to achieve global preeminence in the future. The most far-reaching objective of this defense strategy is to set the military relationship between our two countries on a path of transparency and non-aggression.

Concurrently, Russia seeks veto authority over nations on its periphery in terms of their governmental, economic, and diplomatic decisions, to shatter the North Atlantic Treaty Organization and change European and Middle East security and economic structures to its favor. The use of emerging technologies to discredit and subvert democratic processes in Georgia, Crimea, and eastern Ukraine is concern enough, but when coupled with its expanding and modernizing nuclear arsenal the challenge is clear.

Another change to the strategic enviro
the decades after fascism's defeat in
constructed a free and open internati
aggression and coercion. Although this
of alliances and partnerships remain t
undermining the international order
simultaneously undercutting its princip

Rogue regimes such as North Korea and
weapons or sponsorship of terrorism. N
leverage by seeking a mixture of nuclea
weapons and a growing ballistic missile ca
and the United States. In the Middle East
influence and instability while vying for re
a growing network of proxies, and its mon

Both revisionist powers and rogue regimes
increased efforts short of armed conflict by
sovereignty, exploiting ambiguity, and delibe

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THE WHITE HOUSE
WASHINGTON, DC

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adversary to concentrate resources and attention
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are deployed.

OHIO-class SSBNs and will continue to take
SSBNs remain operationally effective and
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program to begin the replacement of
l also modernize the 450 ICBM launch
Ms.

pable B-52H and 20 nuclear-capable
ited States has initiated a program to develop
n bomber, the B-21 Raider. It will first supplement, and
elements of the conventional and nuclear-capable bomber force
ning in the mid-2020s.

The B83-1 and B61-11 gravity bombs can hold at risk a variety of protected targets. As a result, both will be retained in the stockpile, at least until there is sufficient confidence in the B61-12 gravity bomb that will be available in 2020.

Beginning in 1982, B-52H bombers were equipped with ALCMs. Armed with ALCMs, the B-52H can stay outside adversary air defenses and remain effective. The ALCM, however, is now more than 25 years past its design life and faces continuously improving adversary air defense systems. The Long-Range Stand-Off (LRSO) cruise missile replacement program will maintain into the future the bomber force capability to deliver stand-off weapons that can penetrate and survive advanced integrated air defense systems, thus supporting the long-term effectiveness of the bomber leg.

The current non-strategic nuclear force consists exclusively of a relatively small number of B61 gravity bombs carried by F-15E and allied dual capable aircraft (DCA). The United States is incorporating nuclear capability onto the forward-deployable, nuclear-capable F-35 as a replacement for the current aging DCA. In conjunction with the

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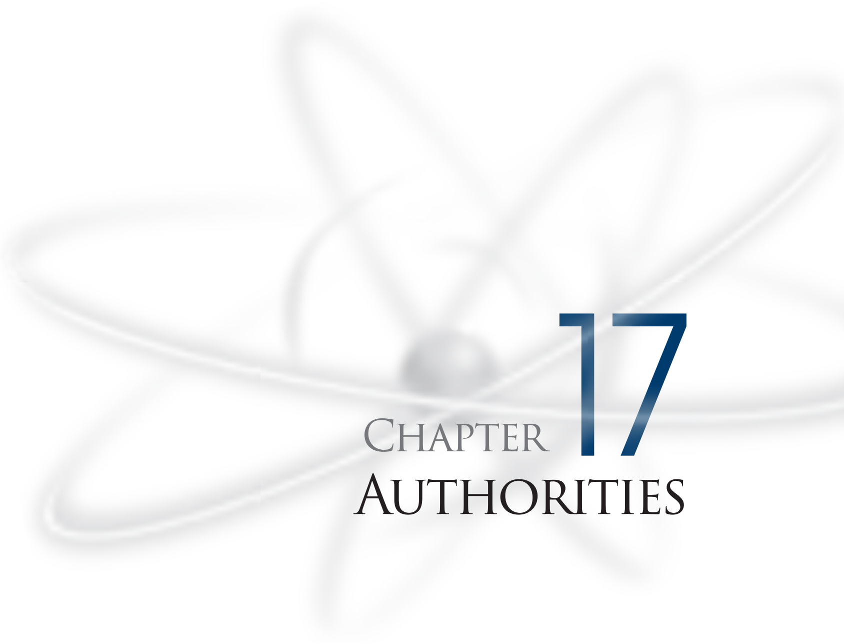
NUCLEAR POSTURE REVIEW



CHAPTER 17

AUTHORITIES

OVERVIEW

Leaders and personnel of organizations within the nuclear enterprise execute the authorities given to them through a variety of guidance documents and numerous processes. The most fundamental are the constitutionally granted authorities executed through Executive Branch and Legislative Branch processes. National-level and departmental-level processes provide the overarching direction to DoD and DOE, supplemented by guidance issued from DoD, Military Departments, DoD agencies, and DOE/NNSA via instructions, directives, military standards, memoranda, policy documents, orders, etc. The discussion on authorities in this chapter is not all-inclusive, but provides an overview of the essential authorities governing the nuclear enterprise.

NATIONAL GUIDANCE

The President executes authority through the Executive Branch by issuing Executive Orders (EOs), directives, memoranda, and letters. The guidance remains in effect throughout an administration and continues in the next administration unless modified, revoked, or superseded. Guidance documents are identified in Figure 17.1.

Document	Identifying Feature
Executive Order	Number
Directive	Number
Memorandum	Subject
Letter	Subject

Figure 17.1 Guidance Documents

For directives, administrations may use different naming conventions, for example:

- *Clinton Administration* – Presidential Decision Directive (PDD)
- *Bush Administration* – National Security Presidential Directive (NSPD) and Homeland Security Presidential Directive (HSPD)
- *Obama Administration* – Presidential Policy Directive (PPD)
- *Trump Administration* – National Security Presidential Memorandum (NSPM)

Usually early in a given administration, the functioning and relationship of the President's cabinet is articulated in the first presidential authoritative document. President Trump accomplished this with NSPM-4, Organization of the National Security Council, the Homeland Security Council, and subcommittees in April 2017. Administrations also seek to establish a National Security Strategy (NSS) from which the department heads and other leaders craft their respective department strategies with regard to national security.

Congress executes authority through laws and regulations. Laws remain in effect unless amended, revoked, superseded, or in some rare cases reach a designated expiration.

Treaties (including international agreements, protocols, covenants, conventions, pacts, or exchange of memoranda) establish authorities affecting the nuclear enterprise. The Executive Branch negotiates and signs a treaty. The Senate must ratify the treaty (and the treaty must enter into force) before it becomes legally binding on the United States. A treaty is an agreement under international law and is not U.S. domestic law.

DEPARTMENTAL GUIDANCE

Individual departments and agencies have a wide variance of processes through which the respective departmental leaders execute the authorities provided by the national level. The most influential document governing DoD today is the *2018 National Defense Strategy* which is used to establish the objectives for military planning regarding force structure, force modernization, business processes, supporting infrastructure, and required resources (funding and manpower). The Department of Energy uses DOE Orders (DOE O) to promulgate guidance.

AUTHORITATIVE DOCUMENTS

Throughout the 2020 *Nuclear Matters Handbook* authoritative documents that govern and shape the nuclear enterprise are referenced. Most of this governance comes in the way of issuances (directives, instructions, manuals), orders, strategies, plans, reports, requirements, memoranda of agreement/understanding, etc. Figure 17.2 lists and describes the governing documents referenced in this handbook.

Title	Type	Description
U.S. Nuclear Deterrent		
National Security Strategy	National	Outlines the administration policies for handling the major national security concerns of the United States. 2017 NSS is organized around four pillars—protect the homeland, protect American prosperity, preserve peace through strength, and advance American influence—guided by a return to principled realism.
National Defense Strategy	DoD	Translates the overarching themes from the NSS into broad military guidance for planning, strategy, force posture and modernization, and other Department-wide initiatives.
Nuclear Posture Review	DoD	Primary policy document of the U.S. nuclear enterprise. NPR describes the security environment, the roles and types of nuclear weapons the U.S. should field, and technical requirements to support the nuclear deterrent.
Nuclear Command, Control, and Communications		
JP 6-0, Joint Communications System	DoD	Keystone document for communications system support to joint operations, providing guidelines to commanders regarding information systems and networks. Includes a section on the Nuclear Command and Control System.
Nuclear Weapons Stockpile		
Nuclear Weapons Stockpile Plan	DoD-DOE, signed by POTUS	Identifies long-term planning considerations affecting the nuclear weapons stockpile.
Requirements Planning Document	NWC	Long-term planning document, covering 25 years of stockpile management. Aligns weapon system modernization plans with delivery systems and platform schedules, and outlines investments for renovating nuclear security enterprise infrastructure.
Nuclear Weapon Deployment Authorization	DoD, signed by POTUS	Yearly presidential directive officially authorizing the Secretary of Defense to deploy nuclear weapons in accordance with policy and programming decisions.
FY1994 National Defense Authorization Act (NDAA)	Law	Prohibits any allocation of funding for explosive nuclear testing, codifying the end of testing in law.
Stockpile Stewardship and Management Plan	NNSA	Describes NNSA plans to ensure the safety, security, and effectiveness of the U.S. nuclear stockpile and to maintain the scientific and engineering tools, capabilities, and infrastructure that underpin the nuclear security enterprise.

Title	Type	Description
FY2017 NDAA	Law	Reorganizes the former USD(AT&L); this increased the number of voting members of the NWC from five to six, as the USD(A&S) inherited the chair and the Under Secretary for Research and Engineering became a voting member.
1946 Atomic Energy Act	Law	Foundational legislation of the U.S. nuclear enterprise creating the Atomic Energy Commission, the predecessor of DOE, in order to put U.S. nuclear weapons research and development outside the immediate control of the military. Established several national laboratories, research into nuclear power and peaceful uses of nuclear weapons, and governed the classification of nuclear weapons information.
1953 Agreement Between the Atomic Energy Commission and the DoD for the Development, Production, and Standardization of Atomic Weapons	Agreement	Follow-on agreement to the Atomic Energy Act that specified and divided basic departmental responsibilities between the AEC and DoD.
1983 Memorandum of Understanding, DoD-DOE	Departmental MOU	Reaffirms the obligation of DoD and DOE to protect public health and safety; provides the basic premise for dual-agency judgment and responsibility for safety, security, and control of nuclear weapons.
Title 10 USC, §179, Nuclear Weapons Council	Law	Establishes the NWC, and defines its membership, responsibilities, budgeting, and staffing.
1988 Memorandum of Understanding, DoD-DOE	Departmental MOU	Provides the details on the establishment and implementation of the NWC.
Operational Plans, Requirements Documents	DoD	Combatant Command, Military, and other DoD plans and documents establishing and setting forth nuclear operations and requirements.
Nuclear Weapons Stockpile Memorandum	NWC, signed by SecDef and SECENG	Joint memorandum signed by the Secretaries of Defense and Energy. Includes a proposed five-year table of stockpile quantities as well as specific policies, military requirements, joint DoD-NNSA planning factors.
CJCSI 5123.01H, *Joint Capabilities Integration and Development System (JCIDS)*	DoD	Assesses joint military capabilities and identifies gaps in those capabilities to fill. Nuclear weapons are not governed by JCIDS, but capability requirements for related systems (delivery platforms, command and control, etc.) are.
DoDD 5000.01, *The Defense Acquisition System*	DoD	Governs the management process by which DoD provides effective, affordable, and timely aquisition to users. Commonly referred to as “The 5000 Process,” this system is managed by the USD(A&S) as the primary process for transforming validated capability requirements into materiel capability solutions.

