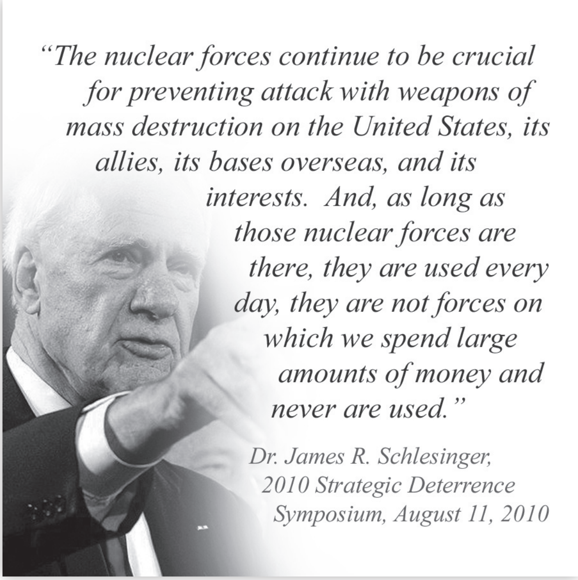
Chapter 1

Nuclear Deterrence – U.S. Policy and Strategy

1.1 Overview

The U.S. nuclear deterrent, with its unique attributes, is a central element of U.S. national security policy. First, the U.S. nuclear deterrent reduces the probability a nuclear peer or nuclear-armed adversary might engage the United States in a strategic nuclear exchange. Second, U.S. nuclear forces provide a nuclear "umbrella" of protection for many allied nations, reducing their need to develop and field their own nuclear weapons, thereby helping to dissuade nuclear proliferation. Third, the U.S. nuclear arsenal deters nuclear or radiological attack against the United States, its allies, and partners by state-sponsored terrorist organizations or proliferant nations. The U.S. nuclear weapons programs also provide the scientific, technological, and engineering foundation for the U.S. nuclear counterterrorism and counterproliferation programs. For these reasons, it is the policy of the United States to retain and maintain its nuclear deterrent indefinitely until verifiable worldwide nuclear disarmament is achieved.

Integral to U.S. nuclear deterrence policy is the United States' commitment to strengthen bilateral and regional security. The United States continues the forward deployment of U.S. forces in key regions, strengthens U.S. and allied non-nuclear capabilities, and provides extended deterrence in order to deter potential threats. This demonstrates to neighboring states that the pursuit of nuclear weapons will only undermine their goal of achieving military or political advantages and reassures non-nuclear U.S. allies and partners their security interests can be protected without their own nuclear deterrent capabilities. Security architectures in key regions will retain a nuclear dimension as long as nuclear threats to U.S. allies and partners remain. The United States will continue to be able to extend its nuclear umbrella through forward deployable fighters and bombers as well as through other U.S. strategic nuclear systems. The United States plans to retain the capability to forward deploy U.S. nuclear weapons on tactical fighters and heavy bombers which would involve a life extension of the B61 bomb.



> *"The nuclear forces continue to be crucial for preventing attack with weapons of mass destruction on the United States, its allies, its bases overseas, and its interests. And, as long as those nuclear forces are there, they are used every day, they are not forces on which we spend large amounts of money and never are used."*
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> *Dr. James R. Schlesinger, 2010 Strategic Deterrence Symposium, August 11, 2010*

1.2 U.S. Nuclear Strategy

The *Quadrennial Defense Review* (QDR) is a legislatively-mandated review of Department of Defense (DoD) strategy and priorities and sets the long-term course for the DoD as it assesses the threats and challenges the Nation faces and re-balances DoD strategies, capabilities, and forces to address today's conflicts and tomorrow's threats. The 2014 QDR states that the number one priority of the DoD is to "maintain a secure and effective nuclear deterrent" and, as U.S. nuclear forces are reduced through negotiated agreements with Russia, the importance of ensuring its remaining forces are safe, secure, and effective increases. Thus, the DoD, in collaboration with the Department of Energy (DOE), continues to invest in modernizing its essential nuclear delivery systems, warheads, warning, command and control, and nuclear weapons infrastructure. These programs will ensure the United States retains an effective triad of strategic nuclear delivery systems (strategic bombers, intercontinental ballistic missiles, and submarine-launched ballistic missiles) and forward deployable tactical aircraft capable of delivering nuclear weapons.

The fundamental role of U.S. nuclear forces is to deter nuclear attack on the United States as well as its allies and partners. The United States continues to reduce the role of nuclear weapons in deterring non-nuclear attack. However, nuclear forces continue to play a limited but critical role in the Nation's strategy to address threats posed by states that possess nuclear weapons and states not in compliance with their nuclear nonproliferation obligations. Against such potential adversaries, our nuclear forces deter strategic attack on the homeland and provide the means for effective responses, should deterrence fail. Our nuclear forces contribute to deterring aggression against U.S. and allied interests in multiple regions, assuring U.S. allies its extended deterrence guarantees are credible, and demonstrating we can defeat or counter aggression if deterrence fails. U.S. nuclear forces also help convince potential adversaries they cannot successfully escalate their way out of failed conventional aggression against the United States or its allies and partners.

The *U.S. National Security Strategy* of February 2015 states the United States will protect investment in foundational capabilities, like the nuclear deterrent. Furthermore, it states no threat poses as grave a danger to our security and well-being as the potential use of nuclear weapons and materials by irresponsible states or terrorists. Therefore, while we seek the peace and security of a world without nuclear weapons, as long as they exist, the United States must invest the resources necessary to maintain, without underground nuclear testing, a safe, secure, and effective nuclear deterrent that preserves strategic stability.

1.3 International Security Environment

The United States is faced with a new security environment that has changed dramatically since the end of the Cold War. While the threat of global nuclear war has become remote, the risk of nuclear attack has increased. Immediate and extreme dangers for the United States are dual threats of nuclear proliferation and nuclear terrorism. Additional countries, especially those who do not conform to international norms and structures, may acquire or seek to acquire nuclear weapons. Sub-state actors and terrorist organizations have

New START Timeline

April 8, 2010 – Treaty Signature

May 2010: Exchanged Facility List and Site Diagrams

Entry Into Force (EIF) – Begin providing all notifications

Provisional Application

No later than (NLT) 5 days after EIF: Exchange Inspection Airplane Information

NLT 25 days after EIF:
Exchange List of Inspectors
and Aircrew Members

NLT 45 days after EIF: Exchange Databases

60 days after EIF: Right to Conduct Inspections Begins

NLT 60 days after EIF: Exhibit new Strategic Offensive Arms

NLT 120 days after EIF: Exhibit Heavy Bombers at Davis-Monthan AFB

NLT 180 days after EIF: Initial Demo of Telemetry Equipment

7 months after EIF: Exchange Updated Database
(repeat every 6 months)

NLT 1 year after EIF: Exhibit the B-1B Heavy Bomber

NLT 3 years after EIF: Exhibit Previously Converted Missile Launchers

NLT 7 years after EIF:
Meet Treaty Central Limits

Parties must meet central limits on deployed and non-deployed launchers and heavy bombers; and deployed delivery vehicles and heavy bombers; and deployed warheads

10 years after EIF: Treaty Expires
(unless extended for 5 years)

Timeline not to Scale

also declared their intent to acquire nuclear threat devices.[1] Russia remains America's peer in the area of significant nuclear weapons capabilities and continues to modernize its still-formidable nuclear forces. This is while policy differences continue to arise with the United States and Russia as well as between Russia and its regional neighbors.

The United States and China increasingly share responsibilities for addressing global security threats, including weapons of mass destruction (WMD) proliferation and terrorism. At the same time, the United States and China's Asian neighbors remain concerned about the pace and scope of China's current military modernization efforts, including the qualitative modernization of its nuclear forces. China's nuclear arsenal remains much smaller than the arsenals of Russia and the United States. However, the lack of transparency surrounding China's nuclear programs and the strategy and doctrine guiding them raise questions about China's future strategic intentions.

1.4 Nuclear Posture Review

The 2010 *Nuclear Posture Review* (NPR) is the third comprehensive review of U.S. nuclear policies and posture; the first two conducted in 1994 and 2001 by the Clinton and Bush Administrations, respectively. The 2010 review was an interagency effort conducted by the DoD in close consultation with the Departments of Energy and State and in direct engagement with the President. The NPR focused on five key objectives on the United States' nuclear agenda: 1) preventing nuclear proliferation and nuclear terrorism; 2) reducing the role of nuclear weapons; 3) maintaining strategic deterrence and stability at reduced nuclear force levels; 4) strengthening regional deterrence and reassuring U.S. allies and partners; and 5) sustaining a safe, secure, and effective nuclear arsenal.

The 2010 Nuclear Posture Review calls for reducing nuclear dangers and pursuing the long-term goal of a world without nuclear weapons….while maintaining a safe, secure, and effective nuclear arsenal.

Since the end of the Cold War, the United States has sought to reduce the role of nuclear weapons in deterring non-nuclear attacks on itself and its allies and partners. The United

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[1] Nuclear threat devices include improvised nuclear devices (INDs), radiological dispersal devices (RDDs), radiological exposure devices (REDs), and any device that may produce nuclear yield, such as nuclear weapons that have fallen out of state control.

States is continuing to strengthen conventional military capabilities, missile defenses, and counter-WMD capabilities so the role of U.S. nuclear weapons in deterring non-nuclear attacks (conventional, biological, or chemical) can continue to be reduced while strengthening deterrence. The NPR also explains changes in U.S. declaratory policy to include the strengthening of negative security assurances. Specifically, the United States declares that we will not use or threaten to use nuclear weapons against non-nuclear weapons states that are party to the *Treaty on the Nonproliferation of Nuclear Weapons* (NPT) and in compliance with their nuclear nonproliferation obligations.

1.5 Maintaining Strategic Deterrence and Stability at Reduced Nuclear Force Levels

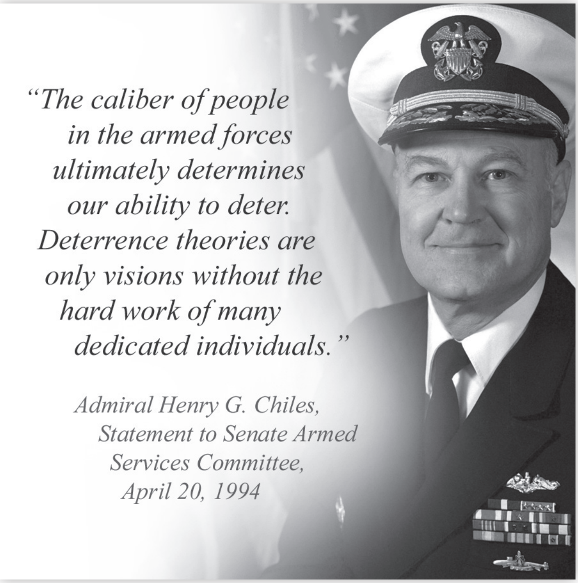
The *Treaty between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms*, also known as New START, was signed on April 8, 2010, entered into force on February 5, 2011, and is expected to stay in force at least until 2021. New START sets the course for the United States' nuclear deterrent of the future. New START replaced the *Strategic Offensive Reductions Treaty* (SORT), commonly referred to as the Treaty of Moscow, which was due to expire in December 2012. In terms of name, it is a follow-up to the *Strategic Arms Reduction Treaty* (START) *I*, which expired in December 2009, the proposed START II, which never entered into force, and START III, in which negotiations were never concluded. Under the terms of New START, the United States and Russia agreed to limits of 1,550 accountable strategic warheads, 700 deployed strategic delivery vehicles, and a combined limit of 800 deployed and non-deployed strategic delivery vehicles. Under New START, the United States retains a nuclear triad. New START does not constrain U.S. missile defenses and allows the United States to pursue conventional global strike systems.

1.6 Nuclear Weapons Employment Policy

The primary purpose of the U.S. nuclear deterrent is to deter a nuclear attack against the United States, its allies, or its interests. If deterrence were to fail, the United States could employ its nuclear forces. The decision to employ nuclear weapons, at any level, requires the explicit authorization of the President of the United States. The use of nuclear weapons represents a significant escalation in conflict and involves many considerations. Other prominent planning and employment factors include the strategic security situation, the type and extent of operations to be conducted, military effectiveness, damage-limitation measures, environmental and ecological impacts, termination objectives, and calculations concerning how such considerations may interact.

1.7 Nuclear Weapons Employment Planning

Defense planning for the employment of nuclear weapons is consistent with national policy and strategic guidance. Planning for the use of nuclear weapons is based upon knowledge of enemy force strength and disposition; the number, yields, and types of nuclear weapons available; and the status and disposition of friendly forces at the time these weapons are to be employed. Employment planning considers the characteristics and limitations of the nuclear forces available and seeks to optimize both the survivability and combat effectiveness of these forces. To provide the desired capabilities, nuclear forces must be diverse, flexible, effective, survivable, enduring, and responsive. If no one weapons system possesses all of the desired characteristics, a variety of systems may be necessary. Strategic stability and centralized control, as well as command, control, communications, computers, and intelligence (C4I), are required enablers in nuclear force planning and employment.


"The caliber of people in the armed forces ultimately determines our ability to deter. Deterrence theories are only visions without the hard work of many dedicated individuals."

*Admiral Henry G. Chiles,
Statement to Senate Armed Services Committee,
April 20, 1994*

1.8 Nuclear Weapons Targeting Policy

Targeting is the process of selecting targets and matching the appropriate weapon to those targets by taking account of national objectives and operational requirements and capabilities. Targeting includes the analysis of enemy situations relative to the military mission, objectives, and capabilities, as well as the identification and nomination of specific vulnerabilities that, if exploited, would accomplish the military goals through delaying, disrupting, disabling, or destroying critical enemy forces or resources.

Nuclear targeting considerations include the inability of friendly forces to destroy targets using conventional or other means; the number and type of individual targets; the vulnerability of those targets, including target defenses; the level of damage required for each target to achieve the overall objective; optimum timing; the adversary's ability to reconstitute or regenerate; avoidance of collateral damage; and environmental conditions in the target vicinity including surface, upper air, and space conditions. **Figure 1.1** illustrates the nuclear targeting process and assessment which is further described in *Appendix C*: *Basic Nuclear Physics and Weapons Effects*.

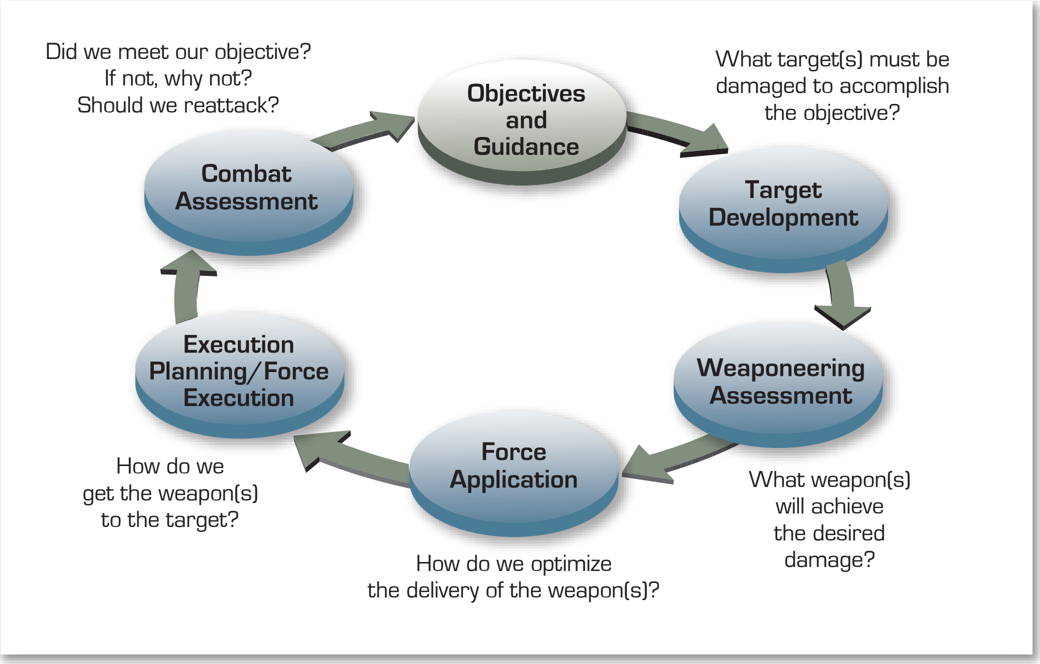


Figure 1.1 Nuclear Targeting Cycle

Chapter 2
Evolution of the Nuclear Deterrent – A History

2.1 Overview

An understanding of the unique status of nuclear weapons is integral to understanding their role. An early realization of their unrivaled destructive power necessitated the development of separate and unique systems and procedures to produce, field, maintain, deploy, employ, and dispose of these special weapons. From the dawn of the nuclear era, even a new vocabulary was required to discuss atomic warfare. Among these terms was the ominous phrase "mutual assured destruction" (MAD), with its connotations of Armageddon and the culture of impending doom it created.

2.2 Nuclear Weapons from 1939–1945

The potential to release nuclear energy for military use was first described in a letter signed by Dr. Albert Einstein to President Franklin D. Roosevelt in August 1939. The letter, written by Einstein at the urging of Dr. Leó Szilárd, described the possibility of setting up a nuclear chain reaction in a large mass of uranium, a phenomenon that would lead to the construction of bombs, and concluded with the statement that experimental

Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

-2-

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work,which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,
A. Einstein
(Albert Einstein)

work grounded in these principles was being carried out by the Nazis in Berlin. Einstein's statement that "such bombs might very well prove to be too heavy for transportation by air" did not diminish his estimate of the potential for a huge increase in the destructive capacity of a single bomb, which he thought could be carried or delivered to a target by ship.

In early 1940, two physicists, Austrian Otto Frisch and German Rudolph Peierls, both of whom had sought refuge from the Nazis and were working at Birmingham University in England, wrote a memorandum suggesting that if a five kilogram mass of uranium-235 (U-235) were made fissionable, it would release an atomic explosion equivalent to thousands of tons of dynamite. Frisch and Peierls explained a method of separating the U-235 and detonating it in a bomb, discussed the radiological hazards the explosion would create, and examined the moral implications of the bomb's use. The significance of Frisch's and Peierls' breakthrough, a massively powerful bomb, light enough to be carried by an aircraft, soon resonated through the government of the United Kingdom, and, in the summer of 1941, the UK government-appointed Maud Committee presented its report endorsing Frisch's and Peierls' conclusions. The Maud Committee report described the facility and processes needed to build an atomic bomb and provided an estimate of the cost. Shortly thereafter, Prime Minister Winston Churchill authorized work to begin on Britain's atomic bomb project, managed by the Nuclear Weapon Directorate, code named *Tube Alloys.*[1]

The first Maud Committee report was sent from Britain to the United States in March 1941, but no comment was received in return. Given the lack of response, a member of the committee flew secretly to the United States in August 1941 to discuss the findings. Subsequent to these discussions, the National Academy of Sciences proposed an all-out U.S. effort to build nuclear weapons.