Title	Type	Description
DoDI 5000.02, *Operation of the Defense Acquisition System*	DoD	Outlines the procedures to navigate the 5000 Process. Capability requirement documents created through the JCIDS provide the critical link between validated capability requirements and the acquisition of materiel capability solutions through the five major 5000 Process phases: 1) Materiel Solution Analysis; 2) Technology Maturation and Risk Reduction; 3) Engineering and Manufacturing Development; 4) Production and Deployment; and 5) Operations and Support.
DoDM 5030.55, *DoD Procedures for Joint DoD-DOE Nuclear Weapons Life-Cycle Activities*	DoD	Implements DoD acquisition processes and procedures as they apply to joint DoD-NNSA nuclear weapon development, production, sustainment, and retirement activities (including studies) and as it applies to refurbishment guidelines issued by the NWC.
Procedural Guidelines for the Phase 6.X Process	DoD	NWC procedures related to the maintenance and sustainment of the existing weapons in the legacy stockpile and oversight of the stockpile sustainment activities in the absence of nuclear explosive testing.
FY2013 NDAA (Pub. L. 112-239)	Law	Requires NWC to submit reports to Congressional defense committees before proceeding beyond phase 6.2 activities with respect to any lifetime extension program to include an assessment of the lifetime extension options considered for the phase 6.2 activities and an assessment of the option selected for the phase 6.2 activities.
Nuclear Weapons Council		
FY1985 NDAA (Pub. L. 98-525)	Law	Directs the President to establish a Blue Ribbon Task Group to examine nuclear stockpile funding and governance issues between DoD and DOE. Eventually resulted in the creation of the Nuclear Weapons Council.
1985 POTUS Blue Ribbon Task Group	National	Establishes by President Reagan as directed by the FY1985 NDAA; recommended creation of a high-level, joint DoD-DOE group (the NWC) to coordinate nuclear weapons program activities.
FY1987 NDAA (Pub. L. 99-661)	Law	Establishes the NWC, as recommended by the 1985 Blue Ribbon Task Group.
FY2013 NDAA (Pub. L. 112-239)	Law	Amends the NWC responsibilities to include an annual certification to Congress of the sufficiency of the NNSA budget to meet nuclear stockpile and stockpile stewardship program requirements of the current and next four fiscal years.
NWSM/RPD, SSMP Assessment, ROSA, JSR, NWC Budget Certification Letter, Plutonium Pit Production Certification	NWC reports	NWC annual reporting requirements: Nuclear Weapons Stockpile Memorandum (NWSM) and Requirements and Planning Document (RPD); the NWC Report on Stockpile Assessments (ROSA); the NWC Joint Surety Report (JSR); the NWC Budget Certification Letter; and, new as of 2019, the NWC Certification of the NNSA Pit Production Strategy.

Title	Type	Description
NDERG Charter	DoD	Creates a group consisting of DoD leaders responsible for training, funding, and implementing the nuclear mission to establish senior leader accountability and bring together all the elements of the DoD nuclear force into a coherent enterprise.
Nuclear Weapons Surety and Nuclear Survivability		
2011 DoD-DOE Nuclear Physical Security Collaboration Memorandum	DoD-DOE	Commits DoD and DOE to develop common standards for the physical security of nuclear weapons and special nuclear material (SNM). Pledges to develop and use a common threat assessment, the Nuclear Security Threat Capabilities Assessment (NSTCA), and methodology to identify and assess threat capabilities and determine nuclear weapons security vulnerabilities. NSTCA is developed, reviewed annually, and updated as necessary to support the preparation of unit or facility vulnerability assessments.
PPD-35, *U.S. Nuclear Weapons Command and Control, Safety, and Security*	National	Classified specifics: establishes policy guidance on nuclear weapons command and control, safety, and security.
DoDD 3150.02, *DoD Nuclear Weapons Surety Program*	DoD	Updates established policy and assigns responsibilities for DoD nuclear weapons surety for the oversight of safety, security, and control of U.S. nuclear weapons and nuclear weapon systems in DoD custody. Assigns responsibility for the nuclear weapons technical inspection (NWTI) system.
DOE O 452.1E, *Nuclear Explosive and Weapon Surety Program*	DOE	Outlines the Nuclear Explosive and Weapon Surety (NEWS) Program and the five DOE surety standards.
DoDD 5210.41, *Security Policy for Protecting Nuclear Weapons*	DoD	Outlines DoD security policy for protecting nuclear weapons in peacetime environments. Provides guidance to commanders to provide security for and to ensure the survivability of nuclear weapons. Also authorizes the publication of DoD S-5210.41-M, the DoD manual providing security criteria and standards for protecting nuclear weapons.
DoDI 5210.42, *Nuclear Weapons Personnel Reliability Assurance*	DoD	Outlines DoD policy and assigns responsibilities for the management of DoD Nuclear Weapons PRP/PRAP and Air Force Arming and Use of Force Program. Authorizes the publication of DoD Manual 5210.42 that prescribes mandatory procedures for DoD Nuclear Weapons PRP/PRAP to ensure the safety and security of the U.S. nuclear deterrent mission.
DoDM 5210.42, *Nuclear Weapons Personnel Reliability Program*	DoD	Implements the policy in DoD Instruction 5210.42 (see above), assigns responsibilities, and prescribes mandatory procedures for DoD Nuclear Weapons Personnel Reliability Program (PRP) to ensure the safety and security of the U.S. nuclear deterrent mission.

Title	Type	Description
DoDI O-5210.63, *DoD Procedures for Security of Nuclear Reactors and Special Nuclear Materials*	DoD	Directs policy, responsibilities, procedures, and minimum standards for safeguarding DoD nuclear reactors and special nuclear materials.
DoD S-5210.92-M, *Physical Security Requirements*	DoD	Implements policy governing physical security requirements of U.S. NC2 facilities and systems that have the capability to make and transmit a nuclear control order.
DoDI 3224.03, *Physical Security Equipment (PSE) Research, Development, Test, and Evaluation (RDT&E)*	DoD	Provides guidance for the acquisition of all physical security equipment. It assigns responsibility for physical security equipment research, engineering, procurement, installation, and maintenance.
DOE O 452.2E, *Nuclear Explosive Safety*	DOE	Addresses security regarding the safety of NNSA nuclear explosive operations.
DOE Policy 470.1A, *Safeguards and Security Program*	DOE	Outlines the DOE Safeguards and Security Program, which provides the basis for security for all NNSA activities related to nuclear weapons.
10 CFR Part 712, *Human Reliability Program (HRP)*	DOE	Establishes the policies and procedures for implementation of the HRP within DOE, including NNSA. Consolidates and supersedes two former programs, the Personnel Assurance Program and the Personnel Security Assurance Program.
DOE O 470.3B, *Graded Security Protection (GSP) Policy*	DOE	Establishes the design basis threat which nuclear weapons facilities must protect against.
DOE O 472.2 Chg 2, *Personnel Security*	DOE	Establishes requirements that enable DOE to operate a successful, efficient, cost-effective personnel security program to ensure accurate, timely, and equitable determinations of individuals' eligibility for access to classified information and SNM, including nuclear weapons.
DOE O 474.2 Admin Chg 3, *Nuclear Material Control and Accountability*	DOE	Establishes performance objectives, metrics, and requirements for developing, implementing, and maintaining a nuclear material control and accountability program, including nuclear weapons, within NNSA.
DOE O 473.3, *Protection Program Operations*	DOE	Establishes requirements for the management and operation of DOE Federal Protective Forces (FPF), Contractor Protective Forces (CPF), and the physical security of property and personnel under the cognizance of DOE, including those which protect nuclear weapons.
DoDM 3150.08, *Nuclear Weapon Accident Response Procedures*	DoD	Implements policy, assigns responsibilities, and provides comprehensive procedures under which DoD will respond to an accident involving a nuclear weapon.
DoDI-S 3150.07, *Controlling the Use of Nuclear Weapons*	DoD	Establishes policy, assigns responsibilities, and prescribes procedures for controlling the use of nuclear weapons and nuclear weapon systems ensuring only authorized use.

Title	Type	Description
DoDI 3150.09, *The Chemical, Biological, Radiological, and Nuclear (CBRN) Survivability Policy*	DoD	Establishes policy, assigns responsibilities, and establishes procedures for the execution of DoD CBRN Survivability Policy (including electromagnetic pulse (EMP)), and specifies the mission-critical systems that must survive and operate in chemical, biological, and radiological environments, nuclear environments, or combined CBRN environments.
DoDD S-5210.81, *United States Nuclear Weapons Command and Control, Safety, and Security*	DoD	Provides general policy and assignment of responsibilities governing U.S. nuclear weapons command and control (C2), safety, and security within DoD.
DTRA Guide to Nuclear Weapons Effects	DoD	Includes comprehensive descriptions of all available facilities in the United States for nuclear survivability testing.
MIL-STD-1766, *Nuclear Hardness and Survivability Program Requirements for ICBM Weapon Systems*	DoD	Defines nuclear hardness and survivability requirements, procedures, and practices for use during the concept exploration and definition, demonstration and validation, engineering and manufacturing, production and deployment, and operations and support phases of the acquisition life cycle of ICBM weapon systems.
MIL-STD-2169C, *HEMP Environmental Standard*	DoD	Defines high-altitude EMP environments for system hardness design and testing.
MIL-STD-3023, *HEMP Protection for Military Aircraft*	DoD	Establishes design margin, performance metrics, and test protocols for HEMP protection of military aircraft with nuclear EMP survivability at three hardness levels. MIL-STD may also be used for aircraft that support multiple missions. Subsystems of the aircraft required to fully comply with the provisions of the standard are designated as Mission-Critical Subsystems having a HEMP survivability requirement. Allows for consideration of platforms not yet addressed in this standard, such as Unmanned Aerial Vehicles.
MIL-STD-188-125, *HEMP Protection for Fixed and Transportable Ground-Based C4I Facilities Performing Critical, Time Urgent Missions*	DoD	Establishes requirements and design objectives for high-altitude electromagnetic pulse (HEMP) hardening of both fixed and transportable systems.
MIL-STD-4023, *HEMP Protection for Military Surface Ships*	DoD	Establishes performance metrics, test protocols, and hardness margin levels for HEMP protection of military surface ships that must function when subjected to a HEMP environment.
Satellite System Nuclear Survivability (SSNS) Environmental Standard	DoD	Defines nuclear weapon environment levels for evaluating satellite system performance in nuclear scenarios.

Title	Type	Description
Comprehensive Atmospheric Nuclear Environments Standard (CANES)	DoD	Provides detailed nuclear environments and effects for a number of different nuclear weapon-types as a function of height of burst. A supplement to this MIL-STD covers nuclear-disturbed communication environments and nuclear ground burst environments.
Nuclear Threat Reduction		
470th UN Plenary, statute for IAEA	International Agreement	The IAEA governing document lays out the objectives and functions that the agency is authorized to pursue research on, and assistance to nations in developing, peaceful uses of nuclear energy, and providing safeguards to prevent the proliferation of nuclear weapons.
Nunn-Lugar Act	Law	1991 legislation created Cooperative Threat Reduction program, for the purpose of securing and dismantling weapons of mass destruction and associated infrastructure in the former states of the Soviet Union. Expanded to non-Soviet countries in Africa and South Asia.
International Nuclear Cooperation		
EOs 10841 and 10956	National	1959 and 1961 executive orders that delegate authority for international transfers of nuclear information from the President to the Secretary of Defense and the Chairman of the Atomic Energy Commission (later Secretary of Energy).
U.S.-UK Mutual Defense Agreement	Agreements	Authorized regular exchanges of information and expertise on nuclear weapons; signed in 1958.
NATO	Agreements	Guarantees mutual defense among members; NATO Nuclear Planning Group provides a forum for NATO member nations to exchange information on nuclear forces and planning, to review the Alliance nuclear policy and adapt it as necessary, and in which member countries can participate in the development of the Alliance nuclear policy and in decisions on NATO nuclear posture, regardless of whether or not they maintain nuclear weapons.
P3	Agreements	Trilateral agreements between the three Western nuclear powers (U.S., UK, and France).
Nuclear Treaties and Agreements		
Treaties	Law	Bilateral, multilateral, and international law that affects the U.S. nuclear deterrent—forces and stockpile.
Classification		
EO 13526, *Classified Nuclear Security Information*	National	Prescribes a uniform system for classifying, safeguarding, and declassifying National Security Information.
10 CFR 1045, *Nuclear Classification and Declassification*	Law	Vehicle by which DOE implements the Atomic Energy Act requirements for classification and declassification of nuclear information.

Title	Type	Description
Atomic Energy Act, Sec. 142	Law	Section of the AEA that categorizes all data concerning the design, manufacture, or utilization of nuclear weapons; production of SNM; or use of SNM in the production of energy as Restricted Data (RD). Also provides for the removal of information from RD, which then categorizes it as Formerly Restricted Data (FRD) (which is still a category of classified nuclear weapons information).
DoDI 5210.02, *Access to and Dissemination of Restricted Data and Formerly Restricted Data*	DoD	States DoD policy governing access to and dissemination of RD and FRD. Categorizes RD information into Confidential RD, Secret RD, and Top Secret RD. CNWDI is a DoD access control caveat for Top Secret RD or Secret RD revealing the theory of operation or design of components of a thermonuclear or implosion-type fission bomb, warhead, demolition munition, or test device.
DOE O 452.7, *Protection of Use Control Vulnerabilities and Designs*	DOE	Establishes the policy, process, and procedures for control of sensitive use control information in Nuclear Weapon Data categories Sigma 14 (concerning the vulnerability of nuclear weapons to a deliberate unauthorized nuclear detonation or to the denial of authorized use) and Sigma 15 (concerning the design and function of nuclear weapon use control systems, features, and components) to ensure the dissemination of the information is restricted to individuals with valid need-to-know.
DOE O 452.8, *Control of Nuclear Weapon Data*	DOE	Sustains Sigma 14 and 15 and establishes Sigma 18 (information that allows or significantly facilitates a proliferant nation or entity to fabricate a credible nuclear weapon or nuclear explosive based on a proven, certified, or endorsed U.S. nuclear weapon or device).
DOE O 457.1A, *Nuclear Counter Terrorism*	DOE	Provides the basis for implementing procedures regulating strict control of and access to Sigma 20 (pertains to "crude, simple, or innovative" improvised nuclear device designs, concepts, and related manufacturing or processing pathways).
DoDM 5200.01-V1, *DoD Information Security Program*	DoD	Describes two types of classification authority: original and derivative. A classifier is any person who makes a classification determination and applies a classification category to information or material. The determination may be an original classification action or derivative classification action.
DoDM 5200.2-R, *Procedures for the DoD Personnel Security Program (PSP)*	DoD	Defines the eligibility standards for access to classified information.
DoDM 5200.01-V2, *DoD Information Security Program: Marking of Classified Information*	DoD	Stipulates marking requirements for classified documents.

Title	Type	Description
NATO – Administrative Arrangements to Implement the Agreement Between Parties to the North Atlantic Treaty for Cooperation Regarding ATOMAL Information	Agreement	Governs the conversion of cleared U.S. classified nuclear material to NATO ATOMAL. These materials, although marked as ATOMAL, have not been assigned a NATO Registry control number and, therefore, are not considered NATO materials and can still be disseminated between DoD components via SIPRNET in the same manner as FRD materials. Once the material is formally handed over to a NATO Registry and assigned a NATO control number, it becomes a controlled NATO ATOMAL document.
Freedom of Information Act	Law	Federal law that requires the full or partial disclosure of previously unreleased information and documents controlled by the United States government upon request. Classified information and Official Use Only documents may be exempt from FOIA release.
DoDI 5210.83, *DoD Unclassified Controlled Nuclear Information*	DoD	States DoD Unclassified Controlled Nuclear Information (UCNI) policy.
Title 42 USC §128	Law	Law governing the designation of DoD information as UCNI.
Title 42 USC §2168	Law	Law governing the designation of DOE information as UCNI.

Figure 17.2 Governing Documents

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
LITTERA SCRIPTA MANET
1985

Federal Register

Tuesday,
January 5, 2010

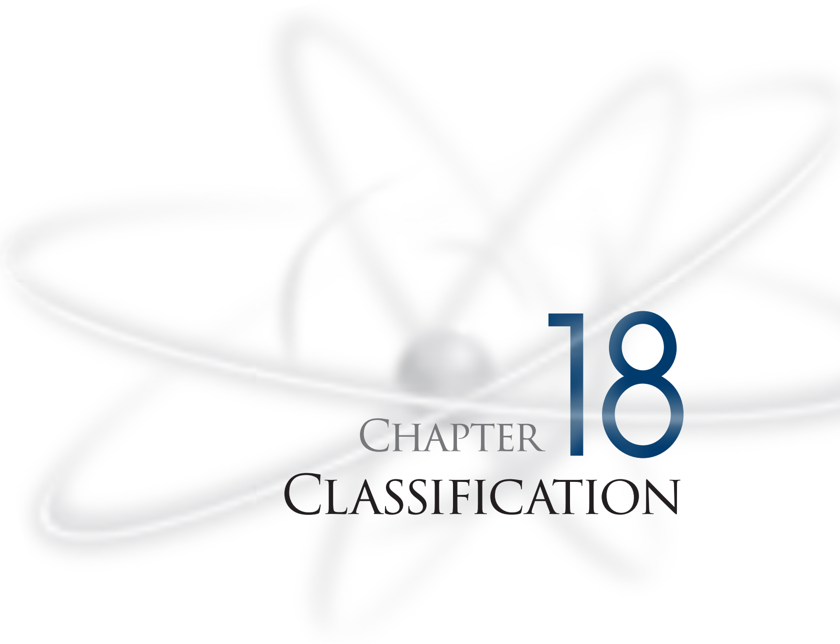
Part VII

The President

Executive Order 13526—Classified National Security Information

Memorandum of December 29, 2009—Implementation of the Executive Order "Classified National Security Information"

Order of December 29, 2009—Original Classification Authority



CHAPTER 18

CLASSIFICATION

OVERVIEW

Throughout history, U.S. national defense has required that certain information be maintained in confidence to safeguard U.S. citizens, democratic institutions, homeland security, and interactions with foreign nations. Today, preserving critical U.S. national security information remains a top priority.

The U.S. government has created a classification system for safeguarding information which includes marking and granting clearances and access to obtain or view documents containing classified information. This chapter provides a classification reference for general issues related to nuclear matters. It includes a discussion of information classification, classification authorities, security clearances, access to classified information, marking classified documents, For Official Use Only (FOUO)/Official Use Only (OUO), and Unclassified Controlled Nuclear Information (UCNI).

INFORMATION CLASSIFICATION

The two categories of classified information are national security information (NSI) and atomic energy (nuclear) information.

NATIONAL SECURITY INFORMATION

Executive Order (EO) 13526, *Classified National Security Information*, prescribes the system for classifying, safeguarding, and declassifying NSI. EO 13526 states national security information may be classified at one of the following three levels:

- *Top Secret (TS)* shall be applied to information, the unauthorized disclosure of which could reasonably be expected to cause exceptionally grave damage to the national security that the original classification authority is able to identify or describe.
- *Secret (S)* shall be applied to information, the unauthorized disclosure of which could reasonably be expected to cause serious damage to the national security that the original classification authority is able to identify or describe.
- *Confidential (C)* shall be applied to information, the unauthorized disclosure of which could reasonably be expected to cause damage to the national security that the original classification authority is able to identify or describe.

NUCLEAR INFORMATION

Nuclear information is protected by the *Atomic Energy Act (AEA) of 1954*, as amended, and is a caveat added to the classification level of specific types of information. Information can be classifed as Secret, Restricted Data (S//RD) or TS//RD. The Department of Energy (DOE) implements the AEA requirements for classification and declassification of nuclear information via 10 CFR 1045, *Nuclear Classification and Declassification*. The AEA classifies nuclear information as RD, which is not subject to EO 13526. DOE controls the classification and declassification of all Restricted Data.

RD comprises all data related to: the design, manufacture, or use of nuclear weapons; production of special nuclear material (SNM); or use of SNM in the production of energy. RD does not include data removed from the Restricted Data category, i.e., data that is designated Formerly Restricted Data (FRD) or Transclassified Foreign Nuclear Information (TFNI).

FRD is still a category of classified information related to nuclear weapons. It does not mean it is formerly classified and therefore is now unclassified. FRD is jointly determined by DoD and DOE to relate primarily to the military use of nuclear weapons, and is safeguarded as defense information (e.g., weapon yield, deployment locations, weapons safety and storage, and stockpile quantities). Information characterized as FRD is not subject to EO 13526. FRD is stored, transmitted, and destroyed in the same ways as RD of the same classification level. FRD declassification requires a joint determination by DoD and DOE.

TFNI is information—from any intelligence source—that concerns the nuclear programs of foreign governments that was removed from the RD category (by transclassification) under section 142 of the *Atomic Energy Act*, by past joint agreements between DOE and the Director of Central Intelligence, or past and future agreements with the Director of National Intelligence. When removed from the RD category, TFNI information is stored, transmitted, and destroyed in the same ways as NSI of the same classification level.

DoD and DOE have separate systems for controlling nuclear information, as follows.

DoD System for Controlling Nuclear Information

DoD policy governing access to and dissemination of RD is provided in DoD Instruction 5210.02, *Access to and Dissemination of Restricted Data and Formerly Restricted Data*. DoD categorizes RD information as Confidential RD, S//RD, or TS//RD. Critical Nuclear Weapon Design Information (CNWDI) is a DoD access control caveat for a specific subset of Restricted Data. CNWDI information is S//RD or TS//RD; it reveals the theory of operation or design of components of a thermonuclear or implosion-type fission bomb, warhead, demolition munition, or test device. Finally, DoD recognizes DOE designations of Sigma 14, Sigma 15, Sigma 18, and Sigma 20 as additional subsets of Restricted Data.

DOE System for Controlling Nuclear Information

DOE policy of categorizing Restricted Data into defined subject areas is known as the Sigma system. The Secret and Top Secret Nuclear Weapon Data (NWD) subsets of RD regard nuclear weapons, components, or explosive devices or materials that have been determined to require additional protection. The current categories of NWD are Sigma 14, Sigma 15, Sigma 18, and Sigma 20; previous Sigma categories 1-13 are no longer in use. DOE controls access to all Sigma categories on a strict need-to-know basis, and DoD personnel requiring access to Sigma information must obtain DOE approval.

DOE Order 452.7, *Protection of Use Control Vulnerabilities and Designs*, establishes the policy, process, and procedures for control of sensitive use control information in NWD categories Sigma 14 and Sigma 15 to ensure the dissemination of the information is restricted to individuals with a valid need-to-know.

- *Sigma 14* – Category of sensitive information, including bypass scenarios, concerning the vulnerability of nuclear weapons to a deliberate, unauthorized nuclear detonation or to the denial of authorized use.
- *Sigma 15* – Category of sensitive information concerning the design and function of nuclear weapon use control systems, features, and components. This includes use control for passive and active systems and may include security verification features or weapon design features not specifically part of a use control system.

DOE Order 452.8, *Control of Nuclear Weapon Data*, sustains Sigma 14 and 15 and establishes Sigma 18.

- *Sigma 18* – Category of NWD including information that allows or significantly facilitates a nation or entity to fabricate a credible nuclear weapon or nuclear explosive device based on a proven, certified, or endorsed U.S. nuclear weapon or device. This information would enable the establishment or improvement of nuclear capability without nuclear testing or with minimal research and development. DOE determines the information placed in the Sigma 18 category, which includes: complete design of a gun-assembled weapon; complete design of a primary or single stage implosion-assembled weapon; complete design of a secondary stage; weapon design codes with one-dimensional hydrodynamics and radiation transport with fission and/or thermonuclear burn; and weapon design codes with two- and three-dimensional capabilities.

DOE Order 457.1A, *Nuclear Counterterrorism*, provides the basis for implementing procedures regulating strict control of and access to Sigma 20 information.

- *Sigma 20* – Specific category of NWD that pertains to "crude, simple, or innovative" improvised nuclear device (IND) designs, concepts, and related manufacturing or processing pathways. Not all INDs fall within the Sigma 20 category.

FOREIGN NUCLEAR INFORMATION

Foreign nuclear information is information on foreign government nuclear programs. It includes the design, manufacture, or use of nuclear weapons; the production of SNM; or the use of SNM in the production of energy. This information is treated as RD.

Considerations for the removal of foreign nuclear information from the RD category include there being no automatic declassification of the information; DOE determination that it can be removed from RD; and the use of appropriate classification markings on the remainder of the information. At a minimum, access to the information will be the same as NSI, and it will be safeguarded based upon the classification determination. Foreign nuclear information which has been removed from RD is categorized as TFNI.

SHARING INFORMATION WITH THE UNITED KINGDOM

DoD and DOE have joint guidelines for complying with each Department's requirements for export controls and classified information exchange for stockpile weapon activities related to the 1958 U.S.-UK Mutual Defense

Agreement (MDA), under the authorities of the AEA. Using Joint Atomic Information Exchange Group (JAIEG)-approved processes, DoD and DOE management may disclose to the United Kingdom transmissible RD, FRD, and unclassified information, which includes Controlled Unclassified Information (CUI) internal to the nuclear weapon. This disclosure may be made without a license or authorization under the International Traffic in Arms Regulations (ITAR) and without prior coordination with the relevant U.S. Military Department. RD and FRD information external to the nuclear weapon may be disclosed using JAIEG-approved processes. However, the disclosure of NSI external to the nuclear weapon, which includes classified military information, shall not be made without approval of the respective Military Department.

Questions on these processes should be referred to the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs (ASD(NCB)) and the DOE National Nuclear Security Administration (NNSA) Deputy Administrator for Defense Programs. See *Chapter 10: International Programs* for more information.

CLASSIFYING DOCUMENTS

To properly classify a document, an individual must have classification authority. DoD Manual 5200.01-V1, *DoD Information Security Program*, describes two types of classification authority: original and derivative. A classifier is any person who makes a classification determination and applies a classification category to information or material. The determination may be an original classification action or derivative classification action. Proper classification enables appropriate protection of information. Persons handling information must abide by the classification markings and also not assume an unmarked document or source does not contain classified or sensitive information. The Internet, in particular, can be a source of unmarked classified information or a combination of unclassified information that is classified in aggregate.

ORIGINAL CLASSIFICATION AUTHORITY

The authority to originally classify information may only be exercised by the President and the Vice President; agency heads and officials designated by the President; and U.S. Government officials delegated the authority pursuant to EO 13526. For NSI, the original classification authority (OCA) also serves as the declassification authority and sets the date for automatic declassification. Within DoD and DOE, only appointed government officials can serve as OCAs to classify NSI. Further, only DOE officials have OCA for RD information. The Deputy Assistant Secretary of Defense for Nuclear Matters (DASD(NM)) is the OCA for FRD.