In a meeting on October 9, 1941, President Roosevelt was impressed with the need for an accelerated program, and by November had authorized the "all-out" effort recommended by the Academy and encouraged by the British. A new U.S. policy committee, the Top Policy Group, was created to inform the President of developments in the program. The first meeting of the group took place on December 6, 1941, one day before the Japanese

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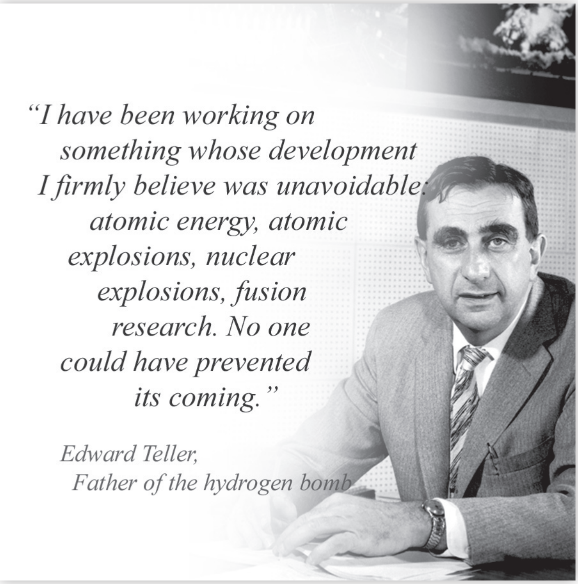
[1] Eventually, the term "tube alloy" was used as the code word for plutonium, whose existence was kept secret at that time. A few years later, scientists in the United States used the term "tuballoy" to refer to depleted uranium.

Prime Minister Mackenzie King, President Franklin D. Roosevelt, and Prime Minister Winston Churchill, Quebec Agreement, August 18, 1943 attack on Pearl Harbor and the entry of the United States into World War II.

Eventually, these efforts led the United States to establish the Manhattan Engineering District, also known as the "Manhattan Project," whose goal was to develop and produce nuclear bombs in time to affect the outcome of World War II. In 1943, as outlined in the Quebec Agreement, the team of scientists working on the British project was transferred to the Manhattan Project along with several scientists from Canada. The U.S. Army Corps of Engineers and Major General Leslie Groves provided oversight management and control of the Manhattan Project, which eventually employed more than 130,000 people. Dr. J. Robert Oppenheimer served as the civilian director of the scientific and engineering research and development activities.


"A few people laughed,
a few people cried,
most people
were silent."

J. Robert Oppenheimer,
recalling the Trinity explosion


"I have been working on
something whose development
I firmly believe was unavoidable:
atomic energy, atomic
explosions, nuclear
explosions, fusion
research. No one
could have prevented
its coming."

Edward Teller,
Father of the hydrogen bomb

On July 16, 1945, the United States detonated the first nuclear explosive device called "Gadget" at the Trinity Site, located within the current White Sands Missile Range, near the town of Alamogordo, New Mexico. Just 21 days later, on August 6, President Harry S. Truman authorized a specially equipped B-29 bomber named *Enola Gay* (**Figure 2.1**) to drop a nuclear bomb, *Little Boy* (**Figure 2.2**), on Hiroshima, Japan. Soon after Hiroshima was attacked, President Truman called for

Figure 2.1 Enola Gay

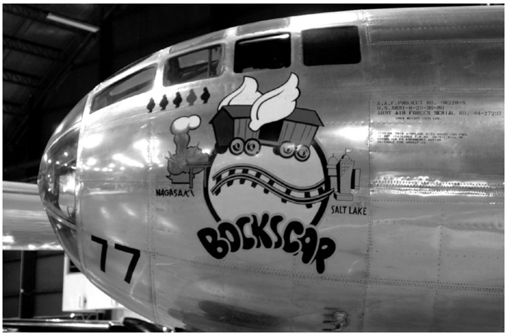


Figure 2.3 Bockscar

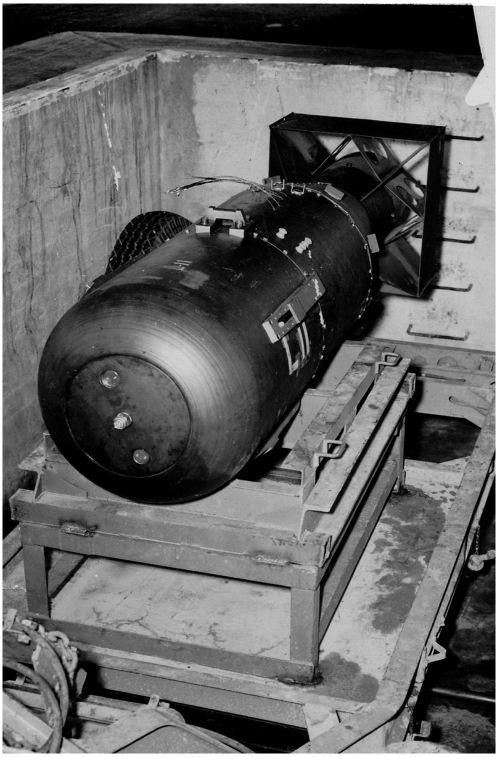


Figure 2.2 Little Boy

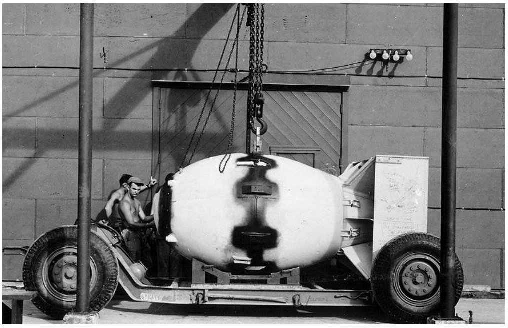


Figure 2.4 Fat Man

Japan's surrender. With no response from the Japanese after three days, on August 9, another B-29 bomber, *Bockscar* (**Figure 2.3**), dropped a second U.S. atomic weapon, *Fat Man* (**Figure 2.4**), on Nagasaki.

On August 14, 1945, Japan surrendered. The use of nuclear weapons had 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 warfare. Many have said their use permanently altered the global balance of power.

2.3 Nuclear Weapons from 1945–1992

The United States enjoyed a nuclear monopoly until the Soviet Union conducted its first nuclear test on August 29, 1949. On October 3, 1952, following the resumption of its independent nuclear weapons program in 1947, the United Kingdom detonated its first nuclear device, becoming the third nation to become nuclear weapons-capable. Less than a month later, on November 1, 1952, the United States detonated its first thermonuclear[2] device, followed nine months later by the Soviet Union's first thermonuclear test. The arms race was on.

Both the United States and the Soviet Union increased their stockpile quantities until each possessed nuclear weapons in sufficient quantities to achieve a second-strike capability, meaning both sides would be capable of massive retaliation even after absorbing an all-out first strike. In this way, the United States and the Soviet Union were certain of mutual assured destruction, which provided both nations deterrence against hostilities toward one another. These were the uneasy years of the nuclear "balance of terror," when the potential for total devastation from a superpower nuclear exchange was the most urgent threat facing the Nation and the prospect of an attack against the North Atlantic Treaty Organization (NATO) in Western Europe was on the forefront in U.S. military planning.

For the first decade or so of the nuclear era, the U.S. nuclear weapons program was focused on producing sufficient nuclear material to build enough weapons to support a nuclear capability for almost every type of military delivery system available at the time.

For the first decade or so of the nuclear era, the U.S. nuclear weapons program was focused on producing sufficient nuclear material to build enough weapons to support a nuclear capability for almost every type of military delivery system available at the time. This was considered essential because of the possibility of Cold War escalation, specifically, the danger that a potential U.S.-Soviet conflict would escalate from a conventional confrontation to the limited use of battlefield and tactical nuclear weapons to an all-out strategic nuclear exchange. Throughout the late 1950s, the United States was committed to increasing nuclear weapons quantities to enhance

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[2] A thermonuclear weapon uses both nuclear fission and nuclear fusion to produce a greatly increased yield in a device small enough to be delivered as a weapon.


TRINITY SITE
WHERE
THE WORLD'S FIRST
NUCLEAR DEVICE
WAS EXPLODED ON
JULY 16, 1945
ERECTED 1965
WHITE SANDS MISSILE RANGE
J FREDERICK THORLIN
MAJOR GENERAL US ARMY
COMMANDING

flexibility in the types of nuclear-capable military delivery vehicles and the bombs and warheads available for delivery.

By the end of 1967, both the Soviet Union and the United States each had more than 30,000 nuclear weapons. Most of these warheads had relatively low yields and were for short-range, non-strategic (also called "tactical" or "theater") systems.[3] At the time, many U.S. weapons were in Europe within the territories of NATO allies. For the United States, the large number of stockpiled non-strategic weapons offset the vast advantage the Soviet Union had in conventional military forces. Beginning in 1968, the United States shifted priorities and began a significant reduction in non-strategic nuclear weapons.

Then by 1991, when the United States signed the first Strategic Arms Reduction Treaty (START I), the total U.S. stockpile was approximately 19,000 nuclear weapons. Also in 1991, President George H. W. Bush initiated further reductions in non-strategic nuclear weapons. In the *Presidential Nuclear Initiative* (PNI) of 1991, the President announced the United States would retain only a small fraction of the Cold War levels of non-strategic nuclear weapons. The PNI decision significantly reduced the number of U.S. forward-deployed nuclear weapons in Europe and eliminated all non-strategic systems, with the exception of gravity bombs, retained primarily to support NATO in Europe, and the Tomahawk sea-launched cruise missile (SLCM), which was removed from deployment but not immediately retired.

Furthermore in the mid-1960s, the United States shifted priorities from quantity to sophistication and U.S. nuclear stockpile production established a recurring pattern of deployment, fielding, and then replacement by more modern weapons. Thus, from the mid-1960s until 1992, the U.S. nuclear weapons program was characterized by a continuous cycle of modernization programs. In addition to warheads that were simpler[4] for the military operator, modern characteristics included greater yield, smaller size,[5]

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[3] Non-strategic or tactical nuclear weapons refer to nuclear weapons designed to be used on a battlefield in military situations. This is opposed to strategic nuclear weapons, which are designed to be used against enemy cities, factories, and other larger-area targets to damage the enemy's ability to wage war.

[4] As a function of simplicity, the United States moved away from warheads requiring in-flight insertion (IFI) of the nuclear component, to warheads that were self-contained sealed-pit devices ("wooden rounds") without requiring the military operator to insert components, or "build" the warhead. While these warheads may have been more complex internally, this was transparent to the operator and the pre-fire procedures were much simpler.

[5] Smaller warhead size allowed strategic missiles to carry a larger number of reentry bodies/vehicles and made nuclear capability possible for a greater number of delivery methods, including the possibility for nuclear weapons to be human-portable or fired by cannon artillery.

better employment characteristics,[6] and more modern safety, security, and control features. A key part of this process was the use of nuclear testing for a wide variety of purposes,[7] including the ability to:

- better understand nuclear physics and weapon design and functioning;
- determine more accurately the nature and distances associated with nuclear detonation effects;
- refine new designs in the development process;
- test the yield of weapons;
- confirm or define certain types of safety or yield problems found in nuclear components in weapons already fielded; and
- certify the design modification required to correct those problems.

During this time the United States utilized a complementary combination of underground nuclear testing and non-nuclear testing and evaluation to refine designs in the development stage, certify weapon designs and production processes, validate safety, estimate reliability, detect defects, and confirm effective repairs. In order for a nuclear weapon to be fielded, it had to go through development, testing and evaluation, initial and subsequent full-scale production, and, finally, fielding for possible wartime employment. Eventually, as the weapon aged and additional modern safety, security, and operational design features became available, the United States began development of a newer, better, and more sophisticated system to replace the fielded weapon. These modernization programs were usually timed to provide replacement weapons after the older warheads had been deployed for 15 to 20 years, a period known as the "protected period."

2.4 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

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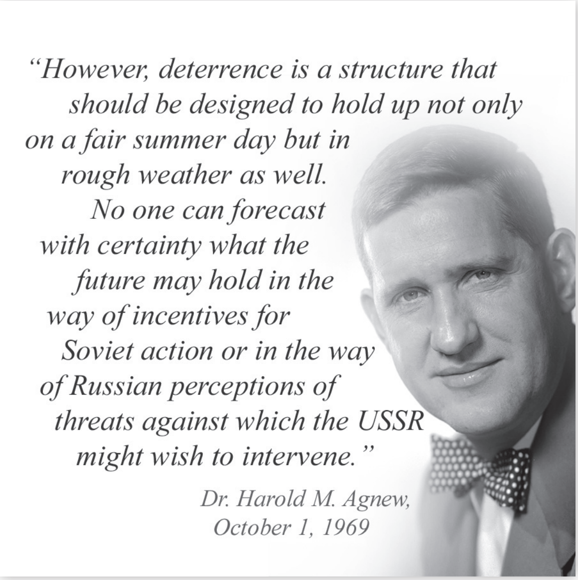
[6] Some of the features that provided increased operational capability included selectable yields, better fuzing (for a more accurate height of burst), increased range (for cannon-fired warheads), and shorter response times.

[7] The United States conducted nuclear tests from 1945 until 1992. The United States, together with the United Kingdom, the Soviet Union, and France, observed a voluntary moratorium on testing from October 1958 to 1960. The moratorium was broken by France in 1960, and the United States and the Soviet Union resumed testing in 1961.

subjected to nuclear explosions. In 1963, three (United States, United Kingdom, Soviet Union) of the four nuclear states 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, the legislation that halted U.S. nuclear testing, had several key elements. The law included a provision for 15 additional nuclear 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.[8] 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.[9] Therefore, the decision was made to forgo the 15 additional tests permitted under the new law and no other tests were conducted.[10]



"However, deterrence is a structure that should be designed to hold up not only on a fair summer day but in rough weather as well. No one can forecast with certainty what the future may hold in the way of incentives for Soviet action or in the way of Russian perceptions of threats against which the USSR might wish to intervene."

Dr. Harold M. Agnew, October 1, 1969

This nuclear test prohibition impacted the stockpile management process in several significant ways. First, the legislation was too restrictive to achieve the objective of

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[8] Pub. L. 102-377, the *Fiscal Year 1993 Energy and Water Development Appropriations Act*, 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).

[9] 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, 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.

[10] The 1992 legislation also stated that if, after September 30, 1996, any other nation conducted a nuclear test, then the restriction would be eliminated. Since October 1996, several nations have conducted nuclear tests. The current restriction is one of policy, not of law.

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 paradigm for the U.S. nuclear weapons program. The modernization and production cycle, in which newer-design warheads replaced older warheads, was replaced 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. Without nuclear testing, there was a possibility that one weapon-type after another would be retired because of an inability to correct emerging problems, which might eventually lead to unintended, unilateral disarmament by the United States. While this has not occurred, it was a projected issue in 1992.

2.5 Nuclear Stockpile Since 1992

In response to these new circumstances and the resulting paradigm shift, the *National Defense Authorization Act for Fiscal Year 1994* (Pub. L. 103-160) required the Department of Energy (DOE) to "establish a stewardship program to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons." In the absence of nuclear testing, the DOE Stockpile Stewardship Program was directed to support a focused, multifaceted program to increase the understanding of the enduring stockpile; predict, detect, and evaluate potential problems due to the aging of the stockpile; refurbish and remanufacture weapons and components, as required; and maintain the science and engineering institutions needed to support the Nation's nuclear deterrent, now and in the future. In other words, the nuclear weapons establishment was called upon to determine how to ensure the continued safety, security, and effectiveness of the weapons in the U.S. nuclear stockpile without underground testing and without any plan to replace aging weapons, even as they aged beyond any previously experienced lifespan.

Public Law 103-160 required the Department of Energy to "establish a stewardship program to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons."

This Stockpile Stewardship Program has served as a substitute for nuclear testing since 1992, maintained the stockpile, and includes advanced computer simulations, experiments, enhanced surveillance, and the data from more than 1,000 previous nuclear tests.

Since early 1993, the United States has maintained its nuclear stockpile through a newer, shortened process comparable to the previous cycle of development, production, retirement, and replacement. The process of *modernize* and *replace* became one of *retain* and *maintain*, consisting primarily of activities associated with the continuous assessment, maintenance and repair, and refurbishment of U.S. nuclear weapons. Periodic reductions in quantities corresponded with the U.S. reductions in strategic forces associated with strategic force reduction treaties.

With the entry into force of START I in 1994, the United States was on a path to a total stockpile of approximately 10,000 weapons, of which the majority were strategic weapons. As a result of the 2003 *Strategic Offensive Reductions Treaty* (SORT) and the 2004 *Strategic Capabilities Assessment*, the United States reduced its total nuclear weapons stockpile to approximately 5,113 weapons in 2009. New START has led to further reductions in the total number of U.S. nuclear weapons and by the end of September 2014, the U.S. nuclear stockpile consisted of 4,717 warheads. **Figure 2.5** shows the size of the U.S. nuclear stockpile from 1945 to 2014.

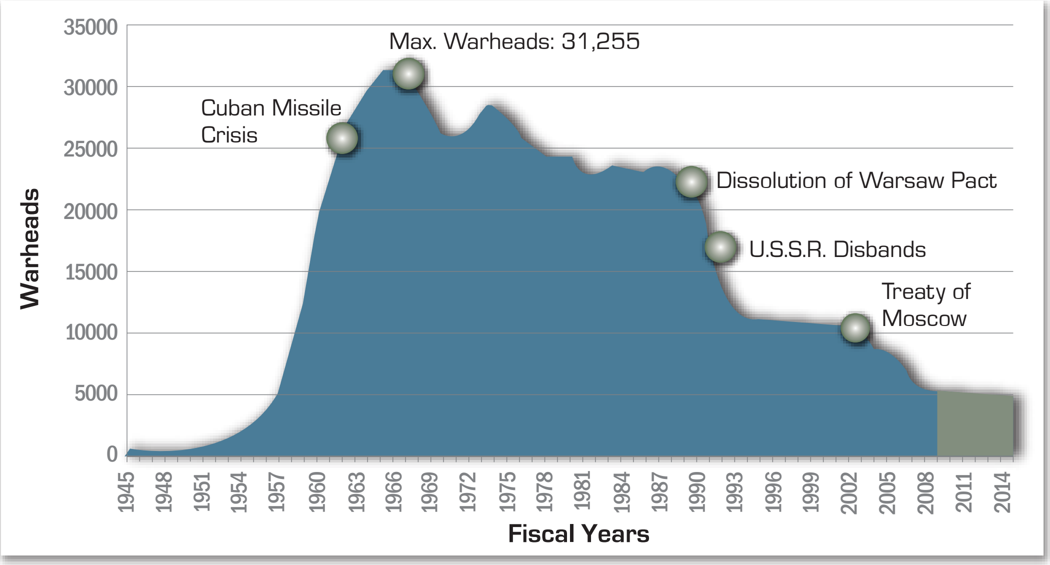

Figure 2.5 U.S. Nuclear Weapons Stockpile, 1945–2014
[Includes active and inactive warheads. Several thousand additional nuclear warheads are retired and awaiting dismantlement.]

Chapter 3

U.S. Nuclear Forces and Weapons

3.1 Overview

On November 14, 2014, following the 2014 *Nuclear Enterprise Reviews* (NERs), Secretary of Defense Chuck Hagel clarified the importance of the nuclear mission and its role in defending the United States. "Our nuclear deterrent plays a critical role in ensuring U.S. national security, and it is DoD's highest priority mission. No other capability we have is more important," stated Secretary Hagel. The U.S. nuclear triad deters nuclear attack on the United States and its allies and partners, prevents potential adversaries from trying to escalate their way out of failed conventional aggression, and provides the means for effective response should deterrence fail. While the Secretary was clear America's nuclear deterrent remains safe, secure, and effective, the reviews found evidence of systemic problems that, if not addressed, could undermine the safety, security, and effectiveness of the elements of the nuclear force in the future. Responding to the NERs concerns, the United States, through the DoD and the DOE/National Nuclear Security Administration (NNSA), seeks to ensure nuclear force modernization, infrastructure upgrades, warhead life extension programs (LEPs), adequate manning, and senior-level

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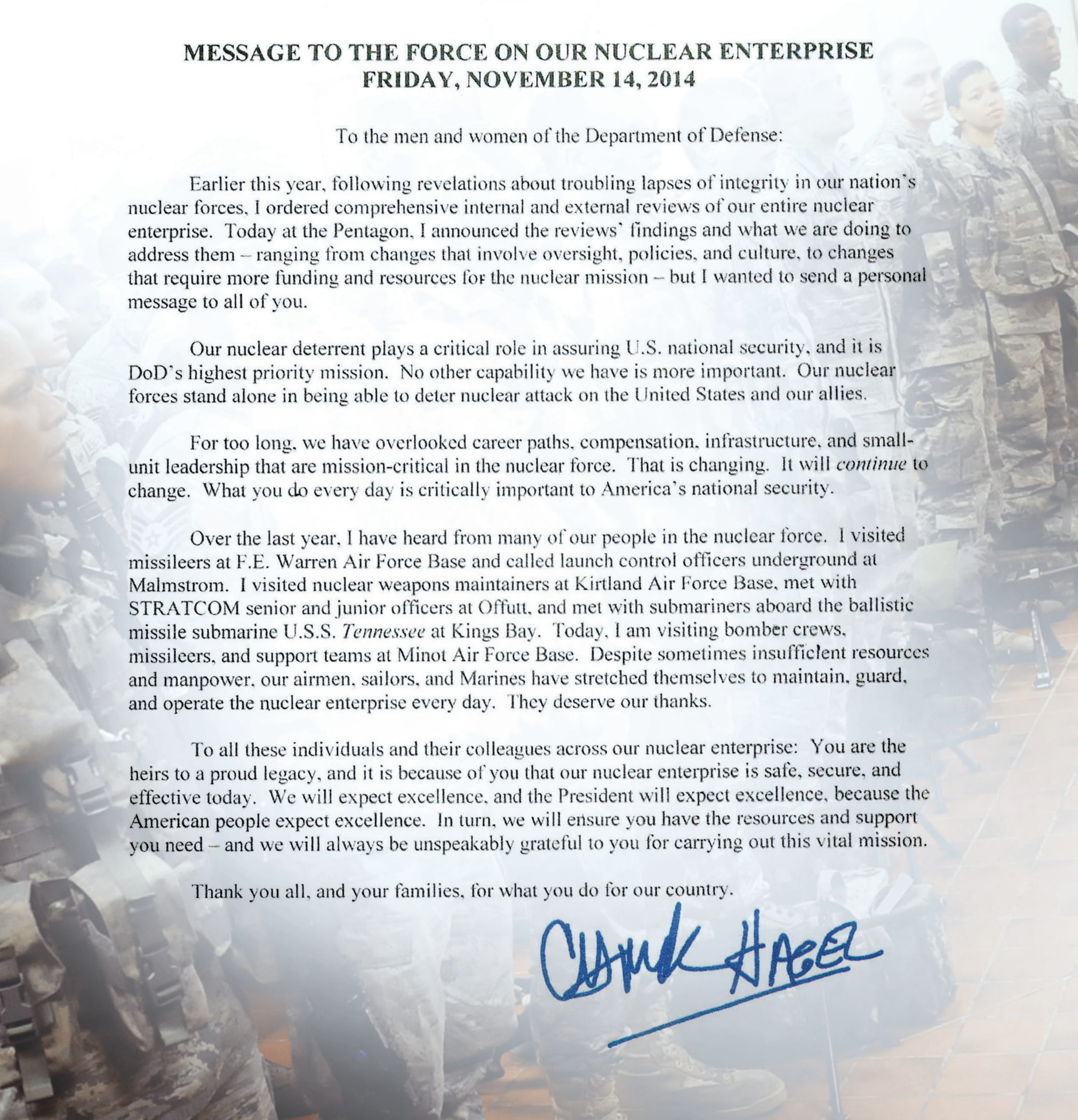

MESSAGE TO THE FORCE ON OUR NUCLEAR ENTERPRISE
FRIDAY, NOVEMBER 14, 2014

To the men and women of the Department of Defense:

Earlier this year, following revelations about troubling lapses of integrity in our nation's nuclear forces, I ordered comprehensive internal and external reviews of our entire nuclear enterprise. Today at the Pentagon, I announced the reviews' findings and what we are doing to address them – ranging from changes that involve oversight, policies, and culture, to changes that require more funding and resources for the nuclear mission – but I wanted to send a personal message to all of you.

Our nuclear deterrent plays a critical role in assuring U.S. national security, and it is DoD's highest priority mission. No other capability we have is more important. Our nuclear forces stand alone in being able to deter nuclear attack on the United States and our allies.

For too long, we have overlooked career paths, compensation, infrastructure, and small-unit leadership that are mission-critical in the nuclear force. That is changing. It will *continue* to change. What you do every day is critically important to America's national security.

Over the last year, I have heard from many of our people in the nuclear force. I visited missileers at F.E. Warren Air Force Base and called launch control officers underground at Malmstrom. I visited nuclear weapons maintainers at Kirtland Air Force Base, met with STRATCOM senior and junior officers at Offutt, and met with submariners aboard the ballistic missile submarine U.S.S. *Tennessee* at Kings Bay. Today, I am visiting bomber crews, missileers, and support teams at Minot Air Force Base. Despite sometimes insufficient resources and manpower, our airmen, sailors, and Marines have stretched themselves to maintain, guard, and operate the nuclear enterprise every day. They deserve our thanks.

To all these individuals and their colleagues across our nuclear enterprise: You are the heirs to a proud legacy, and it is because of you that our nuclear enterprise is safe, secure, and effective today. We will expect excellence, and the President will expect excellence, because the American people expect excellence. In turn, we will ensure you have the resources and support you need – and we will always be unspeakably grateful to you for carrying out this vital mission.

Thank you all, and your families, for what you do for our country.

Chuck Hagel

attention are the focus toward the nuclear deterrent priority mission. This chapter provides an overview of current U.S. nuclear delivery systems/platforms and the nuclear weapons stockpile, as depicted in **Figure 3.1**.

AIR-LAUNCHED

Description: Heavy Bomber
Mission: Air-to-Surface
Platform: B-52H
Weapon: W80-1 on Air-Launched Cruise Missile (ALCM)
Service: USAF

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

Description: Dual-Capable Aircraft
Mission: Air-to-Surface
Platform: F-15, F-16, NATO aircraft, and a future F-35 mission
Weapon: B61-3/4/10
Service: USAF & select NATO Allies

GROUND-LAUNCHED

Description: Intercontinental Ballistic Missile (ICBM)
Mission: Surface-to-Surface
Platform: Minuteman III
Weapon: W78, W87
Service: USAF

SEA-LAUNCHED

Description: Submarine-Launched Ballistic Missile (SLBM)
Mission: Underwater-to-Surface
Platform: Ohio-class SSBN
Weapon: W76-0/1, W88
Service: USN

Note: B = Bomb W = Warhead

Figure 3.1 Current U.S. Nuclear Deterrent (Delivery Systems and Associated Nuclear Weapons)

3.2 Nuclear Weapon Platforms and Delivery Systems

A nuclear weapon delivery system is the military platform by which a nuclear weapon is delivered to its intended target in the event of authorized use. Most nuclear weapons have been designed for specific delivery systems. The United States maintains a nuclear triad, or a system of delivery systems comprised of sea, land, and air based on submarine-launched ballistic missiles (SLBMs), intercontinental ballistic missiles (ICBMs), and heavy bombers. Specifically, the United States deploys a mix of silo-based Minuteman III ICBMs, Trident II SLBMs carried on Ohio-class ballistic missile submarines (SSBNs),[1] and B-2A and B-52H nuclear-capable heavy bombers. Additionally the U.S. nuclear force includes dual-capable aircraft (DCA).

Weapons in the U.S. nuclear arsenal provide a wide range of options that can be tailored to meet desired military and political objectives. Each leg of the triad has advantages that warrant retention and are inextricably linked yet unique. Ballistic missile submarines and the SLBMs they carry represent the most survivable leg of the nuclear triad. ICBMs

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[1] 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.

Figure 3.2. U.S. Nuclear Triad

contribute to stability and ensure a secure second-strike capability and, like SLBMs, ICBMs have low vulnerability to air defenses. Unlike ICBMs and SLBMs, bombers can be deployed forward as a visible show of presence in crisis to strengthen deterrence against potential adversaries and provide assurance to allies and partners, while also retaining the possibility for recall after launch or takeoff toward a target. **Figure 3.2** depicts the U.S. nuclear triad.

3.2.1 Sea-Launched

Nuclear-powered Ohio-class SSBNs are designed to deliver Trident II, also referred to as D5, submarine-launched ballistic missiles. SSBNs are considered the most survivable leg of the nuclear triad due to 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.

As the virtually undetectable undersea launch platforms of 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.

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

Under the requirements of the Strategic Arms Reduction Treaty (START II), which was agreed to in June 1992, the number of ballistic missile submarines was limited to 14 from the year 2002 forward. Rather than decommissioning these four submarines, the U.S. Navy has converted them to SSGNs, or conventionally armed nuclear-powered submarines.

By 2020, U.S. Ohio-class submarines (**Figure 3.3**) will be in service longer than any previous submarines. As a prudent hedge, the Navy will retain all 14 SSBNs for the near term. To maintain an at-sea presence for the long term, the Navy is planning 12 Ohio-class replacement (OCR) SSBNs with the first planned for patrol in Fiscal Year (FY) 2031. Maintaining the replacement schedule is important because, as the delivery of the OCR occurs, the original Ohio-class SSBNs start to come off service.

Figure 3.3 USS Pennsylvania

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). Each generation has been continuously deployed as a survivable force and has been routinely operationally tested and evaluated to maintain confidence and credibility in the deterrent.

Today's Trident II missiles are launched from Ohio-class submarines, each carrying 24 missiles.[2] The Trident II 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 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

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[2] See **Figure 3.8**, *U.S. Nuclear Force Structure Plan* for impact of New START on Trident future loadouts.

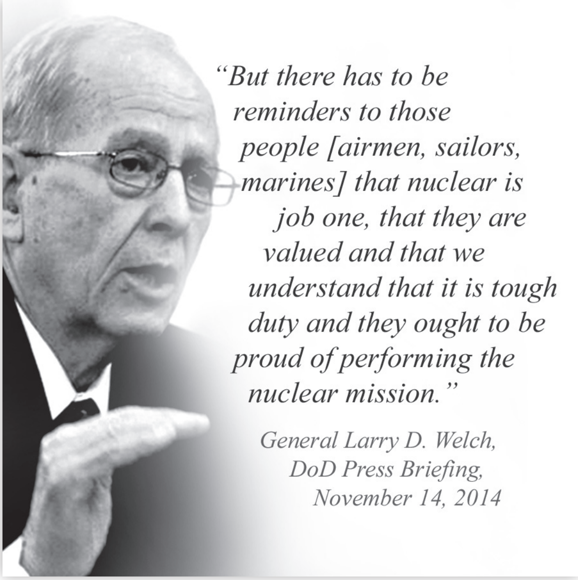
stage motor kicks in, the missile is traveling in excess of 20,000 feet (6,096 meters) per second.

Trident II was first deployed in 1990 and is planned to be deployed past 2020. The Trident II missile is also provided to the United Kingdom, which equips the missile with UK nuclear warheads and deploys the missile on Vanguard Class UK submarines.

3.2.2 Ground-Launched

Intercontinental ballistic missiles, which are launched from stationary silos, are on continuous alert, provide immediate reaction if necessary, and can strike their intended targets within 30 minutes of launch.

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, a project 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. The Titan was the largest ICBM ever deployed; and two versions of the Titan, the I and II, were deployed from 1962–1987. The Titan held a nine megaton nuclear warhead, making it one of the most powerful nuclear weapons in American history. When the Minuteman became operational in 1962, 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 was deployed from 1987 until 2005 and held up to ten nuclear warheads. It was decided under START II, which never entered into force, to remove the Peacekeeper from the ICBM force.



“But there has to be reminders to those people [airmen, sailors, marines] that nuclear is job one, that they are valued and that we understand that it is tough duty and they ought to be proud of performing the nuclear mission.”

General Larry D. Welch,
DoD Press Briefing,
November 14, 2014

An unarmed Minuteman III launches during an operational test March 23, 2015, Vandenberg Air Force Base, California

Currently, the U.S. ICBM force consists of Minuteman III (MMIII) missiles. 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 "deMIRVed"[3] all deployed ICBMs, so that each MMIII is single warhead. The United States continues the Minuteman III LEP, with the aim of keeping MMIII in service until 2030. The DoD is undergoing an analysis of alternatives (AoA) for a follow-on ICBM, referred to as the Ground-Based Strategic Deterrent concept. The study considers a range of possible future options, with the objective of defining a cost-effective approach that supports national security objectives while promoting stable deterrence.

3.2.3 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 offsets the risks of geopolitical uncertainties. Furthermore, nuclear-capable bombers are important to maintain extended deterrence against potential attacks on U.S. allies and partners. The ability to forward deploy heavy bombers signals U.S. resolve and commitment in a crisis and enhances the reassurance of U.S. allies and partners, strengthening regional security architectures.

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 3.4**) 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 nuclear air-launched cruise missiles (ALCMs). B-52H bombers carry six AGM-86B/C/D

Figure 3.4 B-52H "Stratofortress"

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[3] A "MIRVed" ballistic missile is one that carries Multiple Independently Targetable Reentry Vehicles (MIRVs).

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. ALCMs were developed to increase the effectiveness of B-52H bombers with a stand-off capability.

The B-2 "Spirit" stealth bomber (**Figure 3.5**) entered the force in 1997, enhancing U.S. deterrent forces with its deep penetration capability. The B-2 is a multi-role bomber capable of delivering both conventional and nuclear munitions. The B-2 force is located at Whiteman AFB in Missouri.

Figure 3.5 B-2 "Spirit"

In addition to its strategic nuclear forces that make up the nuclear triad, the United States has CONUS-based and forward-deployed **dual-capable aircraft** in Europe consisting of the F-15 (**Figure 3.6**) and the F-16 (**Figure 3.7**). DCA are able to deliver conventional munitions or B61 nuclear bombs and are available to support the North Atlantic Treaty Organization (NATO) in combined-theater nuclear operations.

Figure 3.6 F-15

Figure 3.7 F-16

NATO's announcements over the last five years reinforce the relevance of the DCA mission. At its November 2010 summit in Lisbon, NATO approved the Strategic Concept making clear the intended duration of its nuclear policy: "Deterrence, based on an appropriate mix of nuclear and conventional capabilities, remains a core element of our overall strategy...As long as nuclear weapons exist, NATO will remain a nuclear alliance." Furthermore, the Heads of State and Government mandated the *Deterrence and Defence Posture Review,* and in 2012, the results included reaffirmation that nuclear weapons are a core component of NATO's overall capabilities for deterrence and defence and that allies will ensure that all components of NATO's nuclear deterrent remain safe, secure, and effective for as long as NATO remains a nuclear alliance.

The Air Force is in the process of replacing the F-16s with the F-35 Lightning II, originally referred to as the Joint Strike Fighter, and plans to retain a dual-capable mission in the F-35. The United States retains the capability to forward deploy non-strategic nuclear weapons in support of its commitments to its NATO allies.

3.2.4 Force Structure

Based on requirements levied in the New START agreement, by February 5, 2018, the DoD will transition today's nuclear triad composition to the Treaty-compliant force structure, shown in **Figure 3.8**, which fully supports the President's *National Security Strategy* and *Nuclear Weapons Employment Strategy*:

Existing Types of ICBMs, SLBMs, and heavy bombers	Deployed and Non-Deployed (2014)	Deployed (2018)	Deployed and Non-Deployed (2018)
Minuteman III ICBMs	454	400	454
Trident II SLBMs	336	240	280
B-2A/B-52H Bombers	96	60	66
TOTAL	**886**	**700**	**800**

Figure 3.8 U.S. Nuclear Force Structure Plan

- **400 deployed ICBMs.** The DoD will place 50 currently deployed ICBM launchers into a non-deployed status by removing the ICBMs from these silos. Non-deployed ICBM launchers include four non-deployed test launchers.
- **240 deployed SLBMs on 14 SSBNs.** The DoD will convert four SSBN launch tubes on each of the 14 SSBNs, removing 56 launch tubes from accountability under the Treaty. This will result in a maximum of 12 SSBNs with 20 missiles loaded at any given time, providing 240 deployed SLBMs and SLBM launchers accountable under New START.
- **60 deployed heavy bombers.** The DoD will retain 19 B-2As and 41 B-52Hs as nuclear-capable heavy bombers and will convert 30 B-52H bombers to a

conventional-only role, thereby removing them from accountability under New START. Non-deployed bombers include three non-deployed test bombers.