DERIVATIVE CLASSIFICATION AUTHORITY

According to EO 13526, those individuals who reproduce, extract, or summarize classified information, or who apply classification markings derived from source material or as directed by a classification guide, need not possess original classification authority. Individuals who apply derivative classification markings are required to observe and respect original classification decisions and carry forward the pertinent classification markings to any newly created documents. Individuals within both DoD and DOE can use derivative classification authority on NSI, RD, and FRD information.

SECURITY CLEARANCES

Both DoD and DOE issue personnel security clearances governing the access of their employees and contractors to classified information.

DOD SECURITY CLEARANCE LEVELS

DoD defines a security clearance as an administrative determination by a competent authority that a person is eligible under the standards of DoD 5200.2-R, *Personnel Security Program*, for access to classified information. DoD clearances may be issued at the Top Secret, Secret, or Confidential level. These levels allow the individual holding the clearance, and possessing the proper need-to-know, to view information classified at those levels.[1]

DOE SECURITY CLEARANCE LEVELS

Adhering to the information restrictions and guidelines of the AEA, DOE established a security clearance system that is implemented through DOE Order 472.2, *Personnel Security*, and described in DOE Order 452.8:

- *L Access Authorization* is given to an individual whose duties require access to Confidential RD, Confidential/Secret FRD, or Confidential/Secret NSI.
- *Q Access Authorization* is given to an individual whose duties require access to Secret/Top Secret RD, Top Secret FRD, Top Secret NSI, or any category or level of classified matter designated as communications security, cryptographic, or sensitive compartmented information.

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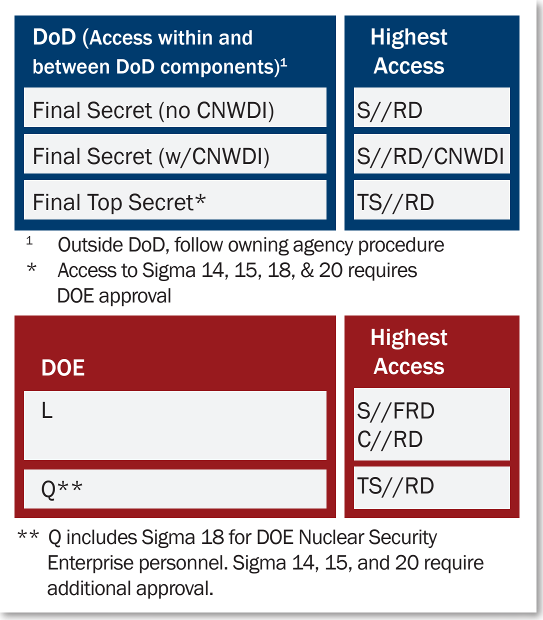
[1] "Need-to-know" is defined in DoD 5200.2-R as a determination made by a possessor of classified information that a prospective recipient, in the interest of national security, has a requirement for access to, knowledge of, or possession of classified information in order to perform tasks or services essential to the fulfillment of an official U.S. government program. Knowledge of, possession of, or access to classified information shall not be afforded to any individual solely by virtue of the individual's office, position, or security clearance.

EQUATING THE TWO CLASSIFICATION SYSTEMS

While it is not possible to directly correlate the two security clearance systems used by DoD and DOE, Figure 18.1 illustrates the clearances and highest level of access for the two Departments.



DoD (Access within and between DoD components)[1]	**Highest Access**
Final Secret (no CNWDI)	S//RD
Final Secret (w/CNWDI)	S//RD/CNWDI
Final Top Secret*	TS//RD

[1] Outside DoD, follow owning agency procedure

* Access to Sigma 14, 15, 18, & 20 requires DOE approval

DOE	**Highest Access**
L	S//FRD C//RD
Q**	TS//RD

** Q includes Sigma 18 for DOE Nuclear Security Enterprise personnel. Sigma 14, 15, and 20 require additional approval.

Figure 18.1 DoD and DOE Clearance Levels and Access

ACCESSING CLASSIFIED INFORMATION

The two basic requirements to access classified information are appropriate clearance and need-to-know, and both must be present for an individual to view classified information. Need-to-know is confirmed by the agency controlling the information and helps govern access to information. Security administrators verify an individual's eligibility for a certain clearance level and then grant need-to-know caveats, as needed. An individual may have access authorization of C, S, TS, or TS/SCI (special compartmented information) clearance in DoD; an individual may have L or Q access authorization in DOE. Each of these clearance levels also has an interim status, which allows the cleared person to view but not create or control documents at that level. However, an interim Secret clearance does not allow access to RD, NATO, or COMSEC (communications security) information at the Secret level. An interim TS is valid for access to TS information and Secret and Confidential levels of RD, NATO, and COMSEC information. An interim TS clearance is the equivalent of a final Secret clearance. Once given a final clearance, an individual is able to access and control documents for that level of classification. Most caveats are granted after individuals review a briefing explaining the nature of the material and sign forms. After completing this process, individuals have the appropriate clearance to access the information. The process is commonly referred to as being "read-in" for a caveat.

To be given access to Top Secret, special compartmented, or Q-level information, a individual must have a favorable Tier 5 investigation (Critical-sensitive access). Access to Confidential, Secret, or L-level information requires at Tier 3 investigation (Non-critical sensitive access).[2]

In both instances, only DoD, DOE, the Nuclear Regulatory Commission, and the National Aeronautics and Space Administration have the authority to grant RD and FRD access. To access CNWDI information, individuals require authorization and a briefing.

MARKING CLASSIFIED DOCUMENTS

All classified documents require classification markings, with some differences between originally classified and derivatively classified documents.

ORIGINALLY CLASSIFIED DOCUMENTS

EO 13526 requires certain essential markings on originally classified documents. DoD Manual 5200.01-V2 stipulates the marking requirements for classified documents, which include: portion marks, banner line, "classified by" line, reason for classification, and "declassify on" line.

Portions can be paragraphs, charts, tables, pictures, illustrations, subjects, and titles. Before each portion, a marking indicating the classification of that portion is placed in parentheses: (U) for Unclassified, (C) for Confidential, (S) for Secret, and (TS) for Top Secret. Additional control markings are included, as appropriate. Each portion has its own classification marking; its classification is not affected by any of the information or markings of other portions within the same document.

The banner line must specify the highest level of classification of the document and include the most restrictive control marking applicable. The classification is centered in both the header and footer of the document. It is typed in all capital letters and in a font size large enough to be readily visible to the reader. This marking is noted on the front cover, the title page, the first page, and the outside of the back cover. Internal pages may be marked with the overall document classification or the highest classification level of the information contained on that page.

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[2] In 2012, the Office of the Director of National Intelligence (ODNI) and the Office of Personnel Management (OPM) began collaborating on development of new standards in order to provide quality control and consistency among investigations and in October 2016, OPM established the Tier access eligibility investigation system. Tier 5 investigation replaced the single scope background investigation (SSBI) and Tier 3 replaced the national agency check with National Agency Check with Law and Credit (NACLC) investigation.

In the lower left-hand corner of the title page, the original classification authority is identified. The OCA must be identified by name, or personal identifier, and position. If the agency of the original classifier is not readily apparent, it must be placed below the "classified by" line.

The "reason for classification" designation is placed immediately below the "classified by" line. This line should contain a brief reference to the classification category or classification guidance. The number 1.4 may appear with corresponding letters, representing Section 1.4 of EO 13526 and the classification categories it defines. The information being classified must relate to one or more of the following:

- military plans, weapons systems, or operations;
- foreign government information;
- intelligence activities (including covert action), intelligence sources or methods, or cryptology;
- foreign relations or foreign activities of the United States, including confidential sources;
- scientific, technological, or economic matters relating to national security;
- U.S. government programs for safeguarding nuclear materials or facilities;
- vulnerabilities or capabilities of systems, installations, infrastructures, projects, plans, or protection services relating to national security; and
- the development, production, or use of weapons of mass destruction.

The final essential marking is the "declassify on" line. All documents must have a declassification date or event entered onto the "declassify on" line. The OCA determines the "declassify on" date using one of the three following guidelines:

- When possible, identify the date or event for declassification that corresponds to the lapse of the information's national security sensitivity. The date or event shall not exceed 10 years from the date of the original classification.
- When a specific date or event cannot be determined, identify the date that is 10 years from the date of the original classification.
- If the sensitivity of the information warrants protection beyond 10 years, then the original classification authority may assign a declassification date up to, but no more than, 25 years from the date of original classification.

For dates 25 years and beyond, refer to DoD Manual 5200.01-V2 for guidance.[3]

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[3] RD and FRD have no automatic declassification timeline. RD can only be declassified by DOE; FRD can only be declassified by a joint DoD-DOE decision.

DERIVATIVELY CLASSIFIED DOCUMENTS

Derivative classification is the act of incorporating, paraphrasing, restating, or generating in a new form information already classified and marking the newly developed material consistent with the markings of the source information. The source information ordinarily consists of a classified document or a classification guide issued by an OCA. It is important to note that DoD can only derivatively classify documents containing RD; DOE retains original classification authority for all RD material.

Single or Multiple Source Documents

When using a classified source document as the basis for derivative classification, the markings on the source document determine the markings applied to the derivative document. As with documents created by original classifiers, each derivative document must have portion markings and overall classification markings.

Derivatively classified documents are handled in much the same manner as originally classified documents, with two differences. In a document derived from a single source, portion markings, overall markings, and, "declassify on" lines all remain the same as the original document. In a document derived from multiple sources, it is necessary to determine which source document requires the longest period of classification before marking the document with the "declassify on" line. Once that has been determined, the derivative document should reflect the longest period of classification in the source documents.

In a derivatively classified document, the "classified by" line identifies the name and position of the individual classifying the document, followed by the derivative classifier's agency and office of origin. In addition, a derivatively classified document includes a "derived from" line. In a document derived from a single source, a brief description of the source document is used to determine the classification of the material.

Documents where classifications are derived from multiple sources are created in the same manner as documents derived from a single classified source. Enter "multiple sources" on the "derived from" line. On a separate sheet of paper, a list of all classification sources must be maintained and included as an attachment to the document. When classifying a document from a source document marked "multiple sources," do not mark the derived document with "multiple sources." Instead, in the "derived from" line, identify the source document. In both cases, the "reason" line, as reflected in a source document or classification guide, is not required to be transferred to a derivatively classified document.

Derivative Classification Using a Classification Guide

A classification guide is a document issued by an OCA that provides classification instructions. A classification guide describes the elements of information that must be protected and the level, reason, and duration of classification. When using a classification guide to determine classification, insert the name of the classification guide on the "derived from" line. Portion markings are determined by the level of classification of the information as listed in the classification guide and the overall marking is determined by the highest level of the portion markings contained within the document. Finally, the "declassified on" line is determined by the classification duration instruction in the guide.

MARKING RESTRICTED DATA, FORMERLY RESTRICTED DATA, AND CNWDI DOCUMENTS

There is a special requirement for marking RD, FRD, and CNWDI documents. The front page of documents containing RD must include the following statement:

RESTRICTED DATA

This document contains Restricted Data, as defined in the Atomic Energy Act of 1954. Unauthorized disclosure is subject to administrative and criminal sanctions.

This may appear on the first page of the document and on a second cover page, placed immediately after the initial classified cover sheet.

FRD material must contain the following statement on the front page of the document:

FORMERLY RESTRICTED DATA

Unauthorized disclosure is subject to administrative and criminal sanctions. Handle as Restricted Data in foreign dissemination, per section 144b, Atomic Energy Act of 1954.

Additionally, documents containing RD and FRD should have abbreviated markings included with the classification portion marking (e.g., S//RD or S//FRD). Documents containing RD and CNWDI material must also contain the following statement, in addition to the RD statement on the front page of the document:

CNWDI

Critical Nuclear Weapon Design Information. DoD Instruction 5210.02 applies.

In addition, CNWDI is marked with an "N" in separate parentheses following the portion marking (e.g., (S//RD)(N)).

Finally, when a document contains RD, FRD, and CNWDI, only the RD and CNWDI warning notices are affixed. No declassification instructions are used.

ATOMAL

ATOMAL is a NATO term used to identify and protect Restricted Data or Formerly Restricted Data provided to NATO by the U.S. government. Because materials marked RD or FRD are not cleared for release to NATO or NATO countries, organizations wanting to transmit RD or FRD materials to NATO must clear the materials through the JAIEG. RD or FRD materials cleared by the JAEIG for release will be assigned a JAEIG reference number (JRN). If the document is modified after a JRN has been assigned, it will require an additional JAEIG review.

The originating organization, or JAEIG in limited situations, will convert the U.S. classification markings to NATO ATOMAL as required by the *Administrative Arrangements to Implement the Agreement Between the Parties to the North Atlantic Treaty for Co-operation Regarding ATOMAL Information*. These materials, although marked as ATOMAL, have not been assigned a NATO registry control number and are therefore not considered NATO materials; they can still be disseminated between DoD components via secure email (SIPRNET) in the same manner as FRD materials. Once the document is formally handed over to a NATO registry and assigned a NATO control number, it becomes a controlled NATO ATOMAL document.

FOR OFFICIAL USE ONLY AND UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION

FOUO and OUO are terms used by DoD and DOE, respectively, that can be applied to certain unclassified information. FOUO and OUO designations indicate information with the potential to damage governmental, commercial, or private interests if disseminated to persons who do not need to know the information to perform their jobs or other agency-authorized activities. This information may be exempt from mandatory release under one of nine applicable Freedom of Information Act (FOIA) exemptions:

1. Records that are properly and currently classified in the interest of national defense or foreign policy.
2. Records related solely to the internal personnel rules and practices of the DoD or any DoD Component.
3. Information specifically exempted by a statute establishing particular criteria for withholding. The language of the statute must clearly state the information will not be disclosed.
4. Information, such as trade secrets and commercial or financial information, obtained from a company on a privileged or confidential basis that, if released, would result in competitive harm to the company, impair the government's ability to obtain similar information in the future, or protect the government's interest in compliance with program effectiveness.
5. Interagency memoranda that are deliberative in nature. This exemption is appropriate for internal documents part of the decision-making process and contain subjective evaluations, opinions, and recommendations.
6. Information, the release of which could reasonably be expected to constitute a clearly unwarranted invasion of the personal privacy of individuals.
7. Records or information compiled for law enforcement purposes that could reasonably be expected to interfere with law enforcement proceedings; would deprive an individual of a right to a fair trial or impartial adjudication; could reasonably be expected to constitute an unwarranted invasion of the personal privacy of others; disclose the identity of a confidential source; disclose investigative techniques and procedures; or could reasonably be expected to endanger the life or physical safety of any individual.
8. Certain records of agencies responsible for supervision of financial institutions.
9. Geological and geophysical information concerning wells.

DoD and DOE also use the term Unclassified Controlled Nuclear Information. DoD defines UCNI as unclassified information pertaining to security measures, including plans, procedures, and equipment, for the physical protection of DoD SNM, weapons, equipment, or facilities. While this information is not formally classified, it is restricted in its distribution. DoD UCNI policy is provided in DoD Instruction 5210.83, *DoD Unclassified Controlled Nuclear Information*. DOE uses the term UCNI in a broader manner than DoD. Designating DoD information as UCNI is governed by Title 10 USC §128, whereas designating DOE information as UCNI is governed by Title 42 USC §2168.

NUCLEAR

adjective

nu·cle·ar | \ nü-klē-ar

Definition of Nuclear

1 : of, relating to, or constituting a nucleus
// annexation of the suburban fringe by the nuclear metropolis
— W. H. Wickwar

2 a : of or relating to the atomic nucleus
// nuclear reaction
// nuclear physics

b : used in or produced by a nuclear reaction (such as fission)
// nuclear fuel
// nuclear waste
// nuclear energy

c (1) : being a weapon whose destructive power derives from an uncontrolled nuclear reaction

(2) : of, produced by, or involving nuclear weapons
// the nuclear age
// nuclear war

(3) : armed with nuclear weapons
// nuclear powers

d : of, relating to, or powered by nuclear energy
// a nuclear submarine
// the nuclear debate
// a nuclear plant

First known use of nuclear: 1822, in the meaning defined at sense 1

History and etymology for nuclear: NUCLE(US) + -AR

"Nuclear." The Merriam-Webster.com Dictionary, Merriam-Webster Inc.

GLOSSARY

abnormal environment

Environments in a weapon's stockpile-to-target sequence in which the weapon is not expected to retain full operational reliability. [Chapters 7, 8, 14]

active hedge

Warheads retained for deployment to manage technological risks in the Active Ready (AR) stockpile or to augment the AR. [Chapter 4]

active logistics

Warheads used to facilitate workflow and sustain the operational status of Active Ready (AR) or Active Hedge quantities. [Chapter 4]

active ready

Warheads which are operational and designated available for wartime employment planning. [Chapter 4]

active stockpile

Warheads maintained in an operational status. [Chapter 4]

air blast

A dense wall of air caused by the rapid expansion of the fireball following a nuclear detonation initially traveling at several times the speed of sound. [Chapters 9, 13]

alteration (Alt)

Material change to, or a prescribed inspection of, a nuclear weapon or major assembly that does not alter its operational capability but is sufficiently important to the user (regarding assembly, maintenance, storage, or test operations) as to require controlled application and identification. [Chapters 4, 7]

atom

Smallest (or ultimate) particle of an element that still retains the characteristics of that element. Every atom consists of a positively charged central nucleus, which carries nearly all the mass of the atom, surrounded by a number of negatively charged electrons, so that the whole system is electrically neutral. [Chapters 13, 15]

atomic bomb

Term sometimes applied to a nuclear weapon utilizing fission energy only. First term used for a nuclear weapon. [Chapters 1, 3, 11, 13, 14, 15]

atomic mass

Number of protons plus neutrons in the nucleus of an atom. [Chapters 11, 13]

atomic number

Number of protons in the nucleus of an atom. [Chapter 11]

attribution

The confluence of intelligence, investigative, and forensics information to arrive at the nature, source, perpetrator, and pathway of an attempted or actual nuclear or radiological attack. [Chapter 11]

authorization

Legislation that establishes, changes, or continues a federal program or agency. Authorizing legislation is normally a prerequisite for appropriations. [Chapters 1, 2, 4, 6, 7, 8, 10, 17, 18]

ballistic missile

Any missile that does not rely upon aerodynamic surfaces to produce lift and consequently follows a ballistic trajectory when thrust is terminated. [Chapters 1, 2, 4, 8, 9, 12, 15, 16]

blackout

Interference with radio and radar waves from an ionized region of the atmosphere following a nuclear detonation in the atmosphere. [Chapter 13]

blast wave

Sharply defined wave of increased pressure rapidly propagated through a surrounding medium from a center of detonation or similar disturbance. [Chapters 9, 13, 14]

cascade

Series of enrichment stages, with each stage consisting of an apparatus designed to enrich uranium by isotope separation. [Chapter 15]

channel

Joint arrangement between the United States and a foreign government for the exchange of specific project or program-type information. [Chapters 6, 10, 13, 16]

component

Assembly or any combination of parts, subassemblies, and assemblies mounted together in manufacture, assembly, maintenance, or rebuild. [Chapters 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 17, 18]

counterproliferation

Efforts to prevent or interdict the illicit transfer of materials, devices, or information. [Chapters 10, 11, 12]

criticality

Term used in reactor physics to describe the state when the number of neutrons released by fission is exactly balanced by the neutrons being absorbed (by the fuel and poisons) and escaping the reactor core. A reactor is said to be "critical" when it achieves a self-sustaining nuclear chain reaction, as when the reactor is operating. [Chapters 4, 13, 15]

critical mass

Minimum amount of fissionable material capable of supporting a chain reaction under precisely specified conditions. [Chapter 13]

cruise missile

Guided missile that travels at an approximately constant velocity for most of its flight and relies on the dynamic reaction of air for lift and on propulsion forces to balance drag. [Chapters 3, 4, 12]

decision conferencing

A means for senior leaders to provide advice to the President regarding nuclear weapon employment. [Chapter 2]

Defense Acquisition System

Management process that guides all DoD acquisition programs. DoD Directive 5000.1, The Defense Acquisition System, provides the policies and principles that govern the defense acquisition system. DoD Instruction 5000.2, Operation of the Defense Acquisition System, establishes the management framework that implements these policies and principles. [Chapters 16, 17]

Defense Planning Guidance

Document issued by the Secretary of Defense that provides firm guidance in the form of goals, priorities, and objectives, including fiscal constraints, for the development of the Program Objective Memorandums by the Military Branches and defense agencies. [Chapters 9, 16]

delivery platform

Any structure or system on which a weapon can be mounted/loaded (e.g., B-2A). [Chapters 4, 16]

delivery system

Term used to include the delivery platform (e.g., SSBN), the delivery vehicle (e.g., Trident D5 LE Missile). [Chapters 1, 2, 3, 4, 6, 7, 8, 9, 16, 17]

delivery vehicle

A portion of the delivery system which provides the means of delivery of a nuclear warhead or bomb (e.g., ALCM). [Chapters 3, 4, 7, 9, 12, 15]

depleted uranium

Quantiy of uranium having a smaller percentage of U-235 than found in natural uranium, i.e., less than 0.72 percent of the total uranium. [Chapters 5, 15]

deuterium

Isotope of hydrogen with one proton and one neutron in the nucleus of each atom. [Chapters 13, 15]

disassembly

Process of taking apart a nuclear warhead and removing one or more subassemblies, components, or individual parts. Disassembly may be required to support quality assurance inspection, reliability testing, or subassembly/component exchange as a part of scheduled maintenance or refurbishment; it is normally done in a manner that permits re-assembly with either the original or replacement subassemblies/components. [Chapters 4, 5, 8]

dismantlement

Process of taking apart a nuclear warhead and removing all subassemblies, components, and individual parts for the purpose of physical elimination of the nuclear warhead. Dismantled subassemblies, components, and parts, including nuclear materials, may be put into a disposal process, may be used again in another warhead, or may be held in strategic reserve. [Chapters 4, 5, 7, 8]

dynamic pressure

Air pressure that results from the mass air flow (or wind) behind the shock front of a blast wave. [Chapter 9, 13]

effects survivability

Ability to withstand, survive, or mitigate the primary (blast, thermal, and prompt radiation) and secondary (delayed radiation, fire, etc.) effects of nuclear weapons on personnel, equipment, and systems. [Chapter 9]

effects testing

Subjecting objects to environments meant to replicate given nuclear effects to measure the response of the object to the energy output of a nuclear weapon. [Chapters 9, 14]

electromagnetic pulse

Electromagnetic radiation from a strong electronic pulse, most commonly caused by a nuclear explosion that may couple with electrical or electronic systems to produce damaging current and voltage surges. [Chapters 2, 9, 12, 13, 14, 17]

electromagnetic radiation

Radiation including visible light, radio waves, gamma rays, and X-rays where electric and magnetic fields vary simultaneously. [Chapters 9, 11, 12, 13, 15]

electron

Particle of very small mass with a negative charge. [Chapters 9, 13]

element

Any of the more than 100 known substances (of which 92 occur naturally) that cannot be separated into simpler substances and that by themselves or in combination constitute all matter. [Chapters 5, 13, 15]

enacted appropriations

Appropriations bills in which a definite amount of money is set aside to pay incurred or anticipated expenditures. [Chapter 16]

enhanced nuclear detonation safety

System of safety features engineered into modern nuclear weapons resulting in a one-in-a-billion chance of a weapon detonating in a normal environment and a one-in-a-million chance of a weapon detonating in an abnormal environment when it is not supposed to detonate. [Chapters 8, 14]

enriched uranium

Quantity of uranium having a larger percentage of U-235 than found in natural uranium, i.e., greater than 0.72 percent of the total uranium. [Chapters 5, 15]

enrichment stage

A single unit apparatus designed to enrich uranium by isotope separation. [Chapter 15]

fallout

Precipitation to Earth of radioactive particulate matter from a nuclear cloud; also applied to the particulate matter itself. [Chapter 2, 9, 12, 13]

fire-resistant pit

Primary in a thermonuclear weapon in which the fissile material is encased in a metal shell with a high melting point and is designed to withstand exposure to jet fuel fire of 1,200 degrees Celsius for several hours. Fire-resistant pits are only used in weapons with insensitive high explosive. [Chapters 8, 14]

fireball

Luminous sphere of hot gases that forms a few millionths of a second after detonation of a nuclear weapon or nuclear device and immediately starts expanding and cooling. [Chapters 13, 14]

fissile

Capable of being split by slow (low-energy) neutrons as well as by fast (high-energy) neutrons. [Chapters 4, 5, 11, 13, 14, 15]

fissile component fabrication

Forming of processed material into a size and shape desirable for a given design. [Chapter 15]

fissile material

Material consisting primarily of atoms of fissile isotopes, i.e., those atoms of certain heavy elements that have a high probability of undergoing immediate fission of the nucleus by absorbing neutrons of any energy level. Examples of fissile material are U-235, U-233, and Pu-239. [Chapters 11, 13, 14, 15]

fission

Process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy. [Chapters 5, 8, 11, 13, 14, 15, 17, 18]

fissionable material

Material consisting primarily of isotopes whose atoms can undergo fission, but only have a high probability of fission when interacting with neutrons of some energy levels. [Chapters 11, 13]