- **Limit of 1,550 accountable warheads.** The DoD will manage the overall accountable warheads under this force structure to meet the New START central limit of 1,550 warheads on deployed ICBMs, warheads on deployed SLBMs, and nuclear warheads counted for deployed heavy bombers.

3.3 Nuclear Weapons

All nuclear weapons in the U.S. stockpile are designated either as a warhead (W) or as a bomb (B).[4] In this handbook, the term "warhead" denotes individual weapons without distinguishing between "W" or "B" designators, and the terms "weapon" and "warhead" are used interchangeably. Weapons that have different engineering requirements because they must interface with a launch or delivery system are called warheads. Weapons that do not have these interface requirements, such as gravity bombs and retired atomic demolition munitions (ADMs) are called bombs. Using these definitions, the total number of U.S. nuclear weapons is equal to the sum of warheads plus bombs. Additionally, the term warhead-type is used to denote a population of weapons with the same design. Warheads in the current force structure include B61, W76, W78, W80, B83, W87, and W88. **Figure 3.9** is a comprehensive list of U.S. nuclear warhead-types.

Throughout the history of nuclear weapons development, the United States has developed families of warheads based on a single-warhead design. Thus, some weapons in the U.S. stockpile were developed as modifications (Mods) to an already complete 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 a few different components that changed the operational characteristics of the weapon in a significant way. Five of these Mods are still in the current stockpile: B61-3, B61-4, B61-7, B61-10, and B61-11. The B61-12 is currently in preproduction phase. Furthermore, this approach is more efficient when conducting quality assurance testing and evaluation because warhead Mods that have common components can be tested as a family of warheads.

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[4] The earliest U.S. nuclear weapons were distinguished by Mark (MK) numbers, derived from the old British system for designating aircraft. In 1949, the MK5 nuclear weapon, intended for the Air Force's surface-to-surface Matador cruise missile and the Navy's Regulus I cruise missile, had interface engineering considerations that were not common to gravity bombs. A programmatic decision was made to designate the weapon as a warhead, using the designation W5. At the programmatic level, the Project Officers Group (POG), and the agencies participating in the POG process, distinguish between warheads and bombs.

Figure 3.9 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	Hounddog ASM/Mace GLCM
W29	Redstone SSM*
W30	Talos AAW/TADM
W31	Nike-Hercules SAM/Honest John SSM/ ADM
W32	240mm AFAP*
W33	8 in. 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

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

Figure 3.9 [cont.] Comprehensive List of Warhead-Types and Descriptions

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 in. AFAP*
W76	Trident II SLBM ▨
B77	Strategic Bomb*
W78	Minuteman III ICBM ▨
W79	8 in. 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)
RNEP	Earth Penetrator (proposed)
RRW-1	Reliable Replacement Warhead-SLBM (proposed)
RRW-2	Reliable Replacement Warhead-Bomb (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

All nuclear weapons in the U.S. stockpile are designated as strategic or non-strategic. Strategic weapons are those delivered by ICBMs, SLBMs, or heavy bombers. All other nuclear weapons are non-strategic. Non-strategic nuclear weapons, which are sometimes called “tactical” or “theater” nuclear weapons, historically have included bombs delivered by DCA that 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 (NDBs).

3.4 Stockpile Quantities

As stated in the 2010 *Nuclear Posture Review*, the United States is committed to reducing the role and number of its nuclear weapons. Nuclear weapons stockpile reductions are commensurate with the sustainment of an effective nuclear force that provides continued deterrence and remains responsive to new uncertainties in the international security arena.

Nuclear weapon stockpile quantities are annually authorized by presidential directive. The directive includes specific guidance to the DoD and the DOE/NNSA. The directive also includes a Nuclear Weapons Stockpile Plan (NWSP) that authorizes specific quantities of warheads, by type and by year, for a multi-year period.

As of September 2014, the U.S. nuclear stockpile consisted of 4,717 warheads. This number represents an 85 percent reduction in the stockpile from its maximum (31,255) at the end of FY 1967, and a 78 percent reduction from its level (22,217) when the Berlin Wall fell in late 1989. Furthermore, the number of U.S. non-strategic nuclear weapons has declined by approximately 90 percent since September 30, 1991. **Figure 3.10** shows U.S. stockpile quantities since 1962.

3.5 Stockpile Configuration

The current U.S. stockpile is composed of weapons developed and produced during the Cold War and maintained well-beyond the original planned lives for roles and missions that have evolved significantly since original production. A large part of modern stockpile management involves maintaining aging weapons in an environment where they cannot be replaced once dismantled or become irreparable. Thus, stockpile composition refers

Figure 3.10 Stockpile Numbers – Fiscal Years 1962–2014

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

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 operationally deployed weapons, those which could be deployed if ever needed.[5]

As part of stockpile composition management, it is necessary 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 assure U.S. allies and partners 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 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

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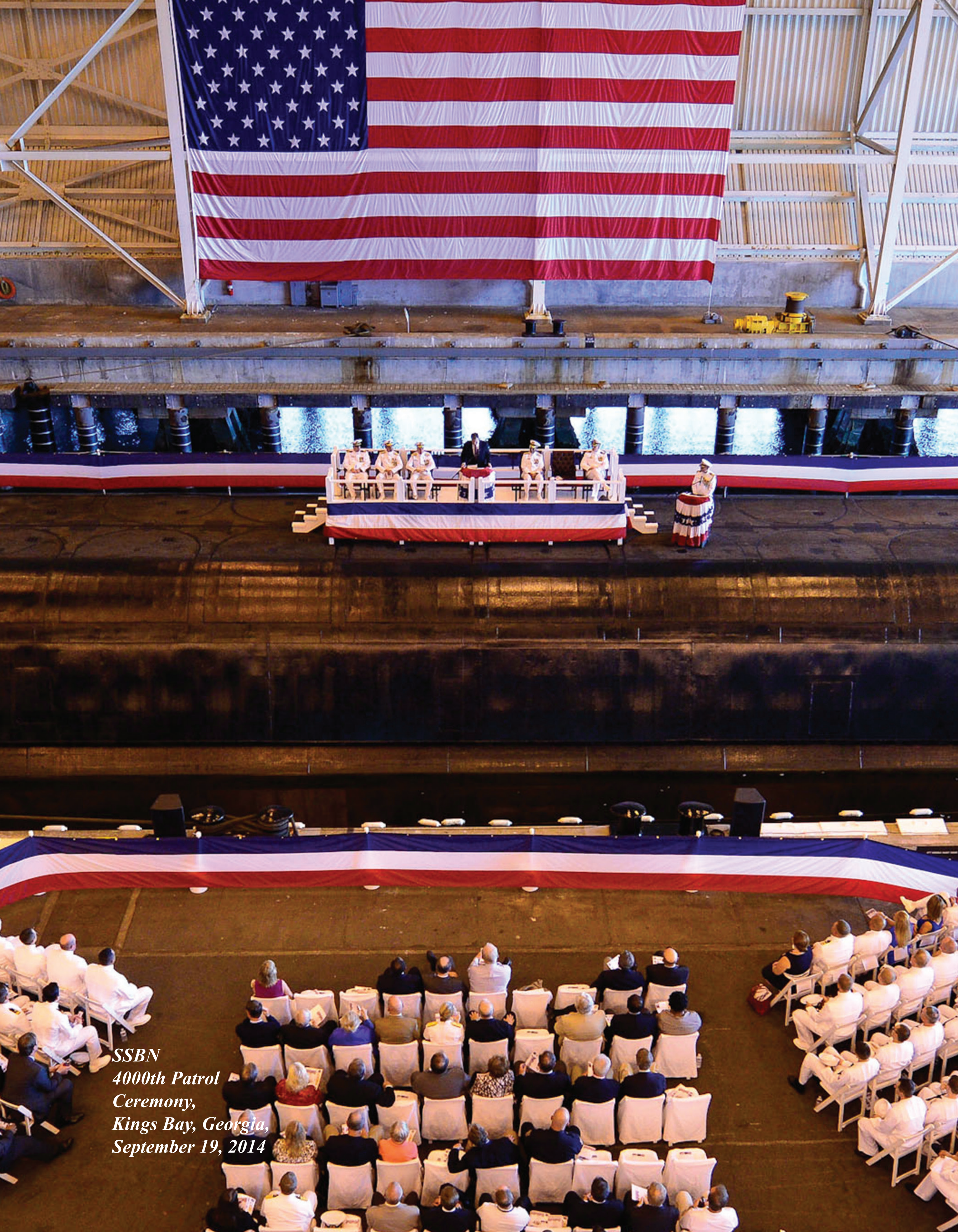
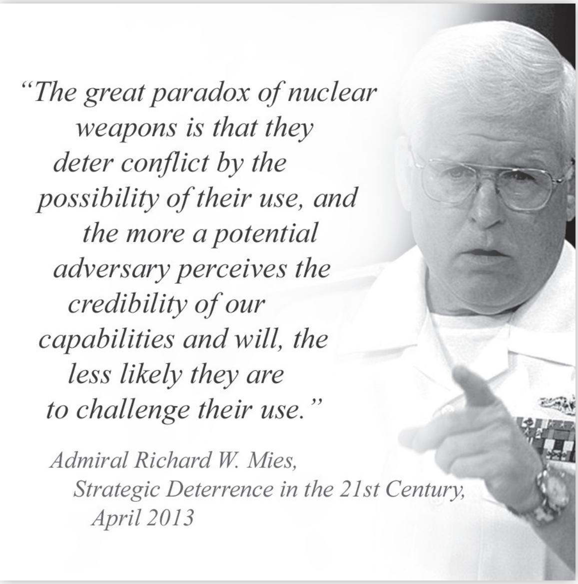
[5] U.S. Strategic Command, the Military Departments, and other Combatant Commanders determine the numbers and types of operational nuclear weapons required to satisfy national security policy objectives. These numbers, combined with DOE/NNSA requirements and capacity to support surveillance, maintenance, and life extension, result in stockpile projections over time. These projections are codified in the annual NWSP issued by the President. See *Appendix A: Nuclear Weapons Council and Annual Reports* for information on the NWSP.



SSBN 4000th Patrol Ceremony, Kings Bay, Georgia, September 19, 2014 resources and preserve limited facilities and capabilities, some weapons are maintained in less-ready modes, requiring maintenance action or component replacement/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, U.S. stockpile composition must retain some flexibility to allow 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, or the categorization of warheads by function and readiness state, and the associated logistical planning.



> *"The great paradox of nuclear weapons is that they deter conflict by the possibility of their use, and the more a potential adversary perceives the credibility of our capabilities and will, the less likely they are to challenge their use."*
>
> *Admiral Richard W. Mies,*
> *Strategic Deterrence in the 21st Century,*
> *April 2013*

3.5.1 Configuration Management

Stockpile maintenance is an intricate process involving almost every part of the DOE/NNSA nuclear security enterprise and organizations with nuclear missions within the DoD. This joint DoD-DOE/NNSA process coordinates technical complexities and operational needs associated with the various weapons systems. The Project Officers Group (POG) is at one end of this joint process while the Nuclear Weapons Council (NWC) is at the other. The role of the NWC and the POG in the stockpile management process is discussed in *Chapter 5: Stockpile Management, Processes, and Organizations*.

Operational warheads are called the *active stockpile*. An operational weapon is maintained with functioning limited life components (LLCs). Non-operational 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.

3.5.2 Nuclear Weapons Stockpile Hedge

The stockpile is subject to several uncertainties and associated risks, including the possibility of an unforeseen catastrophic failure of a class of delivery vehicles, warhead-type or family, or an unexpected change in the geopolitical situation that requires an increase in the number of weapons available for use. It is vital for the DoD and the DOE/NNSA to have procedures in place designed to mitigate these and other risks with a strategy that accounts for threats to the stability of the nuclear deterrent at lower stockpile levels.

Basic approaches to nuclear stockpile risk mitigation include the existence of a significant warhead production capability, maintenance of warheads designated to counter unforeseen significant events noted above, or some combination of the two. Designating 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 or decrease production, as required. Today, the United States does not have an active, robust nuclear weapon production capability and relies on the maintenance of a warhead hedge to reduce accepted 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 dismantle additional weapons is not taken lightly. Even though some components can be maintained, construction and deployment time to a first weapon could take two decades to produce replacement weapons, in quantities, using a qualified production process. Thus, decisions regarding the U.S. nuclear weapons stockpile hedge are more complicated than they might seem and are considered by U.S. policy makers at the highest levels. Hedge weapons are included in both the active and inactive stockpiles.

Active Stockpile

Active stockpile warheads are maintained in an operational status. These weapons 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 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, a reentry vehicle, an air-launched cruise missile, or a delivery aircraft).

Active stockpile warheads include *active ready* warheads which are operational and ready for wartime employment; *active hedge* warheads which 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 the tritium components removed as soon as logistically practical and the tritium is returned to the national repository.[6] 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, others may not require a reliability estimate. All inactive stockpile warheads are validated for safety, usually every year, and are normally stored at a depot, rather than an operational base. These warheads are never uploaded on a delivery vehicle.

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

Readiness States

The annual Requirements and Planning Document (RPD) provides the supporting details upon which the NWSP is based. The RPD uses a system of readiness states (RS) to determine what quantities of warheads require various programmatic activities. For additional information see *Appendix A: Nuclear Weapons Council and Annual Reports*.

3.5.3 Logistical Planning

Logistical planning is necessary for configuration management to ensure components, weapons movements, and locations match as appropriate. Logistical planning includes

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[6] 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.

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-DOE/NNSA agreements and memoranda of understanding, Joint Publications (JPs) published by the Joint Chiefs of Staff, the Joint Nuclear Weapons Publications System (JNWPS),[7] and Military Departments' regulations. The key theme for logistical planning is to ensure weapons are handled or stored in a way that is always safe, secure, and maintained to be reliable, with appropriate controls in place to preclude unauthorized acts or events.

Storage

Storage refers to 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 3.11**). 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 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 at the exclusion area and greater distances for the overall 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.

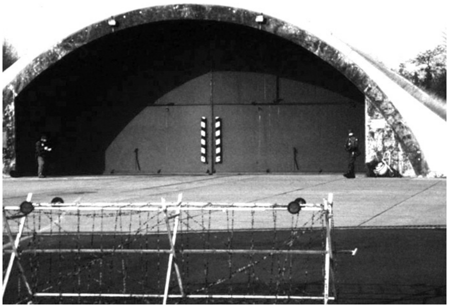

Figure 3.11 Munitions Storage Igloo

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. Logistical planning for nuclear weapons staging includes all of the considerations mentioned above, as well as the planned flow of warheads in the disassembly or dismantlement queue. Nuclear weapons are usually staged in secure areas awaiting

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

disassembly or dismantlement at the DOE/NNSA Pantex Plant near Amarillo, Texas. Many current U.S. nuclear weapons have been staged in the disassembly queue at least once as surveillance samples, where they were disassembled, had components tested and evaluated, and then reassembled for return to the stockpile. Coincidentally, some warheads have been through that 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 at an appropriate military nuclear weapons maintenance facility. Some maintenance operations require the warhead to be disassembled to a greater extent than the military technicians are authorized to accomplish. In the event of such an occurrence, the warhead must be sent back to the Pantex Plant for maintenance.

For each type of warhead, the DOE/NNSA establishes an LLCE schedule. This schedule is managed by individual warhead and serial number and is coordinated with the appropriate military service and DOE/NNSA offices.

Movement

Nuclear weapons are moved for several reasons. Warheads can be moved from an operational base to a depot upon retirement as part of the dismantlement queue and moved again to Pantex for actual dismantlement. Warheads may be moved for maintenance activities or they may be moved within an operational base area. 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 the Military Department 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 DOE/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 DOE/NNSA contract courier aircraft or by DOE/NNSA secure safeguards transport vehicles. Representatives from agencies with nuclear weapons movement responsibilities meet frequently to coordinate the movement schedule.

Surveillance

The logistics aspects 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 minimum loss of operational readiness. The DOE/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 support NATO forces with nuclear weapons forward-deployed in Europe. Recommendations for forward deployment are sent to the President as a *Nuclear Weapons Deployment Plan*. The President issues a classified *Nuclear Weapons Deployment Authorization* (NWDA) as a directive.

Life Extension Program Activities

Weapon systems are being maintained well beyond their original design lifetime. As these systems age, the DOE/NNSA continues to detect anomalies that may ultimately degrade performance of some nuclear weapons to unacceptable levels. The drivers for life extension activities are addressing aging and performance issues, enhancing safety features, and improving security, while meeting strategic deterrence requirements. Additional 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 will improve safety and security, while enabling the DoD to implement a deployment and hedge strategy consistent with national security guidance. In addition, because of production constraints, the DOE/NNSA is pursuing both refurbished and reused components from legacy systems. 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 weapons shown as zero quantity in the NWSP, covering the FY in which they are retired, are not listed in subsequent NWSPs, and fall into one of two categories:

- Retired warheads released for disassembly are scheduled for disassembly consistent with the throughput available in DOE/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 capability in DOE/NNSA facilities.
- Warheads pending approval for disassembly, or weapons in "managed retirement," must be maintained by the DOE/NNSA in such a way they could be reactivated should a catastrophic failure in the stockpile necessitate such action. Weapons in managed retirement cannot be dismantled until approved by the Nuclear Weapons Council Standing and Safety Committee (NWCSSC).

The DOE/NNSA validates the safety of all retired warheads and reports annually to the 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.

Chapter 4
U.S. Nuclear Weapons Infrastructure

4.1 Overview

In support of the Department of Defense, the National Nuclear Security Administration is the Department of Energy entity responsible for maintaining a safe, secure, and effective nuclear weapons stockpile without underground nuclear testing. Additionally, the DOE/NNSA is responsible for detecting and preventing the proliferation of weapons of mass destruction (WMD), securing nuclear and radiological materials, providing the Navy with safe and effective nuclear propulsion, and providing the Nation with state-of-the-art nuclear counterterrorism and emergency response capabilities.

> *"A modern nuclear infrastructure and highly skilled workforce is not only consistent with our arms control and nonproliferation objectives; it is essential to them."*
>
> 2010 Nuclear Posture Review

4.2 DOE/NNSA Nuclear Security Enterprise

In partnership with the DoD, the DOE/NNSA provides the research, development, production, and dismantlement capabilities necessary to support the U.S. nuclear weapons stockpile. The DOE/NNSA manages the physical infrastructure comprising the DOE/NNSA nuclear security enterprise (NSE) that sustains these capabilities. The NSE (**Figure 4.1**) spans eight sites with headquarters elements in Washington, DC, including:

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

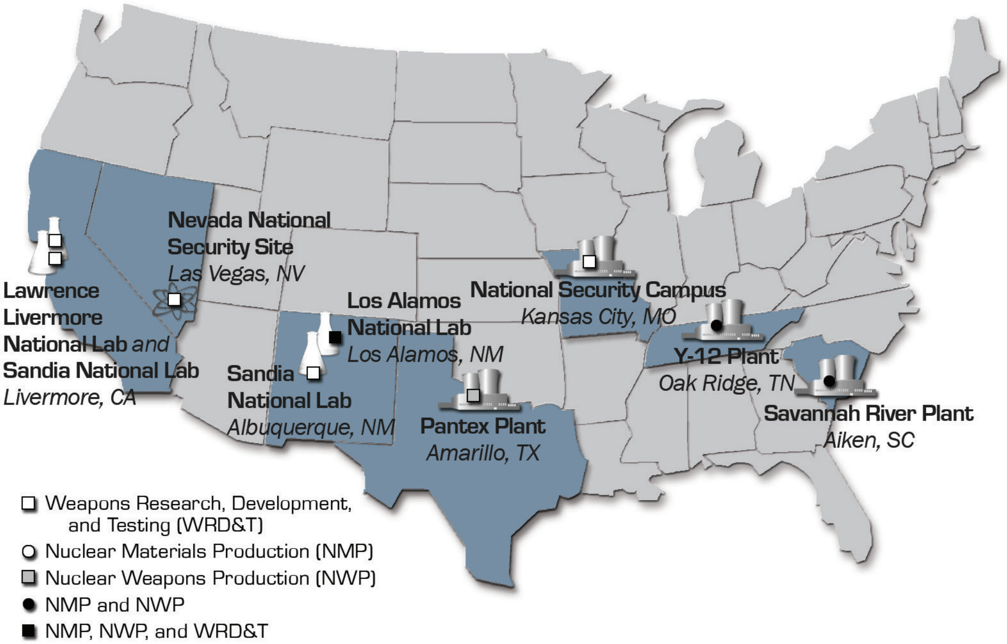
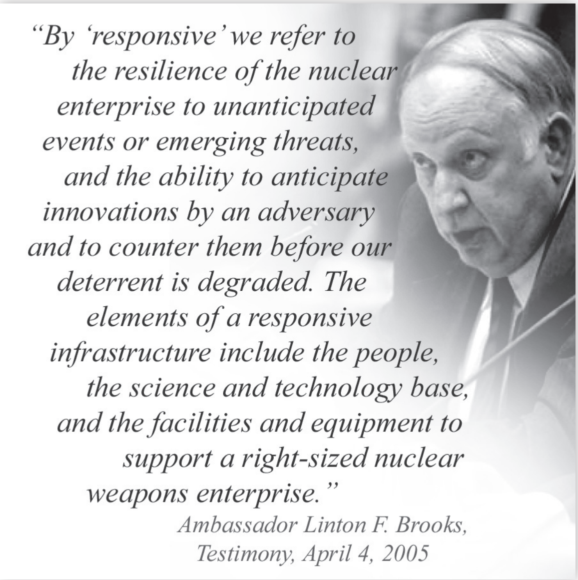


Figure 4.1 DOE/NNSA Nuclear Security Enterprise

Each site within the NSE provides a critical contribution to ensure the safety, security, and effectiveness of the U.S. nuclear deterrent. These sites also have significant roles supporting U.S. nuclear counterterrorism and counterproliferation missions.

The NSE sites are government-owned, contractor-operated (GOCO). This status indicates that the facility, while owned by the U.S. Government, is managed and operated through a contract between the DOE/NNSA and a contractor or contractor team selected by DOE/NNSA through a competitive bid process. As such, the vast majority of the employees at the NSE sites are not federal employees.



> *"By 'responsive' we refer to the resilience of the nuclear enterprise to unanticipated events or emerging threats, and the ability to anticipate innovations by an adversary and to counter them before our deterrent is degraded. The elements of a responsive infrastructure include the people, the science and technology base, and the facilities and equipment to support a right-sized nuclear weapons enterprise."*
>
> *Ambassador Linton F. Brooks, Testimony, April 4, 2005*

The facilities of the NSE are primarily focused on supporting the U.S. nuclear weapons stockpile mission. The DOE/NNSA nuclear counterterrorism and nonproliferation programs heavily leverage the key expertise and facilities developed for and funded by the U.S. nuclear weapons mission. Proposed infrastructure modernization, recapitalization, and downsizing efforts are optimized around the future needs of a reduced capacity weapons complex.

4.2.1 Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) 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 a major participant in the annual stockpile assessment process, has responsibilities to ensure the performance, safety, and reliability of nuclear warheads; support surveillance, assessments, and refurbishments 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 warheads. LLNL operates facilities that support both the DOE/NNSA stockpile and non-stockpile missions, including the High Explosives Application Facility (HEAF), Site 300 Experimental

Test Site, the National Ignition Facility (NIF), and the Nonproliferation and International Security Center (NISC).

Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, a group composed of a corporate management team including Bechtel National, Inc., the University of California, Babcock and Wilcox, the Washington Division of URS Corporation, and Battelle.

4.2.2 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 has responsibilities associated with its participation in the annual stockpile assessment process to ensure the performance, safety, and reliability of nuclear warheads; to support surveillance, assessments, and refurbishments of stockpile weapons; and to 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, W78, and W88 warheads and B61 family of gravity bombs. LANL operates a number of unique facilities that support both the DOE/NNSA stockpile and non-stockpile missions, including the Dual Axis Radiographic Hydrodynamic Test (DARHT) facility, the plutonium science and manufacturing facility (TA-55), and the Los Alamos Neutron Science Center (LANSCE), among others.

Los Alamos National Laboratory is managed and operated by the Los Alamos National Security (LANS) LLC, a group composed of the four organizations of the University of California, Bechtel National, Inc., Babcock and Wilcox, and URS Corporation.

4.2.3 Sandia National Laboratories

Sandia National Laboratories (SNL) 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. The SNL mission encompasses production agency responsibilities for weapon components, including neutron generators and trusted radiation-hardened integrated circuits. Like LLNL and LANL, Sandia plays an important role in providing annual safety, security, and reliability assessments in the annual stockpile assessment process.

SNL 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 support investigation into and certification of weapons without underground nuclear testing.

Sandia National Laboratories is managed and operated by the Sandia Corporation, a subsidiary of the Lockheed Martin Corporation. SNL has locations in California and New Mexico to ensure proximity to each of the national design laboratories.

4.2.4 National Security Campus

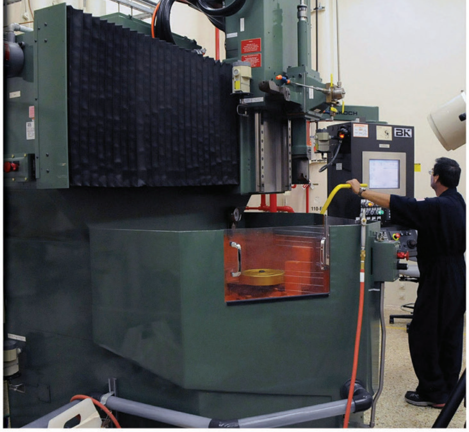
Formerly known as the Kansas City Plant, the National Security Campus (NSC) is the primary entity responsible for the procurement and manufacturing of non-nuclear components for nuclear weapons. These components include radar systems, mechanisms, programmers, reservoirs, joint test assemblies, engineered materials, and mechanical components. The NSC is also responsible for evaluating and testing non-nuclear weapon components.

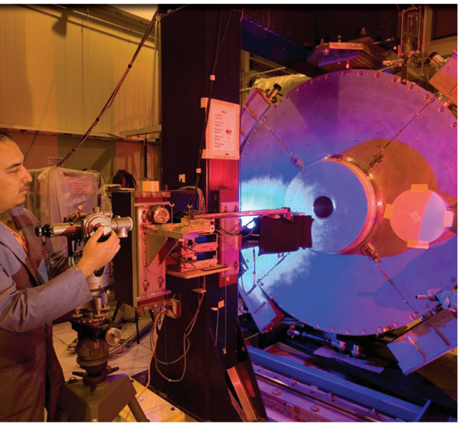
As a part of DOE/NNSA efforts to deliver a smaller, more responsive, and more flexible infrastructure, the non-nuclear components production capability was relocated to a new site as part of the Kansas City Responsive Infrastructure Manufacturing and Sourcing (KCRIMS) initiative. The relocation to the new, leased facility was successfully completed in July 2014, ahead of schedule and under budget. The new facility is LEED® Gold-rated and reduces the operating footprint by over 50 percent.

The National Security Campus is managed and operated by Honeywell Federal Manufacturing & Technologies, LLC.

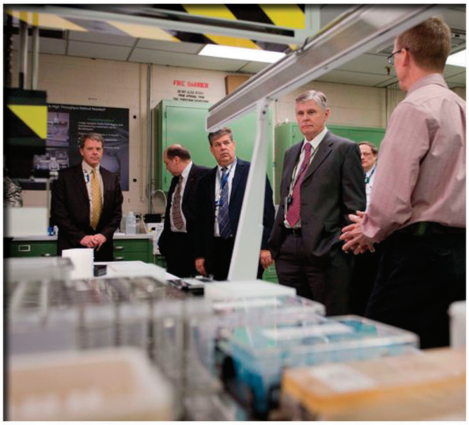
4.2.5 Pantex Plant

In 1951, the Pantex Plant (PX) became operational to focus on high explosive and non-nuclear component assembly operations. Today, PX is



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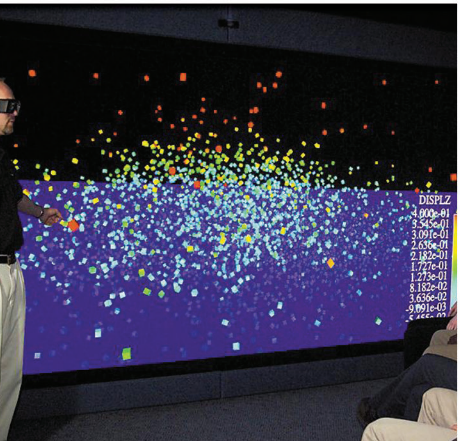
DISPLZ
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3.091e-01
2.636e-01
2.182e-01
1.727e-01
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8.182e-02
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charged with supporting the three key missions of stockpile stewardship, nonproliferation, and safeguards and security. In support of the stockpile stewardship mission, Pantex is responsible for the evaluation, retrofit, and repair of weapons for life extension programs and weapon safety and reliability certification. 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.

The Pantex Plant is operated by Consolidated Nuclear Security, LLC, which combines the resources of Bechtel National, Inc., Lockheed Martin Services, Inc., Orbital ATK, Inc., and SOC LLC, with Booz Allen Hamilton, Inc. as a teaming subcontractor.

4.2.6 Savannah River Site

The Savannah River Site (SRS) 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 the requirements of the Nuclear Weapons Stockpile Plan (NWSP). The NWSP is discussed in *Chapter 5: Stockpile Management, Processes, and Organizations*. SRS is also responsible for the conduct of reservoir surveillance operations, the testing of gas transfer systems, and research and development on tritium operations.

The Savannah River Site is operated by Savannah River Nuclear Solutions, LLC, a partnership among the Fluor Corporation, Newport News Nuclear, Inc., and Honeywell International, Inc. with subcontractors Lockheed Martin Corporation and Nuclear Fuel Services, Inc.

4.2.7 Y-12 National Security Complex

In support of the DOE/NNSA, 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 (SNM); and the dismantlement of weapon secondaries and disposition of weapon components. As part of the Y-12 Infrastructure Reduction program, the Highly Enriched Uranium Materials Facility (HEUMF) began operations in March 2010. The completion of the HEUMF, an ultra-secure uranium warehouse providing uranium storage at Y-12, replaces and consolidates aging buildings. Y-12 is also in the process of designing a Uranium Processing Facility (UPF), which is intended to replace and consolidate approximately 800,000 square feet of highly enriched uranium production capabilities. Construction is expected to be completed by the year 2025.

The Y-12 National Security Complex is managed by Consolidated Nuclear Security, LLC, which combines the resources of Bechtel National, Inc., Lockheed Martin Services, Inc., Orbital ATK, Inc., and SOC LLC, with Booz Allen Hamilton, Inc. as a teaming subcontractor.

4.2.8 Nevada National Security Site

Historically, the Nevada National Security Site (NNSS) was the main site for the United States' underground nuclear testing program. The 1992 moratorium on U.S. underground nuclear testing shifted the NNSS mission areas. Today the NNSS provides facilities, infrastructure, and personnel that the national laboratories and other organizations use to conduct nuclear and non-nuclear experiments essential to maintaining the nuclear stockpile. The NNSS is the primary location where experiments using radiological and other high-hazard materials are conducted and is the only location where highly enriched-driven plutonium experiments can be conducted. Additional mission areas include development and deployment of state-of-the-art diagnostics and instrumentation, data analysis, storage of programmatic materials, conduct of criticality experiments, counterterrorism, and counterproliferation.

The Nevada National Security Site is managed and operated by National Security Technologies, LLC (NSTec), a company that was formed in 2006 as a joint venture between Northrop Grumman Corporation, and corporate partners AFCOM, CH2M Hill, and Babcock and Wilcox.

4.3 Nuclear Security Enterprise Transformation

Since the end of the Cold War and the subsequent transition from the "build and test" paradigm, the NSE has been in the process of transforming from a large complex with an impressive production capability to a smaller, safer, more secure, and cost-effective complex that leverages the scientific and technical abilities of its workforce (see

Figure 4.2 Cold War Nuclear Weapons Complex

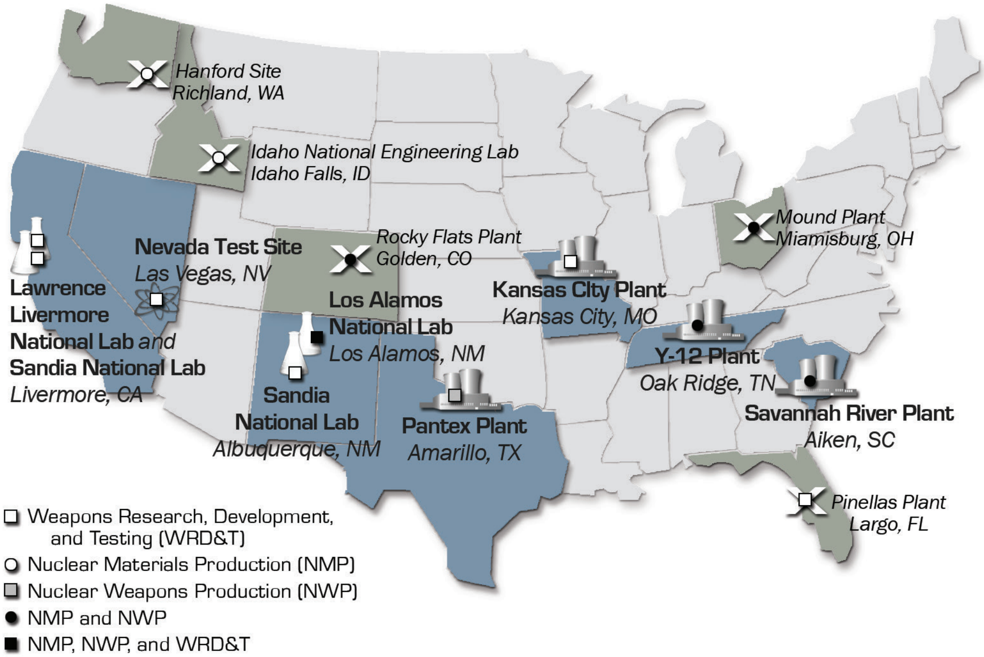

Figure 4.2). There are several facilities that were once part of the NSE and have been transitioned away from nuclear weapons-related activities. Among the largest of these are the Idaho National Engineering Laboratory, the Rocky Flats Plant, the Mound Site, the Pinellas Plant, and the Hanford Site.

4.4 Stockpile Stewardship Program

The Stockpile Stewardship Program (SSP) was established by Presidential Directive 28 and authorized by Congress in October 1993. The SSP ensures a robust weapons infrastructure by sustaining the safety and effectiveness of the Nation’s nuclear arsenal without producing new weapons or conducting nuclear explosive tests. The SSP strategy is to establish a sufficient scientific understanding of the nuclear explosive process to replace those capabilities that were enabled by underground nuclear testing and to support discovery and correction of any deficiencies that might occur during the lifetime of a weapon.

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-type for more than 20 years. The challenge for the DOE/NNSA is maintaining 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 modeled.

4.4.1 Stockpile Stewardship Program Elements

The goals of the SSP are achieved through the integration of stockpile support, surveillance, assessment, certification, design, and manufacturing processes. The need for these activities has remained constant; however, the integrating strategies have evolved as the program has matured. The accelerated and expanded use of strategic computing and simulation tools has been a fundamental innovation of this evolution. Within the DOE/NNSA, SSP implementation has been organized into several different weapons-activity programs. These programs are essential for continuing the assessment and certification of the nuclear weapons stockpile. These program elements can be found in the latest copy of the Stockpile Stewardship and Management Plan (SSMP) on the DOE/NNSA website. The SSMP orginated in current statue that states: “The Secretary of Energy shall develop and annually update a plan for maintaining the nuclear weapons stockpile. The plan shall cover stockpile stewardship, stockpile management, and program direction.” The SSMP has been submitted to Congress every year since 1998. Starting in 2013, however, the SSMP report to Congress is only required every odd-numbered fiscal year, with summaries of the plan provided in even-numbered fiscal years.

The purpose of the Stockpile Stewardship Program is to sustain the safety and effectiveness of the Nation's nuclear arsenal without producing new weapons or conducting nuclear explosive tests.