flag-level

Term applied to an officer holding the rank of general, lieutenant general, major general, or brigadier general in the U.S. Army, Air Force, or Marine Corps or admiral, vice admiral, or rear admiral in the U.S. Navy or Coast Guard. Also may be used for a government official in the senior executive level (SES) grades. [Chapter 6]

flash blindness

The impairment of vision resulting from an intense flash of light. It includes temporary or permanent loss of visual functions and may be associated with retinal burns. [Chapter 13]

force execution/battle damage assessment

Entails measuring the physical and functional effects of target engagement, assessing the extent of collateral damage, and examining the overall impact on adversary military activities. [Chapter 2]

force planning

Combines target development and weaponeering analysis with available forces marking a shift from analysis to operational planning. [Chapter 2]

forward deployment

Presidentially approved warheads positioned in theater, such as those in support of NATO. [Chapter 4]

fusion

The process whereby the nuclei of light elements, especially the isotopes of hydrogen (deuterium and tritium), combine to form the nucleus of a heavier element and release a substantial amount of energy and a high-energy neutron. [Chapters 5, 8, 9, 13, 14, 15]

gamma rays

Electromagnetic radiation of high photon energy originating in atomic nuclei and accompanying many nuclear reactions (e.g., fission, radioactivity, and neutron capture). [Chapters 9, 11, 13]

gun assembly weapon

Device in which two or more pieces of fissionable material, each less than a critical mass, are brought together very rapidly so as to form a supercritical mass that can explode as the result of a rapidly expanding fission chain. [Chapters 11, 13, 15]

half-life

Time required for the activity of a given radioactive species to decrease to half of its initial value due to radioactive decay. [Chapters 13, 15]

hardening

Employment of any design or manufacturing technique that increases the ability of an item to survive the effects of a nuclear environment, including personnel, facilities, and/or equipment. [Chapters 9, 13, 17]

heavy-water reactor

A reactor which uses natural uranium and specially produced 'heavy' water (processed to remove salt and other minerals as well as the ^1H protium atoms from the water molecules which are replaced with ^2H deuterium atoms) to moderate neutrons. [Chapter 15]

height of burst

Vertical angle between the base of a target and the point of burst. [Chapters 2, 9, 13, 17]

igloo

Unofficial but common term to mean a munitions storage bunker, usually protected by several feet (or more) of earth on all sides except for the door, which is normally constructed from large amounts of thick heavy metal. [Chapter 4]

ignition

In theory, the conditions required to heat and compress a fuel of deuterium and tritium to pressures and temperatures that will ignite and burn the fuel to produce an energy gain. [Chapters 5, 9, 13, 14]

implosion weapon

Device in which a quantity of fissile material, less than a critical mass, has its volume suddenly decreased by compression, so that it becomes supercritical and an explosion can take place. [Chapters 13, 15]

improvised nuclear device

Crude nuclear device built from the components of a stolen or bought nuclear weapon or built from scratch using nuclear material (plutonium or HEU). [Chapters 11, 17, 18]

inactive hedge

Warheads retained for deployment to manage technological risks in the Active Ready (AR) stockpile or augment the AR stockpile. [Chapter 4]

inactive logistics

Warheads used for logistical and surveillance purposes. [Chapter 4]

inactive reserve

Warheads retained to provide long-term response for risk mitigation of technical failings in the stockpile. [Chapter 4]

inactive stockpile

Warheads maintained in a nonoperational status and do not contain limited life components (LLC). [Chapter 4]

induced radiation

Radiation produced as a result of exposure to radioactive materials, particularly the capture of neutrons. [Chapters 9, 13]

initial nuclear radiation

Radiation resulting from a nuclear detonation and emitted from the fireball within one minute after burst. Also called prompt nuclear radiation. [Chapters 9, 13]

insensitive high explosive

Type of explosives used in the primary of some modern thermonuclear weapons that are remarkably insensitive to shock, high temperatures, and impact when compared to conventional high explosives. [Chapters 8, 14]

ion

Atom that has gained or lost an electron and thus carries an electrical charge. [Chapter 9]

ionizing radiation

Electromagnetic radiation (gamma rays or X-rays) or particulate radiation (alpha particles, beta particles, neutrons, etc.) capable of producing ions directly or indirectly in its passage through, or interaction with, matter. [Chapters 9, 13, 15]

isotopes

Atoms of the same element that have identical atomic numbers (same number of protons) but a different atomic mass (different numbers of neutrons). [Chapters 5, 11, 13, 15]

life cycle

Total phases through which a nuclear weapon passes from the time it is initially developed until the time it is either consumed in use or retired, dismantled, or disposed of. [Chapters 4, 5, 6, 7, 8, 9, 17]

life extension program (LEP)

Life extension activities addressing aging and performance issues within the stockpile as a result of use beyond the originally designed component/system life span. [Chapters 3, 4]

light-water reactor

A reactor which uses low-enriched uranium as a fuel and natural water to moderate neutrons. [Chapter 15]

limited-life component

Weapon component that degrades with age and must be replaced periodically. [Chapters 4, 7, 15]

low-enriched uranium

Quantity of uranium enriched to any level above natural uranium (greater than 0.72 percent U-235), but less than 20 percent. [Chapters 5, 11, 12, 15]

major assembly

Term for a complete nuclear warhead, usually used in the process of approving or revalidating the design. [Chapter 7]

markup

Process by which congressional committees and subcommittees debate, amend, and rewrite proposed legislation. [Chapter 16]

material security

Measures and policies aimed at preventing loss or theft of materials of concern. [Chapter 11]

military characteristics

Required characteristics of a nuclear weapon upon which depend its ability to perform desired military functions, including physical and operational characteristics but not technical design characteristics. [Chapters 5, 6, 7, 8]

modification (Mod)

Change in operational capability that results from a design change that affects delivery (employment or utilization), fuzing, ballistics, or logistics. [Chapters 4, 5, 6, 7, 9, 14, 16]

munition

Complete device charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological, or chemical material for use in military operations, including demolitions. Also called ammunition. [Chapters 3, 4, 15, 17, 18]

mutual defense agreement (MDA)

Allows for classified information exchange between the two government signatories for the purposes of promoting mutual defense and security. [Chapter 10]

National Defense Authorization Act (NDAA)

Legislation voted on by Congress for each fiscal year to determine and permit the budget for DoD and national security programs maintained by DOE. [Chapters 1, 4, 6, 16, 17]

national security

Collective term encompassing both national defense and foreign relations of the United States. Specifically, the condition provided by: a) a military or defense advantage over any foreign nation or group of nations; b) a favorable foreign relations position; or c) a defense posture capable of successfully resisting hostile or destructive action from within or without, overt or covert. [Chapters 1, 4, 5, 6, 7, 8, 10, 12, 13, 14, 16, 17, 18]

near-surface burst

Detonation in the air that is low enough for the immediate fireball to touch the ground. [Chapter 13]

neutron

Neutral particle (i.e., with no electrical charge) of approximately unit mass, present in all atomic nuclei, except those of ordinary (light) hydrogen. [Chapters 4, 5, 9, 11, 12, 13, 15]

New Material and Stockpile Evaluation (NMSE) program

Assess the safety, security, performance, and reliability of the current condition of active and inactive stockpile. [Chapter 4]

nonproliferation

Actions (e.g., diplomacy, arms control, multilateral agreements, threat reduction assistance, and export controls) taken to prevent the proliferation of weapons of mass destruction by dissuading or impeding access to, or distribution of, sensitive technologies, material, and expertise. [Chapters 4, 5, 10, 11, 12, 16]

normal environment

Expected logistical and operational environments as defined in a weapon's stockpile-to-target sequence and military characteristics in which the weapon is required to survive without degradation in operational reliability or safety performance. [Chapters 8, 14]

nuclear command and control (NC2)

Exercise of authority and direction by the President, as commander in chief through established command lines over nuclear weapon operations of military forces, as chief executive over all government activities that support those operations, and as head of state over required multinational actions that support those operations. [Chapters 2, 9]

Nuclear Command and Control System (NCCS)

Collection of activities, processes, and procedures performed by appropriate commanders and support personnel who, through the chain of command, allow for senior-level decisions on nuclear weapons employment to be made based on relevant information and subsequently allow for those decisions to be communicated to forces for execution. [Chapters 1, 2, 6, 9, 17]

nuclear command, control, and communications (NC3)

Facilities, equipment, communications, procedures, and personnel that enable presidential nuclear direction to be carried out. [Chapters 1, 2, 3, 17]

nuclear deterrent

A desired strategic effect of the U.S. nuclear offensive and defensive capability seeking to assure allies and dissuade adversaries regarding nuclear and strategic attack endeavors. [Chapters 1, 3, 17]

nuclear enterprise

Composite of DoD U.S. nuclear forces and elements, to include the deterrent forces of Air Force nuclear-capable bombers and fighters and associated nuclear weapons, as well as ICBMs and cruise missiles; the Navy's ballistic missile submarines and associated nuclear SLBMs; the nuclear infrastructure to build, maintain, and sustain the nuclear forces; U.S. nuclear-capable bases and scientific facilities; nuclear command and control; and military personnel, civilians, and contractors performing the nuclear mission. [Chapters 1, 5, 6, 17]

nuclear fuel cycle

The process required to obtain nuclear fuel for use in a nuclear reactor. [Chapter 10]

Nuclear Posture Review (NPR)

Legislatively-mandated review that establishes U.S. nuclear policy, strategy, capabilities, and force posture for five to ten years into the future. [Chapters 1, 2, 11, 17]

nuclear radiation

Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from a nuclear weapon standpoint, are alpha and beta particles, gamma rays, and neutrons. [Chapters 2, 9, 13]

Nuclear Security Enterprise (NSE)

Composite of DOE/NNSA nuclear weapons complex, to include the laboratories, plants, test sites, science and technology, computing tools, and federal and contractor personnel. [Chapter 5]

nuclear survivability

Ability of personnel, equipment, and systems to withstand, survive, or mitigate the effects of nuclear weapons. [Chapters 9, 17]

nuclear threat device

Improvised nuclear or radiological device, a foreign nuclear weapon of proliferation concern, or any nuclear device that may have fallen outside of a foreign nuclear weapon state's custody. [Chapters 10, 11, 13]

nuclear threat reduction (NTR)

Refers to the integrated and layered activities across the full range of U.S. government efforts to prevent and counter radiological and nuclear incidents. [Chapters 10, 11]

nuclear triad

The U.S. nuclear triad consists of strategic forces operating at sea, on land, and in the air. Today's nuclear triad consists of: 14 SSBNs armed with 240 SLBMs; 400 land-based ICBMs; and 60 nuclear-capable heavy bomber aircraft capable of delivering gravity bombs and cruise missiles. [Chapters 1, 3, 4, 14]

nuclear weapon

Complete major assembly (i.e., implosion, gun, or thermonuclear) in its intended ultimate configuration, or in a disassembled configuration for a temporary period of time, which, upon completion of the prescribed arming, fusing, and firing sequence, is capable of producing the intended nuclear reaction and release of energy. [All Chapters]

nuclear weapons surety

Procedures and actions contributing to the safety, security, and control of nuclear weapons, and to the assurance that there will be no nuclear weapon accidents, incidents, or unauthorized weapon detonations, nor any degradation of weapon performance. [Chapters 6, 8]

nuclear weapon system safety

The application of engineering and management principles, criteria, and techniques to protect nuclear weapons against the risks and threats inherent in their environments within the constraints of operational effectiveness, time, and cost throughout all phases of their life cycle. [Chapters 7, 8]

Nuclear Weapon-Free Zone (NWFZ)

Prohibits the stationing, testing, use, and development of nuclear weapons inside a particular geographical region. [Chapter 12]

Nuclear Weapons Council (NWC)

Legislatively mandated body comprised of DoD and DOE members to ensure safety, security, and effectiveness of the nuclear weapons stockpile including multiple aspects of budget, maintenance, development, etc. [Chapters 4, 6, 17]

nuclear weapons design safety

Features meant to provide high assurance that an accident, or other abnormal environment, will not produce a nuclear detonation. [Chapter 8]

nuclear yields

Energy released in the detonation of a nuclear weapon, measured in terms of the kilotons or megatons of TNT required to produce the same energy release. Yields are categorized as follows: very low: less than 1 kiloton; low: 1 kiloton to 10 kilotons; medium: over 10 kilotons to 50 kilotons; high: over 50 kilotons to 500 kilotons; and very high: over 500 kilotons. [Chapters 1, 2, 4, 9, 11, 12, 13, 14, 15]

nucleus

Small, central, positively charged region of an atom, which carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which is a single proton, all atomic nuclei contain both protons and neutrons. [Chapters 11, 13, 15]

one-point safety

Probability of achieving a nuclear yield greater than 4 pounds TNT equivalent in the event of a one-point initiation of the weapon's high explosive must not exceed one in a million. [Chapter 8]

P3

A trilateral partnership between the United States, United Kingdom, and France to maintain a program of enhanced technical collaboration on a wide range of NTR subjects. [Chapter 10]

peak overpressure

Maximum value of overpressure at a given location that is generally experienced at the instant the shock (or blast) wave reaches that location. [Chapter 9]

Phase 6.X Process

Established in 2000, this process focuses on developing and fielding of replacement non-nuclear components for the nuclear stockpile; the original Nuclear Weapons Life-Cycle Process focuses on development of a complete new warhead, including new nuclear components. [Chapter 7]

phase process

Refers to the complete life cycle of the weapons from conceptualization through retirement and dismantling. Generally encompasses seven steps: concept, design, develop, produce, assess/repair, maintain, retire, dismantle/dispose, and replace. [Chapter 7]

photon

Unit of electromagnetic radiation consisting of pure energy and zero mass. [Chapters 9, 11, 13]

power reactor

Nuclear reactor that operates to generate electricity; plutonium produced as a part of the spent fuel is not intended to be used for nuclear weapons. [Chapters 5, 12, 15]

production reactor

Nuclear reactor designed to produce plutonium for use in nuclear weapons. Most also generate electricity that can be used. [Chapter 15]

Project Officers Groups (POGs)

Joint DoD-NNSA groups associated with each warhead-type, created toward the beginning of a weapon development program and charged with the responsibility to coordinate the development and assure the compatibility of a warhead-type with its designated delivery system(s). [Chapter 6]

prompt radiation

Gamma rays produced in fission and as a result of other neutron reactions and nuclear excitation of the weapon materials appearing within a second or less after a nuclear explosion. The radiations from these sources are known either as prompt or instantaneous gamma rays. [Chapters 9, 13]

proton

Particle with approximately one atomic mass unit carrying a unit positive charge; it is identical physically with the nucleus of the ordinary (light) hydrogen atom. All atomic nuclei contain protons. [Chapters 9, 13]

radioactivity

Spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of unstable isotopes. [Chapters 13, 15]

reactor-grade plutonium

Quantity of plutonium with the percentage of heavier isotopes (above Pu-239) more than 7 percent but less than 15 percent. [Chapter15]

readiness state

Refers to the configuration of weapons in the active and inactive stockpiles. [Chapter 4]

reentry vehicle or reentry body

A reentry vehicle (term used by the Air Force) or reentry body (the term used primarily by the Navy SLBM program) protects a warhead as it re-enters the atmosphere from space; it can carry only one warhead. [Chapter 4, 9]

reliability

Probability, without regard to countermeasures, that a nuclear weapon, subassembly, component, or other part will perform in accordance with its design intent or requirements. [Chapters 2, 4, 5, 6, 8, 9, 10, 15, 17]

reprocessing

Activity conducted to extract plutonium from the spent fuel of a nuclear reactor. [Chapter 15]

residual radiation

Nuclear radiation caused by fallout, artificial dispersion of radioactive material, or irradiation that results from a nuclear explosion and persists longer than one minute after burst. [Chapters 9, 13]

retired warhead

Warheads no longer part of the stockpile and set for release for disassembly. [Chapter 4]

special nuclear material

Defined by the Atomic Energy Act of 1954 as plutonium or uranium enriched in the isotopes of U-233 or U-235. [Chapters 4, 5, 8, 11, 17, 18]

staged weapon

Weapon in which energy from the primary initiates the explosion of a secondary. [Chapters 13, 15]

stockpile or nuclear stockpile

Quantity of weapons necessary for U.S. national security including operational weapons and logistical warheads. [Chapters 1, 4, 6, 7, 8, 11, 12, 14, 16, 17, 18]

stockpile evaluation

Efforts taken to plan for and conduct tests of the stockpile for assurance. [Chapters 4, 7]

stockpile hedge

Designated warheads to counter unforeseen significant events adversely affecting U.S. nuclear weapons. [Chapter 4]

stockpile management

Sum of the activities, processes, and procedures for the design, development, production, fielding, maintenance, repair, storage, transportation, physical security, employment (if directed by the President), dismantlement, and disposal of U.S. nuclear weapons and their associated components and materials. [Chapters 4, 14, 17]

stockpile stewardship

Processes or programs aimed at increasing the understanding of the elements of the current and future stockpile. [Chapters 1, 4, 5, 6, 17]

stockpile surveillance

Review of stockpile for purpose of evaluation and quality assurance. [Chapters 4, 6]

stockpile sustainment

Encompasses the refurbishment of existing warheads and the reuse or replacement of nuclear and non-nuclear components in order to maintain the security, safety, reliability, and effectiveness of the nuclear weapon stockpile. [Chapters 6, 7, 17]

stockpile-to-target sequence

1) Order of events involved in removing a nuclear weapon from storage and assembling, testing, transporting, and delivering it on the target. 2) Document that defines the logistic and employment concepts and related physical environments involved in the delivery of a nuclear weapon from the stockpile to the target. It may also define the logistic flow involved in moving nuclear weapons to and from the stockpile for quality assurance testing, modification and retrofit, and the recycling of limited life components. [Chapters 6, 8]

strategic collaborations

Mechanisms categorized by information type for technical exchanges of information between signatories to the U.S./UK Mutual Defense Agreement. [Chapter 10]

subcritical

Mass of fissile material below the amount necessary to cause a self-sustaining nuclear chain reaction. [Chapters 4, 13, 15]

supercritical mass

Quantity of fissionable material needed to support a multiplying chain reaction. [Chapters 11, 13, 15]

surety

Materiel, personnel, and procedures that contribute to the security, safety, and control of nuclear weapons and to the assurance that there will be no nuclear weapon accidents, incidents, unauthorized weapon detonations, or degradation in performance at the target. [Chapters 5, 6, 8, 10, 17]

surveillance

Activities involved in making sure nuclear weapons continue to meet established safety, security, and reliability standards. [Chapters 2, 4, 5, 6, 7, 11, 12, 14]

system survivability

Ability to withstand, survive, or mitigate the effects of nuclear weapons on systems (ie communication or weapon operating in a nuclear environment) across a range of potential environmental exposures (i.e. atmospheric, in-flight, near-earth surface). [Chapter 9]

target development

Part of the nuclear planning process, based on analysis of the strategic environment as well as the identification of adversary weaknesses that, if exploited, would help achieve U.S. military goals and objectives. [Chapter 2]

technical nuclear forensics (TNF)

Refers to the analysis and characterization of pre- and post-detonation radiological or nuclear materials, devices, and debris as well as prompt effects from a nuclear detonation. Used in conjunction with law enforcement and intelligence information to identify those responsible for the planned or actual attack. [Chapters 10, 11, 12]

thermal radiation

1) Heat and light produced by a nuclear explosion. 2) Electromagnetic radiations emitted from a heat or light source as a consequence of its temperature; it consists essentially of ultraviolet, visible, and infrared radiations. [Chapters 9, 13, 14]

thermonuclear

Refers to the process (or processes) in which very high temperatures are used to bring about the fusion of light nuclei such as those of hydrogen isotopes (e.g., deuterium and tritium) with the accompanying release of energy and high-energy neutrons. [Chapters 13, 14, 15, 17, 18]

TNT equivalent

Measure of the energy released from the detonation of a nuclear weapon or from the explosion of a given quantity of fissionable material in terms of the amount of TNT that could release the same amount of energy when exploded. [Chapter 8]

Transclassified Foreign Nuclear Information (TFNI)

Information from any intelligence source concerning the nuclear energy programs of foreign governments that was removed from the RD category (by transclassification) under section 142(e) of the Atomic Energy Act by past joint agreements between DOE and the Director of Central Intelligence or past and future agreements with the Director of National Intelligence. [Chapter 18]

transient radiation effects on electronics (TREE)

Effects on electronics that are exposed to transient gammas, neutrons, and X-rays. [Chapters 9, 13]

tritium

Radioactive isotope of hydrogen consisting of one proton and two neutrons in the nucleus; it is produced in nuclear reactors by the action of neutrons on lithium nuclei. [Chapters 4, 5, 7, 13, 15]

two-person rule

Continuous surveillance and control of positive control material at all times by a minimum of two authorized individuals, each capable of detecting incorrect or unauthorized procedures with respect to the task being performed and each familiar with established security requirements. [Chapter 8]

uranium enrichment

Process of isotope separation increasing the percentage of uranium-235 atoms in any given amount of uranium. [Chapters 5, 11, 12, 15]

use control

Positive measures that allow the authorized use and prevent or delay unauthorized use of nuclear weapons. Use control is accomplished through a combination of weapon system design features, operational procedures, security, and system safety rules. [Chapters 7, 8, 17, 18]

warhead

The part of a missile, projectile, torpedo, rocket, or other munition that contains either the nuclear or thermonuclear system, high explosive system, chemical or biological agents, or inert materials intended to inflict damage. [All Chapters]

weaponeering assessment

Part of the nuclear planning process, that considers the characteristics of nuclear systems against the characteristics of targets and seek to identify applications of weapons on targets that would succeed in delaying, disrupting, disabling, or destroying critical enemy forces or resources. [Chapter 2]

weaponization

Weaponization includes all of the activities required to research, develop, test, evaluate, produce, and maintain nuclear weapons components, including those that will interface with weapon system delivery vehicles, other than the production of fissile materials and the fissile component. [Chapter 15]

weapons-grade highly enriched uranium

Quantity of uranium enriched to 90 percent or higher. [Chapter 15]

weapons-grade plutonium

Quantity of plutonium with the percentage of heavier isotopes (above Pu-239) not greater than 7 percent, and the percentage of Pu-239 is at least 93 percent or higher. [Chapters 11, 15]

weapon system

Combination of one or more weapons with all related equipment, materials, services, personnel, and means of delivery and deployment (if applicable) required for self-sufficiency. [Chapters 2, 4, 5, 6, 7, 8 , 9, 12, 17]

X-ray

Electromagnetic radiations of high energy having wavelengths shorter than those in the ultraviolet region. [Chapters 5, 9, 12, 14, 17]

yield

Total effective energy released in a nuclear (or atomic) explosion. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. [Chapters 1, 2, 3, 4, 5, 6, 8, 9, 11, 12, 13, 14, 15, 18]

ACRONYM LIST

3-D	three-dimensional
AAM	air-to-air missile
ABM	anti-ballistic missile
ACM	advanced cruise missile
ACRR	Annular Core Research Reactor
ADM	atomic demolition munition
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AEHF	advanced extremely high frequency
AFAP	artillery fired atomic projectile
AFB	Air Force Base
AFTAC	Air Force Technical Applications Center
A&L	aging and lifetimes
ALCM	air-launched cruise missile
Alt	alteration
ANWFZ	African Nuclear Weapon-Free Zone
ANFO	ammonium nitrate and fuel oil

AO	action officer
AoA	analysis of alternatives
APEX	adaptive planning and execution
APS	active protection system
AR	active ready
AS	active stockpile
ASD(NCB)	Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs
ASEAN	Association of Southeast Asian Nations
ATSD(AE)	Assistant to the Secretary of Defense for Atomic Energy

B	bomb
BA	budget authority
BCR	Baseline Cost Report
BDA	battle damage assessment
BES	Budget Estimate Submission

C	Confidential
C4I	command, control, communications, computers, and intelligence
CAC	Compartmented Advisory Committee
CANES	Comprehensive Atmospheric Nuclear Environments Standard
CANWFZ	Central Asian Nuclear Weapon-Free Zone
CAPE	Cost Assessment and Program Evaluation
CAS-D	Continuous-At-Sea-Deterrent
CBR	chemical, biological, and radiological
CBR	congressional budget resolution
CBRN	chemical, biological, radiological, and nuclear
CCD	coded control device
CCJO	Capstone Concept for Joint Operations
CDMC	Consolidated Uranium Manufacturing Capability
CCMD	Combatant Command
CDRUSSTRATCOM	Commander, United States Strategic Command
CDS	command disablement system

CEP	circular error probable
cGy	centigray
CHE	conventional high explosive
CJCS	Chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CMRR	Chemistry and Metallurgy Research Building Replacement
CNWDI	Critical Nuclear Weapon Design Information
COMSEC	Communications Security
CONOP	concept of operation
CONPLAN	concept plan; operation plan in concept format
CONUS	continental United States
CPF	contractor protective forces
CR	continuing resolution
CSOG	CBRN Survivability Group
CSOG-CBR	CBRN Survivability Oversight Group - Chemical, Biological, and Radiological
CSOG-N	CBRN Survivability Oversight Group - Nuclear
CTBT	Comprehensive Nuclear-Test-Ban Treaty
CTBTO	Comprehensive Nuclear-Test-Ban Treaty Organization
CTR	cooperative threat reduction
CUI	Controlled Unclassified Information
D-test	destructive test
DARHT	dual axis radiographic hydrodynamic test
DAS	Defense Acquisition System
DASA	Defense Atomic Support Agency
DASD(NM)	Deputy Assistant Secretary of Defense for Nuclear Matters
DCA	dual-capable aircraft
DE	damage expectancy
DGZ	desired ground zero
DHS	Department of Homeland Security
DHS/CWMD	DHS Countering Weapons of Mass Destruction