Chapter 5

Stockpile Management, Processes, and Organizations

5.1 Overview

Stockpile management is a complex undertaking because of the sophistication of U.S. nuclear weapons and the numbers of weapons and components involved. All stockpile management activities are coordinated between the DoD and the DOE/NNSA. Stockpile management is the sum of the activities, processes, and procedures for the design engineering, concept development, 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. It ensures the stockpile is safe, secure, and reliable to perform as the Nation's nuclear deterrent.

The stockpile management process is dynamic. Programs and activities must be properly coordinated to ensure all U.S. nuclear weapons will work as designed, when authorized, and remain safe and secure at all times. For example, weapon surveillance,[1] scheduled maintenance, refurbishment programs, and assembly or disassembly activities must all be coordinated in the context of future year resources such as budgets, human capital, and facilities.

5.2 Stockpile Management Evolution

The U.S. approach to stockpile management has evolved over time to reflect the military and political realities of the national and 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 in the stockpile (usually for a period of 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 5.1** illustrates U.S. nuclear stockpile management during the Cold War. This continuous replacement cycle was used to ensure U.S. nuclear weapons exploited technological advances and achieved the greatest military performance possible.

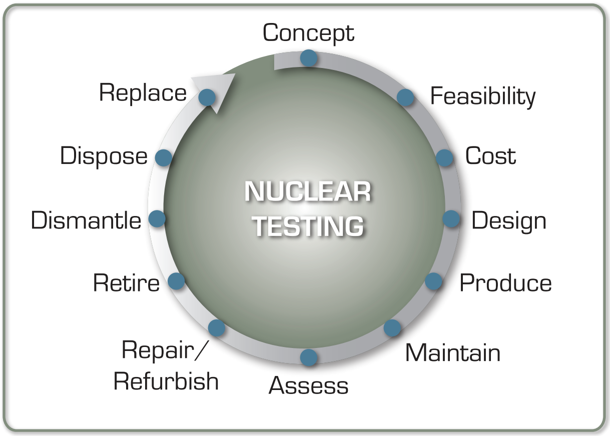

Figure 5.1 U.S. Nuclear Stockpile Management during the Cold War

During the Cold War, a primary objective in U.S. nuclear weapons design and development was to maximize yield in the smallest possible package, resulting in a maximum yield-to-weight ratio. Warheads were designed to be carried by increasingly more sophisticated and more capable delivery systems.[2] A second objective was to incorporate

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[1] 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.

[2] The first nuclear delivery system, the *Enola Gay*, was a specially modified long-range bomber. Since 1945, the United States has added intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) to its force posture to achieve the nuclear triad for strategic systems. For additional information on nuclear delivery systems, see *Chapter 3: U.S. Nuclear Forces and Weapons*.

modern safety and security features in the warheads, which added to the design complexity and the 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. This offered the President a wide range of options in the event nuclear weapons would need to be used. For a list of these delivery options, see **Figure 5.2**.

Figure 5.2 Cold War Nuclear Weapon Delivery Options

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 currently existing U.S. nuclear weapon delivery vehicles

Weapons were designed so every component had to work independently and together exactly as specified for proper functioning of the weapon. The current U.S. nuclear 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 are approaching or have exceeded their original planned life.

In the period 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 coincided with the closure of the Rocky Flats production facility.[3] The United States adjusted our national security

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[3] The Rocky Flats Plant in Colorado was the only U.S. facility that mass-produced plutonium fissile components (called “pits”). When the Rocky Flats Plant closed, the United States lost capacity to mass produce pits. As recognized by the Nuclear Posture Review and subsequent Nuclear Enterprise Reviews, reestablishing a pit production capability (including plutonium processing) and building a modern secondary production facility are necessary steps for the DOE/NNSA to achieve a modernized and responsive capacity to produce nuclear components for stockpile life extension. When component manufacturing is reestablished in quantity, it will mark the beginning of a new stockpile support paradigm whereby the DOE/NNSA can meet stockpile requirements through its production infrastructure, rather than through the retention of a large inactive stockpile to support requirements. An important benefit of the

priorities and reconsidered the appropriate role for our nuclear weapons. In the early 1990s, there was a desire to realize the benefits of the "peace dividend," especially with reduced funding for nuclear weapons and nuclear forces. There was also an increasing awareness that nuclear proliferation and the possibility of a nuclear accident or nuclear terrorism was becoming the most urgent threat 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 nuclear testing, which began in 1992 and has continued ever since. As a result, the nuclear weapons modernization and replacement model was abruptly terminated and replaced with a mandate for the indefinite retention of the weapons in the legacy stockpile without underground nuclear testing. To fulfill this mandate, stockpile management strategies evolved to maintain an established stockpile of aging weapons without underground nuclear testing that were originally designed to last no more than 20 years when supported with nuclear testing.

5.2.1 Stockpile Life Extension from 1992–Present

By 1992, when warhead production and underground nuclear testing had 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 very 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 U.S. stockpile as close as possible to their original designs and specifications. This has been achieved through stockpile refurbishment life extension programs (LEPs). 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. The LEP planning and the reductions in numbers associated with the various treaties led to a revised life-cycle for nuclear weapons as illustrated in **Figure 5.3.**

Refurbishment LEPs, which have been conducted since the 1990s, involve the use of existing or newly manufactured components that are based on the original designs specific to that weapon. Additionally, nuclear and non-nuclear components are produced as closely as possible to the original designs for a specific warhead. Deviations from original designs are often a result of "sunset" technologies (where there are no longer technologies

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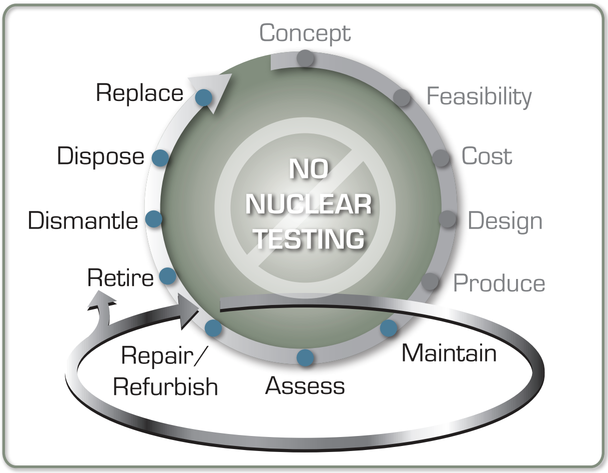
re-creation of this capability will be the eventual reduction in the total number of warheads retained in the stockpile and the creation of a responsive infrastructure that has the ability to respond to technical and geopolitical surprise. For a more in-depth discussion of this subject, see *Chapter 3: U.S. Nuclear Forces and Weapons*.

in existence to produce items) or manufacturing processes that cannot be replicated because of environmental or health hazards.

Figure 5.3 U.S. Approach to Stockpile Management, 1992–Present



There are two increasingly problematic issues with a refurbishment-only stockpile maintenance strategy. First, as a growing number of incremental changes are made to nuclear weapons through the refurbishment process, the further away from their original specifications the weapons become. Because these legacy weapons were built to push the envelope of the technologically possible in terms of achieving yield-to-weight ratios, very little margin for error exists so any deviations from very exact specifications could negatively impact confidence in the performance of the weapon in all its aspects (safety, security, and reliable yield). As confidence degrades and uncertainty is introduced, it is increasingly difficult to certify these weapons continue to meet safety, security, and yield standards.

The second issue is refurbishment offers little opportunity to enhance safety or security performance by introducing modern technological improvements. Currently fielded stockpile weapons have safety and security features that were developed in the 1970s and 1980s. Today, the United States has the technical capacity to produce safety and security features that are superior to those in the current warheads. However, the refurbishment LEP process restricts incorporation of more advanced safety and security features due to the limited ability to understand how these new technologies would interact with the function of existing safety, security, and yield characteristics of the weapon due to the testing moratorium.

5.2.2 Advancement of Stockpile Life Extension

The United States is taking advantage of innovations in safety and security and to preclude the need to resume underground nuclear testing. U.S. strategy is to ensure the continued safety, security, and effectiveness of the aging U.S. nuclear stockpile through the expansion of life extension options beyond a refurbishment-only approach. Every LEP involves the potential use of existing and newly manufactured nuclear and non-nuclear components. LEPs do not provide new military capabilities, nor do they result in "new" warheads.[4]

The newly expanded life extension process includes three technical approaches:

- *Refurbishment LEP approach*—replaces aging or otherwise defective non-nuclear and/or nuclear components using the same design as in the originally fielded warhead. This is the approach that has been used since the end of underground nuclear testing in the United States.
- *Reuse LEP approach*—replaces aging or otherwise defective nuclear components using a previously tested design from another type of weapon.[5]
- *Replacement LEP approach*—replaces aging or otherwise defective nuclear components using a previously tested design that has never been fielded in any U.S. weapon (but would not require underground nuclear testing to certify).

The LEP strategy is based on the following principles:

- LEPs will only use nuclear components based on previously tested designs and will not support new military missions or provide for new military capabilities.
- Without underground nuclear testing, each LEP will be certified to ensure the weapons meet military requirements and safety and security standards.
- Each LEP will follow the established Phase 6.X Process and will consider all three technical approaches. For more detailed information about the Phase 6.X Process, see *Appendix B: U.S. Nuclear Weapons Life-Cycle*.
- The use of the replacement LEP approach requires presidential approval and congressional authorization.

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[4] A warhead is defined as "new" if the design of one or more of the nuclear components (within the nuclear explosive package—the pit or the secondary, either individually or together) was neither previously produced or tested nor based on previously tested designs. The use of newly manufactured non-nuclear components does not cause a nuclear weapon to be considered new.

[5] Both refurbishment and reuse LEPs may involve minor modifications to the nuclear components to ensure warhead safety, security, and reliable yield. Additionally, non-nuclear replacement components are routinely manufactured for use in warhead maintenance and stockpile sustainment.

5.3 Dual-Agency Responsibility for Stockpile Management

The U.S. nuclear weapons stockpile is co-managed by the Departments of Defense and Energy. Because of the special nature of the weapons, the management process is complex. Stockpile management is governed by laws, presidential directives, and joint agreements. Additionally, both the DoD and the DOE/NNSA have rules, processes, and documentation governing stockpile management. However, neither department is bound by the internal rules and regulations of the other. To further complicate the process, the DoD and the DOE/NNSA are appropriated funds to pay for nuclear weapon activities through different congressional committees.

> *"... this Stockpile Stewardship Program has allowed the Secretaries of Energy and Defense to certify to the President that the nation's nuclear weapons stockpile is safe, secure, and reliable, and that there is no need to resume underground testing... Thanks to the dedication of our 25,000 men and women across the country, using the best science and engineering tools, we have a more complete understanding of the health of the stockpile with each passing year."*
>
> *Dr. Everett H. Beckner, Former Deputy Administrator for Defense Programs, NNSA*

5.3.1 1953 Agreement

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 the DOE assumed the responsibilities of the AEC/ERDA. In 1983, the DoD and the 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 the DOE responsible for the U.S. nuclear weapons complex and associated nonproliferation activities. **Figure 5.4** illustrates the evolution of the AEC to the NNSA. **Figure 5.5** illustrates the timeline of basic DoD-DOE nuclear weapons organization.

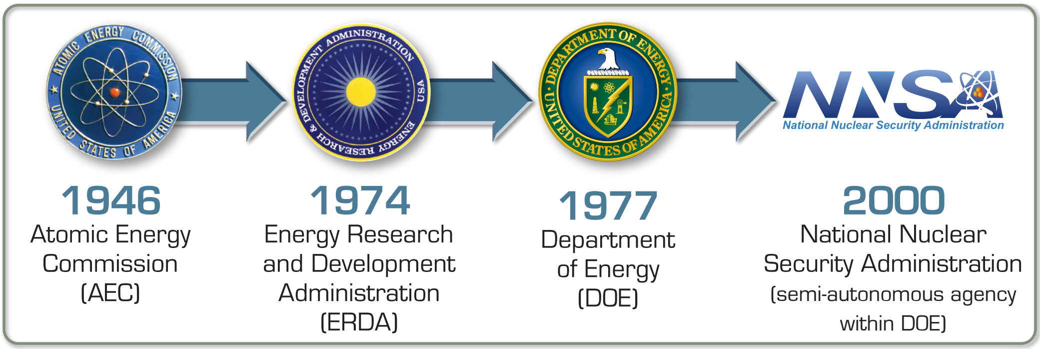

Figure 5.4 AEC to NNSA

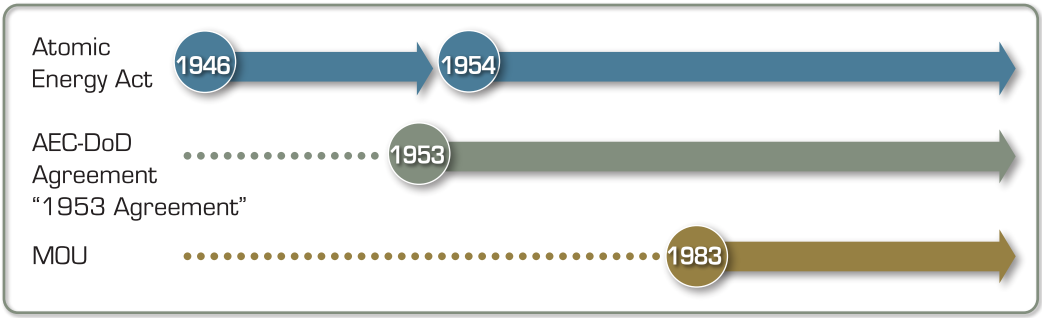

Figure 5.5 Timeline of DoD-DOE Nuclear-Related Agreements

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 Nuclear Weapons Council (NWC).

5.3.2 Departmental Responsibilities

The DoD is responsible for identifying the requirements that drive the retention of existing weapons and the need for modifications or additional weapons. The DoD is also responsible for operational employment preparedness, security, accountability, and logistical maintenance of weapons in DoD custody. Overall the DOE/NNSA is responsible for developing, producing, and maintaining nuclear weapons.

Specifically, the 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 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 NWC Standing and Safety Committee (NWCSSC), working groups, and the warhead Project Officers Group (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.

The DOE/NNSA is responsible for:

- participating in authorized concept and feasibility studies;
- evaluating and selecting the baseline warhead design approach;
- determining the resources (funding, nuclear and non-nuclear materials, human capital, facilities, etc.) required for the program;
- performing development engineering to establish and refine the warhead design;

DoD

- Establish military requirements
- Design, develop, test, and produce delivery systems
- Operate complete nuclear weapons system
- Secure and maintain nuclear weapons
- Train personnel and plan for employment

Nuclear Weapons Council

DOE

- Maintain safety, security, and reliability of the stockpile
- Research and develop nuclear weapon science, technology, and engineering
- Support stockpile levels
- Validate warhead safety and access reliability
- Produce and manage nuclear materials
- Train personnel and plan for employment

The DoD-DOE/NNSA Relationship

- 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 limited life components (LLCs) and replacement components for refurbishment;
- conducting a jointly approved quality assurance program;
- developing a life extension plan, when required, for sustaining the stockpile;
- securing warheads, components, and materials while at DOE/NNSA facilities;
- accounting for individual warheads in DOE/NNSA custody;
- participating in the joint nuclear weapons decision process;
- receiving and dismantling retired warheads; and
- disposing of components and materials from retired warheads.

Both the Department of Defense and the Department of Energy rely primarily on the Nuclear Weapons Council to serve as a coordinating body for interagency activities associated with stockpile management.

The two departments communicate through multiple channels, which range from direct interaction among personnel from the scientific and engineering communities and military operators, to dialogue and activities among more senior officials and policy makers. Both the DoD and the DOE/NNSA rely primarily on the NWC to serve as a coordinating body for interagency activities associated with stockpile management.

5.3.3 Nuclear Weapons Council

The NWC serves as the focal point for interagency analyses and decisions to maintain and manage the U.S. nuclear weapons stockpile. The NWC is a joint DoD-DOE organization established to facilitate cooperation and coordination, reach consensus, and set priorities between the two departments as they fulfill their dual-agency responsibilities for U.S. nuclear weapons stockpile management.

The NWC provides policy guidance and oversight of the nuclear stockpile management process to ensure high confidence in the safety, security, and reliability of U.S. nuclear weapons. It meets regularly to raise and resolve issues between the DoD and the DOE/NNSA regarding concerns and strategies for stockpile management. The NWC is responsible for a number of annual reports that focus senior-level attention on important nuclear weapons issues. Specifically, the NWC is required to report to the President regarding the safety and reliability of the U.S. stockpile as well as to provide an annual recommendation on the need to resume underground nuclear testing to preserve the credibility of the U.S. nuclear deterrent. The NWC is obligated to evaluate the surety[6] of the stockpile and to report its findings to the President each year. **Figure 5.6** illustrates NWC membership as stated in *Title 10, section 179 of the U.S. Code*. For more information on the NWC and its subordinate bodies, see *Appendix A: Nuclear Weapons Council and Annual Reports*.

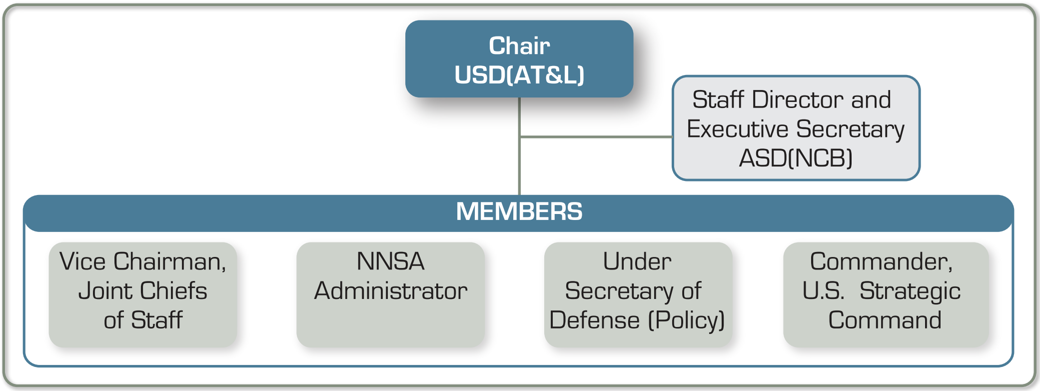

Figure 5.6 NWC Membership

5.4 Nuclear Weapon Development and Acquisition Policy

Existing nuclear weapons have been maintained well beyond their original programmed life. To ensure these weapons remain safe, secure, and reliable, the Departments of Defense and Energy have developed several approaches for maintaining these weapons. For the foreseeable future, there exists a need for a nuclear weapon development and acquisition policy. The responsibility to provide forces and the acquisition of military capability rests solely with the Military Departments.