DIA	Defense Intelligence Agency
DNA	Defense Nuclear Agency
DNDO	Domestic Nuclear Detection Office
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DoDM	Department of Defense Manual
DOE	Department of Energy
DOE O	Department of Energy Order
DOJ	Department of Justice
DOS	Department of State
DOTMLPF-P	doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy
DP	Defense Program
DPF	Dense Plasma Focus
DPG	Defense Planning Guidance
DRAAG	Design Review and Acceptance Group
DRB	Defense Resources Board
DTRA	Defense Threat Reduction Agency
DU	depleted uranium
DUE	domestic uranium enrichment
DUU	deliberate unauthorized use
DLI	direct laser impulse

EAM	emergency action message
EDD	Extended Deterrence Dialogue
EIVR	Exchange of Information by Visit and Report
EMP	electromagnetic pulse
EMR	electromagnetic radiation
ENDS	enhanced nuclear detonation safety
EO	Executive Order
ERDA	Energy Research and Development Agency
ESD	environment sensing device

FAB-T	Family of Advanced Beyond Line-of-Sight Terminals
FBI	Federal Bureau of Investigation
FBM	fleet ballistic missile
FBR	fast burst reactor
FEMA	Federal Emergency Management Agency
FFRDC	federally funded research and development center
FOIA	Freedom of Information Act
FOUO	For Official Use Only
FPU	first production unit
FRD	Formerly Restricted Data
FSU	former Soviet Union
FRP	fire-resistant pit
FWDR	Final Weapon Development Report
FPF	federal protective forces
FXR	flash X-ray machine
FY	fiscal year
FYDP	Future-Years Defense Program
FYNSP	future-years nuclear security program

GA	gun assembly
GBSD	ground-based strategic deterrent
GEF	Guidance for Employment of the Force
GICNT	Global Initiative to Combat Nuclear Terrorism
GLBM	ground-launched ballistic missile
GLCM	ground-launched cruise missile
Global ASNT	Global Aircrew Strategic Network Terminal
GOC	Global Operations Center
GOCO	government-owned, contractor-operated
GSP	graded security protection
GZ	ground zero

HE	high explosive
HEAF	High Explosives Application Facility
HED	high-energy-density

HEMP	high-altitude electromagnetic pulse
HERMES	high-energy radiation megavolt electron source
HEU	highly enriched uranium
HLG	High Level Group
HOB	height of burst
HRP	Human Reliability Program
HWR	heavy-water reactor
IAEA	International Atomic Energy Agency
ICBM	intercontinental ballistic missile
ICD	Interface Control Document
IFI	in-flight insertion
IHE	insensitive high explosive
IND	improvised nuclear device
INF	intermediate-range nuclear forces
IOC	initial operational capability
IS	inactive stockpile
ITAR	International Traffic in Arms Regulations
ITW/AA	Integrated Tactical Warning/Attack Assessment
J/kg	joules per kilogram
JAIEG	Joint Atomic Information Exchange Group
JCIDS	Joint Capabilities Integration and Development System
JCPOA	Joint Comprehensive Plan of Action
JILT	joint integrated laboratory test
JIPP	Joint Integrated Project Plan
JNWPS	Joint Nuclear Weapons Publications System
JOE	joint operating environment
JOPES	Joint Operation Planning and Execution System
JOWOG	Joint Working Group
JP	Joint Publication
JRN	Joint Atomic Information Exchange Group Reference Number

JROC	Joint Requirements Oversight Council
JS	Joint Staff
JSR	Joint Surety Report
JTA	joint test assembly
JTSMG	Joint Theater Surety Management Group
KCNSC	Kansas City National Security Campus
keV	kiloelectron-volt
kg	kilogram
KIDD	Korea-U.S. Integrated Defense Dialogue
kt	kiloton
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LAP4	Los Alamos Plutonium Pit Production Project
LBTS	large blast thermal simulator
LD50	lethal dose for 50 percent of the population
LE	life extension
LEP	life extension program
LEU	low-enriched uranium
LIHE	light-initiated high explosive
LINAC	linear accelerator
LLC	limited-life component
LLCE	limited-life component exchange
LLNL	Lawrence Livermore National Laboratory
LPF	Lithium Processing Facility
LRSO	long-range standoff
LTBT	Limited Test Ban Treaty
LWR	light-water reactor
MAR	Major Assembly Release
MBS	Modular Bremsstrahlung Source
MC	military characteristic
MCCS	multiple-coded control switch

MDA	Missile Defense Agency
MDA	mutual defense agreement
MFD	military first destination
MG	MIGHTY GUARDIAN
MILCON	military construction
MILPERS	military personnel
MIL-STD	Military Standard
MIR	major impact report
MIRV	multiple independently targetable reentry vehicle
MK	mark
MLC	Military Liaison Committee
MMIII	Minuteman III
MMPU	Minuteman Minimum Essential Emergency Communications Network Program Upgrade
M&O	management and operating
MOA	memorandum of agreement
Mod	modification
MOU	memorandum of understanding
MPC&A	Material Protection, Control, and Accounting
MT	megaton
mV/m	millivolt to meter

NACLC	National Agency Check with Law and Credit
NAOC	National Airborne Operations Center
NATO	North Atlantic Treaty Organization
NC2	nuclear command and control
NC3	nuclear command, control, and communications
NCCS	Nuclear Command and Control System
NDAA	National Defense Authorization Act
NDS	National Defense Strategy
NDSB	nuclear depth/strike bomb
NEWS	nuclear explosive and weapons surety
NGE+	Neutron Generator Enterprise Consolidation
NIF	National Ignition Facility

NLCC	National Leadership Command Capability
NMCC	National Military Command Center
NMS	National Military Strategy
NMSE	New Material and Stockpile Evaluation
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
NORAD	North American Aerospace Defense Command
NPG	Nuclear Planning Group
NPR	Nuclear Posture Review
NPT	Treaty on the Nonproliferation of Nuclear Weapons (Nuclear Nonproliferation Treaty)
NRF	National Response Framework
NSE	Nuclear Security Enterprise
NSI	national security information
NSPD	National Security Presidential Directive
NSPM	National Security Presidential Memorandum
NSS	National Security Strategy
NSTCA	Nuclear Security Threat Capabilities Assessment
NSWC	Naval Surface Warfare Center
NTD	nuclear threat device
NTNF	national technical nuclear forensics
NTR	nuclear threat reduction
NTRG	Nuclear Trafficking Response Group
NTS	Nevada Test Site
NU	natural uranium
NWC	Nuclear Weapons Council
NWCSC	Nuclear Weapons Council Standing Committee
NWCSSC	Nuclear Weapons Council Standing and Safety Committee
NWCWSC	Nuclear Weapons Council Weapons Safety Committee
NWD	nuclear weapon data
NWDA	Nuclear Weapons Deployment Authorization
NWRWG	Nuclear Weapons Requirements Working Group

NWSM	Nuclear Weapons Stockpile Memorandum
NWSP	Nuclear Weapons Stockpile Plan
NWSS	nuclear weapon security standard
NWSSG	Nuclear Weapon System Safety Group
NWTI	nuclear weapons technical inspection
OAU	Organization of African Unity
OCA	original classification authority
ODASD(NM)	Office of the Deputy Assistant Secretary of Defense for Nuclear Matters
ODNI	Office of the Director of National Intelligence
O&M	operations and maintenance
OMB	Office of Management and Budget
OPLAN	operation plan
OPM	Office of Personnel Management
OSCC	Open Skies Consultative Commission
OSD	Office of the Secretary of Defense
OUO	Official Use Only
P3	U.S.-UK-France
PA	probability of arrival
PAL	permissive action link
PBD	program budget decision
PBR	president’s budget request
PCI	pulsed current injection
PCTFE	polychlorotrifluoroethylene
PD	probability of damage
PDD	Presidential Decision Directive
PDM	Program Decision Memoranda
PLS	prelaunch survivability
PNET	Peaceful Nuclear Explosions Treaty
PNI	Presidential Nuclear Initiative
PNVC	Presidential and National Voice Conferencing
POE	point of entry
POG	Project Officers Group

POM	Program Objective Memorandum
POTUS	President of the United States
PPBE	Planning, Programming and Budgeting, and Evaluation (DOE)
PPBE	Planning, Programming, Budgeting, and Execution (DoD)
PPD	Presidential Policy Directive
PPE	personal protective equipment
PPI	process prove-in
PRAP	personnel reliability assurance program
PRC	People's Republic of China
PRP	Personnel Reliability Program
PRS	plasma radiation source
PSP	Personnel Security Program
psi	pounds per square inch
PTP	probability to penetrate
Pu-239	plutonium-239
Pub. L.	Public Law
PX	Pantex Plant
QA	quality assurance
QART	Quality Assurance and Reliability Testing
RAAC	Rack Assembly and Alignment Complex
RB	reentry body
RD	radius of damage
RD	Restricted Data
RDD	radiological dispersal device
RDT&E	research, development, test, and evaluation
RED	radiological exposure device
RG-Pu	reactor-grade plutonium
ROPA	Report on Platform Assessments
ROSA	Report on Stockpile Assessments
RPD	Requirements and Planning Document
RS	readiness state

RTG	radioisotope thermoelectric generator
RV	reentry vehicle

S	Secret
SAM	surface-to-air missile
SAOC	survivable airborne operations center
SALT I	Strategic Arms Limitation Talks
SALT II	Strategic Arms Limitation Treaty
SCN	shipbuilding and conversion, Navy
SCI	Sensitive Compartmented Information
SCT	Stockpile Confidence Test
SD	statutory determination
SECENG	Secretary of Energy
SEP	Stockpile Evaluation Plan
SFI	significant finding investigation
SHAPE	Supreme Headquarters Allied Powers Europe
SLBM	submarine-launched ballistic missile
SLCM	sea-launched cruise missile
SNL	Sandia National Laboratories
SNM	special nuclear material
SORT	Strategic Offensive Reductions Treaty
SREMP	source-region electromagnetic pulse
SRH	strategic radiation-hardened
SRHEC	Strategic Radiation-Hardened Electronics Council
SRPPF	Savannah River Plutonium Processing Facility
SRS	Savannah River Site
SSBI	single scope background investigation
SSBN	ship, submersible, ballistic, nuclear (ballistic missile submarine)
SSM	surface-to-surface missile
SSMP	Stockpile Stewardship Management Plan
SSNS	Satellite System Nuclear Survivability
SSP	Stockpile Stewardship Plan
SSP	Strategic Systems Programs

START	Strategic Arms Reduction Treaty
ST&E	science, technology, and engineering
STS	stockpile-to-target sequence
TA-55	LANL plutonium facility technical area
TACAMO	take charge and move out
TCC	Transformation Coordinating Committee
TCG-NAS-2	Joint DOE/DoD Topical Classification Guide for Nuclear Assembly Systems, March 1997
TFF	Tritium Finishing Facility
TFNI	Transclassified Foreign Nuclear Information
Th	thorium
TNF	technical nuclear forensics
TNT	trinitrotoluene
TREE	transient radiation effects on electronics
TRS	thermal radiation source
TS	Top Secret
TSSG	trajectory-sensing signal generator
TTBT	Threshold Test Ban Treaty
U	Unclassified
U-235	uranium-235
U-238	uranium-238
UCNI	Unclassified Controlled Nuclear Information
UHF	Ultra High Frequency
UGT	underground nuclear test
UPF	Uranium Processing Facility
UQS	unique signal
USAF	United States Air Force
USC	United States Code
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USD(A&S)	Under Secretary of Defense for Acquisition and Logistics
USD(C)	Under Secretary of Defense, Comptroller
USD(P)	Under Secretary of Defense for Policy

USD(R&E)	Under Secretary of Defense for Research and Engineering
USEUCOM	United States European Command
USG	United States Government
USN	United States Navy
USSOCOM	United States Special Operations Command
USSTRATCOM	United States Strategic Command
VCJCS	Vice Chairman of the Joint Chiefs of Staff
VHF	very high frequency
VLF	very low frequency
W	warhead
WDCR	Weapon Design and Cost Report
WETL	Weapons Evaluation Test Laboratory
WG-HEU	weapons-grade highly enriched uranium
WG-Pu	weapons-grade plutonium
WMD	weapons of mass destruction
WR	war reserve
WS3	weapon storage and security system (United States) weapon security and survivability system (NATO)
WSR	weapon system reliability
WSV	weapon storage vault