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[6] Nuclear weapons surety refers to the materiel, personnel, and procedures that contribute to the security, safety, and reliability of nuclear weapons and to the assurance there will be no nuclear weapon accidents, incidents, unauthorized weapon detonations, or degradation in performance at the target. For more on surety, see *Chapter 7: Nuclear Surety*.

5.4.1 Process Flow

Figure 5.7 depicts the high-level process flow associated with the development and maintenance of nuclear weapons.[7] Presidential guidance, as promulgated through national security documents like Nuclear Posture Reviews, National Security Strategies, and Quadrennial Defense Reviews, informs planning documents that DoD Combatant Commanders (CCDRs) use in the development of operational plans. 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.

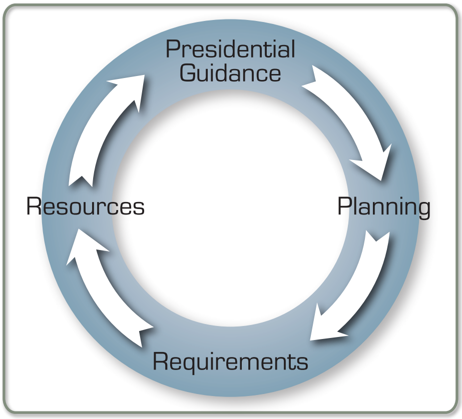

Figure 5.7 High-Level Process Flow

Nuclear weapons 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 terms National Security Directives (NSDs), Presidential Decision Directives (PDDs), and National Security Presidential Decisions (NSPDs). Currently, the term Presidential Policy Directives (PPDs) 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 nuclear weapons.

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 (DPG), nuclear-related Department of Defense Directives (DoDDs), and Department of Defense Instructions (DoDIs).

Based on the detailed guidance and CCDRs' general planning, nuclear weapons requirements are developed by the CCDRs, the Military Departments, and the Joint Staff. These requirements are submitted to the NWC staff and combined with other inputs to

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[7] This process also applies to life extension programs and major weapons alterations and modifications.

inform the development of the internal NWC Requirements and Planning Document (RPD). The RPD includes specific policies, military requirements, joint DoD-DOE/NNSA planning factors, a long-range projection of nuclear forces, and supporting programmatic details. The RPD is the basis for the draft presidential Nuclear Weapons Stockpile Plan (NWSP), usually in the form of a five-year table of stockpile quantities, that is submitted annually to the President through the Nuclear Weapons Stockpile Memorandum (NWSM), signed by the Secretaries of Defense and Energy. When the President signs the associated PPD, the NWSP table becomes the presidential guidance on stockpile quantities that starts the process flow all over again.

This continuous cycle relies on the current CCDRs' operational plans as a basis for the requirements analysis process. If necessary, requirements are modified based on the most recent detailed guidance. If the fielded weapons stockpile does not meet those requirements, the next version of the RPD, the NWSM, and the draft NWSP incorporates the necessary changes needed to ensure compliance. However, if the difference is within 10 percent, a simple update to the NWSP can be issued by the NWC before the next full version is published. During the Cold War, the majority of requirements changes were made to gain increased weapon effectiveness, to achieve better weapon safety and security, and to increase weapons quantities. 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. If the requirement is a nuclear weapon, the interagency Joint Acquisition Process for Nuclear Weapons, more commonly known as the Phase Process, is used.

The Joint Capabilities Integration and Development System

The JCIDS was established by the CJCS and the Joint Requirements Oversight Council (JROC) (established through CJCS Instruction (CJCSI) 5123.01G, *Charter of the JROC*) to identify, assess, and prioritize joint military capability needs. The JCIDS is governed by CJCSI 3170.01I, and its associated manual. Its scope includes major acquisitions or modifications such as nuclear launch platforms (e.g., ballistic missile submarines) and delivery vehicles (e.g., intercontinental ballistic missiles). The Military Departments retain the responsibility for developing and acquiring the appropriate capability. The JCIDS is an intra-DoD system operating among the Military Departments and DoD Agencies and does not operate in an interagency manner between the DoD and the DOE/NNSA. The Vice Chairmain of the Joint Chiefs of Staff (VCJCS) leads the JROC in the JCIDS process. This "closes the loop" between the CJCS, Combatant Commands, 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 management process by which the 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, Technology and Logistics (USD(AT&L)) 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.

Acquisition efforts in all phases inform further refinement of capability requirements for proposal to the appropriate validation authority, and the generation of additional or refined capability requirement documents that will re-enter the JCIDS process for staffing and validation.

The Joint Acquisition Process for Nuclear Weapons

The nuclear weapon acquisition process has been in existence for nearly six decades. The process, which covers the seven life-cycle phases of a nuclear weapon from concept to retirement, is often called the "Phase Process." When the United States was developing and fielding new nuclear weapons, the Phase Process was relied on throughout the life-cycle of each weapon-type. However, in the 1990s, the Phase Process was modified to account for the previously described system of weapons refurbishments, commonly referred to as the Phase 6.X Process. Today, the Phase 6.X Process is used to manage all nuclear weapons life extension programs, including major weapon alterations (Alts) and modifications (Mods) to stockpile weapons. While U.S. policy precludes the development and fielding of new nuclear weapons, the Phase 6.X Process (and Phase 7, Retirement, Dismantlement, and Disposal) allow the NWC to manage all aspects of nuclear weapons refurbishment. For more detailed information about the Phase Process, see *Appendix B: U.S. Nuclear Weapons Life-Cycle*.

There are two groups, under the NWC, responsible for integrating the interagency acquisition of nuclear weapons, the NWCSSC and the POGs. The NWCSSC serves as a flag-level organization that executes and evaluates actions related to the U.S. nuclear stockpile for the NWC. The POGs are joint DoD-DOE/NNSA committees usually led by the Military Departments that provide support for their assigned weapon-type. In addition to a POG for each weapon-type, there is also a use control POG. The POGs are chartered by the NWC and have representation from both the DoD and the DOE/NNSA. They coordinate and approve all activities associated with maintaining nuclear weapons in accordance with DoD and DOE/NNSA requirements. For major actions on weapons (e.g., life extension programs), the POGs collect information on the requirements and submit them to the NWCSSC and then the NWC for approval in accordance with the *Nuclear Weapons Council Procedural Guideline for the Phase 6.X Process*.

DoDI 5030.55, *DoD Procedures for Joint DoD-DOE Nuclear Weapons Life-Cycle Activities* implements DoD's acquisition processes and procedures as they apply to joint DoD-DOE/NNSA nuclear weapon development, production, sustainment, and retirement activities (including studies) and as it applies to refurbishment guidelines issued by the NWC.

5.4.2 Acquisition Process Drivers

The nuclear weapons program is not static and various changes to nuclear weapons are routinely considered. In the past, new weapons capabilities were developed in response to requirements for increased military capability as a result of changing geopolitical circumstances or for a nuclear capability in a new delivery system, to attain greater military flexibility, or to incorporate newer and better safety or security features.

Today, aging weapons components may require action in order to sustain the warheads' safety or reliability. These actions could be in the form of a Mod or an Alt. A Mod is generally a change that impacts military operations (e.g., a change in logistical procedures for maintenance or transportation) or a change in weapon effects due to a change in yield or fuze functioning. An Alt is usually a replacement of an older component with a newer component that does not impact military operations, logistics, or maintenance. Alts are usually transparent to the military unit.

Aging components cause the majority of the problems and concerns that lead to requirements for Alts or Mods. These problems may be detected in a variety of ways, including through evaluations from non-nuclear flight and laboratory testing, observations made by field maintenance technicians, special laboratory surveillance of aging components, or changes to the delivery system requiring different electrical or mechanical interface between the warhead and the delivery vehicle.

Chapter 6

Nuclear Command and Control System

6.1 Overview

The U.S. Nuclear Command and Control System (NCCS) relies on a collection of activities, processes, and procedures performed by appropriate military commanders and support personnel that, through the chain of command, allow for senior-level decisions on nuclear weapons employment. Leadership decisions are communicated to the nuclear forces via an intricate NCCS.[1] The NCCS is an essential element to ensure crisis stability, deter attack against the United States and its allies, and maintain the safety, security, and effectiveness of the U.S. nuclear deterrent. The NCCS provides the President with the means to authorize the use of nuclear weapons in a crisis and to prevent unauthorized or accidental use. This is accomplished through nuclear command and control (NC2) and communications (NC3), managed by the Military Departments, nuclear force commanders, and the defense agencies. For information on the prevention of unauthorized or accidental use, see *Chapter 7: Nuclear Surety*.

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[1] The NCCS is made possible through the cooperation of multiple departments and agencies within the U.S. Government; this chapter focuses on the DoD-related portion of the system.

6.2 Nuclear Command and Control System

The President's ability to exercise authorities is ensured by the elements of the NCCS (personnel, procedures, facilities, equipment, and communications) which are essential for supporting the President's NC2. The NCCS is an interagency system including stakeholders from the White House, DoD, Department of State (DOS), Department of Homeland Security (DHS), Department of Justice (DOJ), Federal Bureau of Investigation (FBI), DOE, and Office of the Director of National Intelligence (ODNI).

The DoD ensures the communications architecture for the nuclear deterrent can serve as the core component of a broader national command, control, communications, computers, and intelligence (C4I) system supporting the President.

6.2.1 DoD-Operational NCCS Elements

The five elements of the NCCS detailed below compose the infrastructure that supports the President, through his military commanders, in exercising presidential authority over U.S. nuclear weapons operations.

Personnel

Because of the policy implications, military importance, destructive power, and the political consequences of an accident or an unauthorized act, only those individuals who demonstrate reliability are authorized to perform NCCS duties. NCCS personnel include the operators, security personnel, and maintainers of the facilities, equipment, communications, weapons, and delivery systems.

Procedures

NCCS procedures support the President and the Secretary of Defense in the exercise of 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

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

The primary NC2 facility is the NMCC located within the Pentagon. The NMCC provides daily support to the President, the Secretary of Defense, and the Chairman of the Joint Chiefs of Staff (CJCS), allowing for the monitoring of nuclear forces and ongoing conventional military operations.

Another NC2 command center resides with U.S. Strategic Command (USSTRATCOM) Headquarters at Offutt Air Force Base in Nebraska. The USSTRATCOM GOC enables the Commander of USSTRATCOM to conduct NC2 while also enabling the day-to-day management of forces and the monitoring of world events.

Figure 6.1 E-4B NAOC

Figure 6.2 E-6B TACAMO/Airborne Command Post

Figure 6.3 Secretary of Defense Ashton B. Carter onboard the E-4B NAOC

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 6.1**, **6.2**, and **6.3**). A NAOC aircraft is continuously ready to launch within minutes, from random basing locations, thus enhancing the survivability of the aircraft and the mission.

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 intercontinental ballistic missiles 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 missiles and bombers.

Equipment

NCCS 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: surveillance,[2] correlation,[3] warning,[4] and assessment.[5]

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.

Communications

The NCCS 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 systems (**Figure 6.5**). 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

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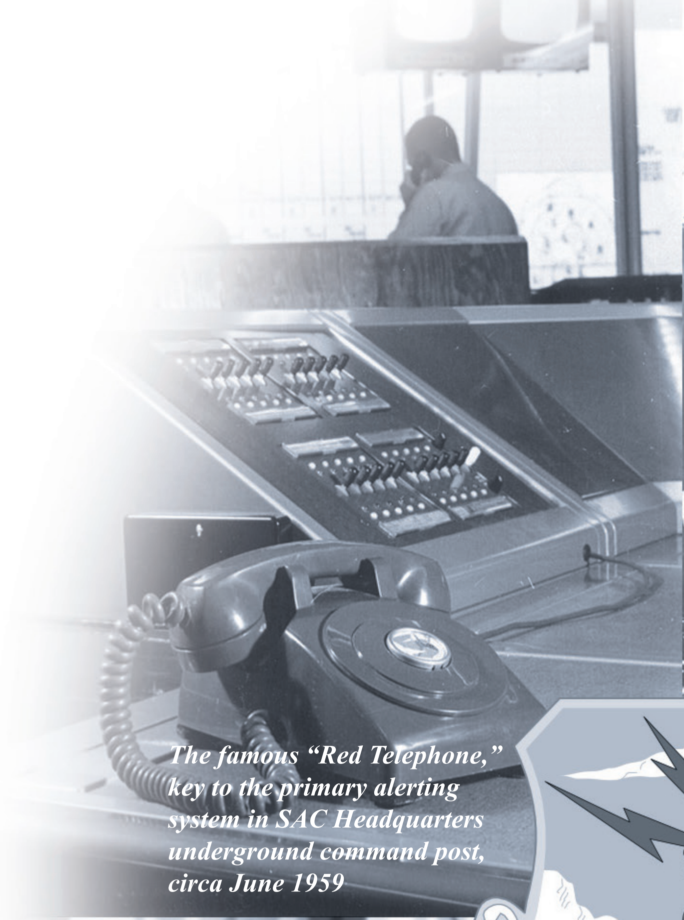
[2] Surveillance is the detection, collection, identification, processing, and reporting of ballistic missile, atmospheric, and space events by means of a worldwide network of ground- and space-based sensors.

[3] Correlation is the collection, integration, analysis, and interpretation of surveillance data along with intelligence information on all potentially hostile events.

[4] Warning is the 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.

[5] 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, 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.



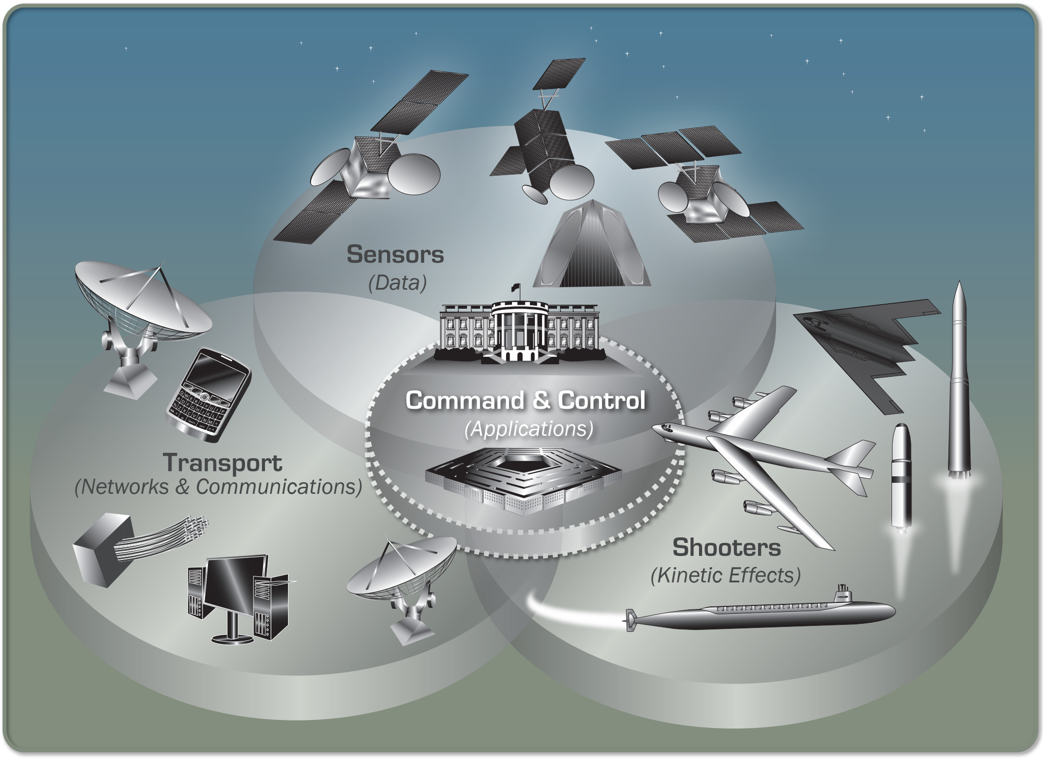
The famous "Red Telephone," key to the primary alerting system in SAC Headquarters underground command post, circa June 1959

Airborne Command Post , circa early 1961

STRATEGIC AIR COMMAND

Underground Command Post, circa February 1961

Figure 6.4 NC3 Systems



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.[6]

6.2.2 NCCS Requirements, Functions, and Elements

Presidential guidance, via presidential policy directives, is the authoritative source for NCCS requirements. The requirements have been translated into NC3 functions that 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. Many factors, including both current and future projections, can influence presidential

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[6] As with other critical elements of the 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.

decision making. Thus, the command elements of the NC2 system must maintain constant awareness of world events, both through classified means, usually through access to national intelligence systems and other sensors, and open sources such as news networks, weather forecasts, crowd sourcing data, and other reliable governmental or public media.

The elements of the supporting NCCS provide the means to perform the functions of NC3 for the President and his senior advisors in a nuclear crisis.

6.3 Nuclear Command and Control

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 paramount; it must be assured, timely, secure, survivable, and enduring in providing the information and communications for the President to make and communicate critical decisions without being constrained by limitations in the systems, the people, or the procedures that make up the systems used by the NCCS.

Five NC2 functions exist that encompass all of the nuclear-related activities performed by DoD personnel as they carry out their assigned military missions, including force management, planning, situation monitoring, decision making, and force direction.

Force Management

Force management includes the assignment, training, deployment, maintenance, and logistics support of nuclear forces and weapons before, during, and after any crisis. This understanding of force readiness status enables key leaders to quickly ascertain the ability to initiate or continue operations.

Planning

Planning involves the development and modification of plans for the employment of nuclear weapons and other operations in support of nuclear employment. Planning enables U.S. forces to survive and respond quickly to any contingency, a necessary condition given the short flight time of ballistic missiles.

Situation Monitoring

Situation monitoring comprises the collection, maintenance, assessment, and dissemination of information on friendly forces, adversary forces and possible targets, emerging nuclear powers, and worldwide events of interest. Effective situation monitoring creates a comprehensive picture based on formal sources, such as warning data from system sensors and field commander assessments, classified intelligence sources, and unclassified or open sources.

Decision Making

Decision making refers to the assessment, review, and consultation that occur when the employment or movement of nuclear weapons is considered for the execution of nuclear control orders. This function relies on time-critical secure phone and video conferencing to enable the President to consult with his senior advisors, including the Secretary of Defense and other military commanders. Decision-support tools and rapid reliable connectivity are critical to this function.

Force Direction

Force direction entails the implementation of decisions regarding the execution, termination, destruction, and disablement of nuclear weapons. This function relates to nuclear surety, accomplished through procedures, physical security (e.g., gates, guns, and guards), and internal warhead locks and disabling mechanisms to prevent unauthorized use of nuclear weapons. Force direction also relies on positive control, accomplished through procedures, continuous training, equipment, and communications that ensure the President's nuclear control orders are received and properly implemented through the NC2 system.

6.4 Nuclear Command, Control, and Communications

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.[7]

6.4.1 NC3 Requirements

Many NC3 requirements are set forth in national and DoD policy; among these are the requirements that NC3 must be reliable, assured, enduring, redundant, unambiguous, survivable, secure, timely, flexible, and accurate. These requirements have been translated into specific, measurable, and testable criteria to evaluate the performance of the NC3 through exercise, testing, and analysis.

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[7] The NC3 system 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.

Mission-critical NCCS 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 *Appendix C: Basic Nuclear Physics and Weapons Effects* and *Appendix E: Nuclear Survivability* 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.

> *"The aging NC3 systems continue to meet their intended purpose, but risk to mission success is increasing as key elements of the system age. The unpredictable challenges posed by today's complex security environment make it increasingly important to optimize our NC3 architecture...so that NC3 systems operate together as a core set of survivable and endurable capabilities that underpin a broader, national command and control system."*
>
> *Admiral Cecil D. Haney, Senate Armed Services Committee Testimony, March 19, 2015*

6.4.2 Current NC3 Architecture

The present U.S. NC3 architecture is described in two layers. The first layer is the day-to-day and crisis architecture, which can also be described as a "thick-line." This architecture supports current U.S. national policy in that it responds under all conditions in both peacetime and war to provide the means to exercise positive control and direction by the President, the Secretary of Defense, and Combatant Commanders; provides secure, reliable, immediate, and continuous access to the President; and provides 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 the designated commanders through all threat environments to perform all necessary NC2 functions. The thin-line NC3 architecture must be sustained and supported during any modernization effort to ensure presidential requirements can be met.

Chapter 7
Nuclear Surety

7.1 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, reliable, and under positive control, a concept commonly referred to as "surety." This chapter provides a basic understanding of the various elements contributing to nuclear weapons surety.

7.2 Dual-Agency Surety Responsibilities

The DoD and the DOE, working through the National Nuclear Security Administration, share primary responsibility for the safety, security, and control of U.S. nuclear weapons. A 1983 DoD-DOE Memorandum of Understanding (MOU), signed by the Secretaries of Defense and Energy, reaffirmed "the obligation of the DoD and the 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." In 2011, Deputy Secretaries of Defense and Energy signed a DoD-DOE *Nuclear Physical Security Collaboration*

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

> *Because a nuclear weapon is in DoD custody for the majority of its lifetime, the Department of Defense is responsible for a wide range of operational requirements, including accident prevention and response.*

7.3 National Policy

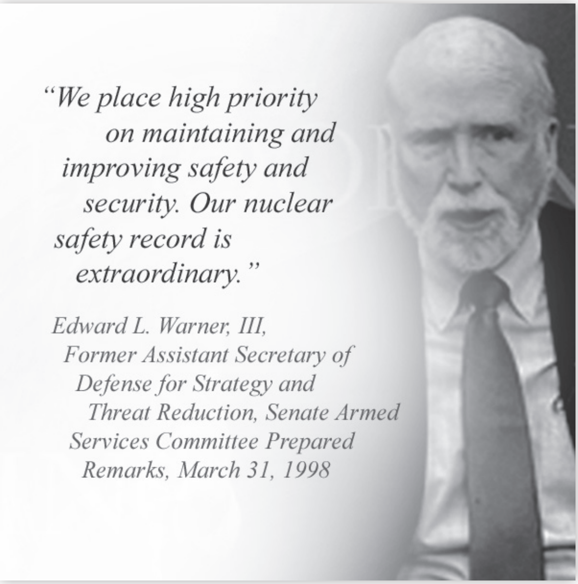
National policy provides guidance for coordinated interagency efforts concerning safety, security, and control across the nuclear enterprise. National Security Presidential Directive (NSPD) 28, *U.S. Nuclear Weapons Command and Control, Safety, and Security*, was issued on June 20, 2003. The document supersedes three former presidential directives:

- National Security Decision Memorandum 312, *Nuclear Weapons Recovery Policy* (1975);
- National Security Decision Directive 281, *Nuclear Weapons Command and Control* (1987); and
- National Security Decision Directive 309, *Nuclear Weapons Safety, Security, and Control* (1988).

NSPD-28 provides explicit guidance and standards in three nuclear weapons-related areas: nuclear command, control, and communications (NC3); nuclear weapons safety; and nuclear weapons security. Ongoing interagency-coordinated revisions for the presidential guidance accounts for these areas and reaffirms the necessity of continued diligence throughout the nuclear enterprise.

7.4 Nuclear Weapon System Safety

Nuclear weapons systems require special safety considerations due to the weapons' 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, inadvertent errors, or acts of nature. For 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 see DoD Directive (DoDD) 3150.08, *DoD Response to Nuclear and Radiological Incidents*.



> *"We place high priority on maintaining and improving safety and security. Our nuclear safety record is extraordinary."*
>
> *Edward L. Warner, III,*
> *Former Assistant Secretary of Defense for Strategy and Threat Reduction, Senate Armed Services Committee Prepared Remarks, March 31, 1998*

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. For instance, an airplane is considered safe as long as critical systems, such as the engines and landing gear, work reliably. Active intervention (i.e., the pilot) is relied upon for accident prevention. With nuclear weapons, however, 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 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.

7.4.1 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 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*. The 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 7.1** compares DoD and DOE nuclear weapons surety standards.

7.4.2 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. In the past, there have been 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.

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 anticipated 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

Figure 7.1 Comparison of DoD Nuclear Weapon System Surety and DOE Nuclear Explosive and Weapon Surety Standards

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 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.

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 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*—The 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.

Enhanced Nuclear Detonation Safety

Nuclear detonation safety deals with preventing nuclear detonation through 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 7.2** illustrates this modern nuclear safety architecture.

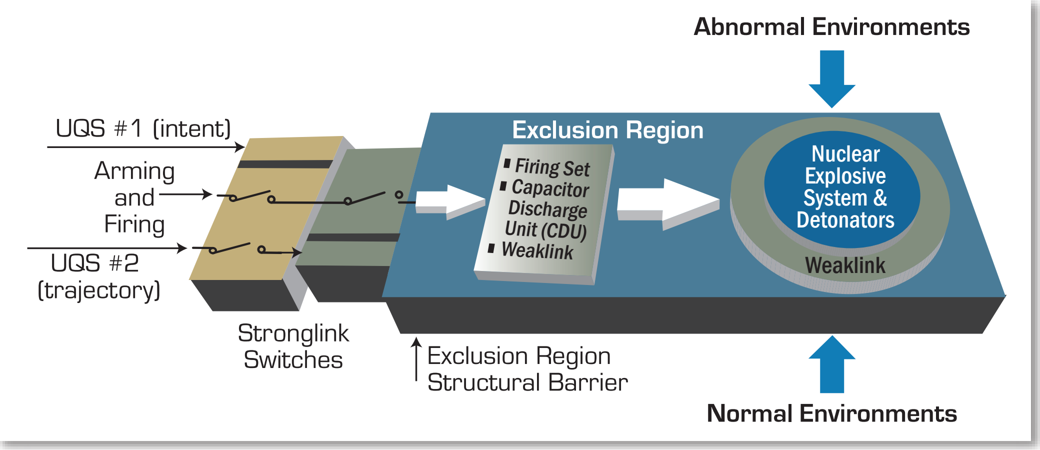


Figure 7.2 Modern Nuclear Safety Architecture

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 a 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 being. The unique signal pattern for the trajectory stronglink is frequently stored in a device known as a trajectory-sensing signal generator (TSSG).

The four principal safety themes for nuclear weapons are 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, only a perfect barrier would make a weapon perfectly safe. However, the result of perfect isolation is a non-functional weapon. 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 act activates the stronglinks and opens the energy circuit. The act can originate from human intent or the delivery environments of 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 and any other pattern is incompatible. An incompatible pattern will cause the switch to lock up and remain in a safe condition. **Figure 7.3** illustrates the concept of incompatibility.

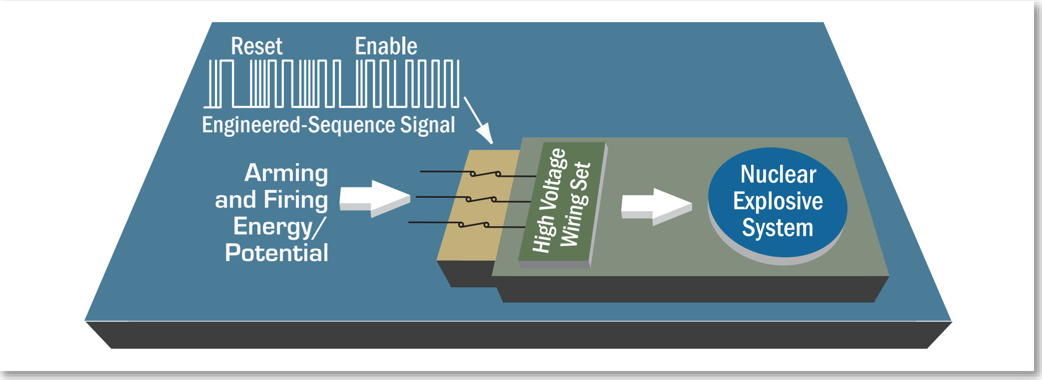


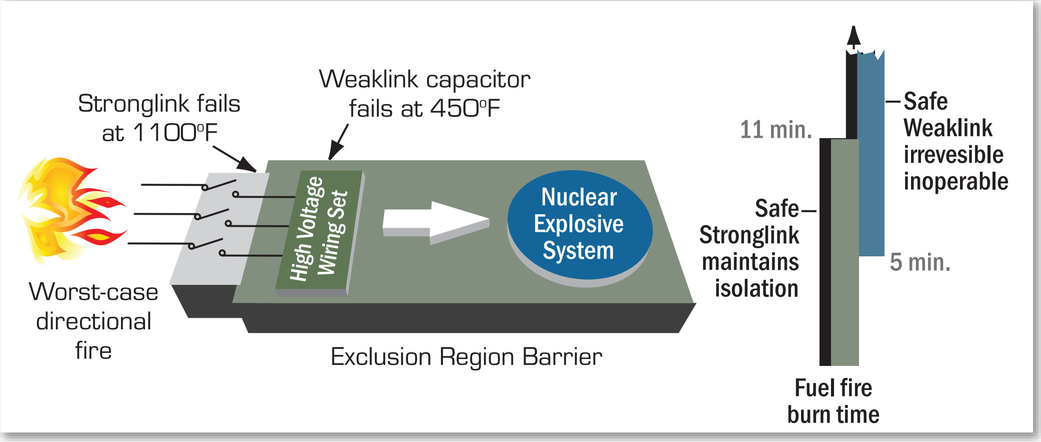
Figure 7.3 Incompatibility

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. 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 surroundings becomes so intense 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 7.4** is a diagram of the concept of inoperability.

Figure 7.4 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

An intrinsic feature of nuclear weapon design safety is the use of insensitive high explosive (IHE), as opposed to conventional high explosive. By reducing sensitivity to shock or heat, a weapon is more resistant to accidental detonation and represents a great advance in safety by reducing the likelihood of plutonium scatter.

Fire-Resistant Pit

Another feature of 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. In theory, this barrier will contain the highly corrosive, molten plutonium for a sufficient amount of time to extinguish the fire.

7.5 Nuclear Weapons Security

Nuclear weapons security refers to the range of active and passive measures employed to protect a weapon from access by unauthorized personnel and to prevent loss or damage. These measures include nuclear security policy; security forces; equipment; technology;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tactics, techniques, and procedures (TTPs); and personnel security standards. Ensuring security is vital throughout the entire life-cycle of a weapon, as it contributes directly to the shared surety objectives of both DoD and DOE/NNSA.

The Departments of Defense and Energy 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. If unauthorized access is obtained by an adversary, the control is lost but custody is maintained.

7.5.1 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:

- prevent unauthorized access to nuclear weapons;
- prevent loss of control; and
- prevent, to the maximum extent possible, radiological contamination caused by unauthorized acts.

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 of unauthorized access, commanders will take any and all actions necessary...to immediately reestablish security, prevent loss, or regain control of nuclear weapons."

The overriding objective of nuclear weapons security is *denial* of unauthorized access. This is achieved by employing physical features, technical devices, or security measures and forces in an integrated, defense-in-depth concept that leverages five distinct security capabilities. 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 7.5**).

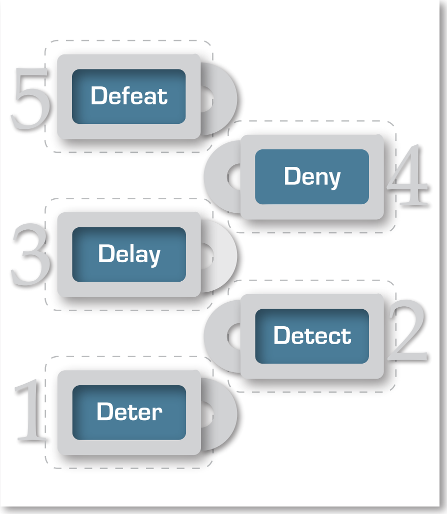


Figure 7.5 The 5 "Ds" of Nuclear Security

First, a security system must be sufficiently robust to *deter* adversaries from attempting to achieve unauthorized access. Deterrence is accomplished through facility hardening; security forces tactics, techniques, and procedures; and an aggressive counterintelligence program.

If deterrence fails, a security system must ensure rapid *detection* of an adversary's presence and intention as far away from the nuclear weapon as practical. Detection is achieved through close coordination between law enforcement and the intelligence community coupled with an integrated system of alarms, sensors, procedural requirements, and human surveillance (e.g., patrols).

In concert with detection, security systems must sufficiently *delay* adversaries from gaining unauthorized access before armed security forces can respond. Delay is achieved through physical security barriers, facility hardening, response forces, and the design features of the weapons storage facility.

Security forces must *deny* adversaries unauthorized access to nuclear weapons. Denial is achieved through lethal or non-lethal technological means, or by creating adversarial duress sufficient to prevent unauthorized access.

If denial fails, however, security forces and systems must *defeat* a hostile adversary and immediately regain control of the nuclear weapon.

The DoD Mighty Guardian (MG) program is designed to ensure vulnerabilities are identified and potential risks are minimized. The MG process combines force-on-force exercises and engineering assessments to evaluate the effectiveness of nuclear security policy and standards. MG results are used to improve the U.S. nuclear security system. Commanders use risk management principles to identify potential risks to nuclear weapons and to prioritize risk reduction requirements. The DoD Nuclear Security Risk Management Model assists commanders in this responsibility and incorporates security enhancements into the *DoD Nuclear Weapons Physical Security (NWPS) Roadmap*. The Roadmap examines the current state of NWPS and plans for the future to ensure security capabilities are adequate to meet the NWSS.

To develop a standardized approach to nuclear security, as it is applied to DoD-DOE nuclear weapons environments, the 2011 DoD-DOE *Nuclear Physical Security Collaboration Memorandum* 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. The NSTCA is developed, reviewed annually, and updated as necessary to support the preparation of unit or facility vulnerability assessments.

7.5.2 DOE Safeguards and Security

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

7.5.3 DoD and DOE Personnel Security

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

The DoD-PRP is designed to ensure the highest possible standards of individual reliability for those personnel assigned to nuclear weapons duties. It emphasizes the importance of the individual's loyalty, integrity, trustworthiness, behavior, and competence. The program applies 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-PRP or DOE-HRP positions, a screening process is conducted that includes a:

- personal security investigation and the granting of a security clearance;
- medical evaluation or screening to determine the physical 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 opportunity for the individual to disclose information that may affect the final decision to certify under the applicable reliability program.

The most important aspect of procedural security is the two-person rule, which requires the presence of at least two cleared, PRP- or HRP-certified, and task-knowledgeable individuals whenever there is authorized access to a nuclear weapon.

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-PRP 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.

7.5.4 Procedural Security

The most important aspect of procedural security is the *two-person rule*, which requires the presence of at least two cleared PRP- or HRP-certified, task-knowledgeable individuals whenever there is authorized access to a nuclear weapon. Each person is required to be capable of detecting incorrect or unauthorized actions 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.

7.5.5 DoD and DOE Security Program Authorities

Within the United States, nuclear weapon security programs are governed by DoD and DOE policy. For U.S. nuclear weapons in other countries, the United States has established Programs of Cooperation to delineate the duties and responsibilities involved in the weapons' deployment. DoD policies and procedures for nuclear weapons security are found in DoDDs, DoD Instructions (DoDI), and DoD Manuals (DoDM). DOE/NNSA policies and procedures for nuclear weapons security and security of SNM are found in DOE Os and Defense Nuclear Security (DNS) implementing guidance.

DOD SECURITY PROGRAM AUTHORITIES

DoDD 5210.41, Security Policy for Protecting Nuclear Weapons, outlines the DoD security policy for protecting nuclear weapons in peacetime environments. It gives guidance to commanders to provide security for and to ensure the survivability of nuclear weapons. The directive also authorizes the publication of DoD S-5210.41-M, which is the DoD manual providing security criteria and standards for protecting nuclear weapons.

DoDI 5210.42, Nuclear Weapons Personnel Reliability Program, outlines DoD policy and assigns responsibility for the management of the DoD Nuclear Weapons PRP. This instruction also authorizes the publication of DoD Manual 5210.42-R that prescribes mandatory procedures for the DoD Nuclear Weapons PRP to ensure the safety and security of the U.S. nuclear deterrent mission.

DoDI O-5210.63, DoD Procedures for Security of Nuclear Reactors and Special Nuclear Materials, directs policy, responsibilities, procedures, and minimum standards for safeguarding DoD nuclear reactors and special nuclear material.

DoD S-5210.92-M, Physical Security Requirements for Nuclear Command and Control (NC2) Facilities, 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 as part of the NCCS.

DoDI 3224.03, Physical Security Equipment (PSE) Research, Development, Test, and Evaluation (RDT&E), provides guidance for the acquisition of all physical security equipment. It assigns responsibility for physical security equipment research, engineering, procurement, installation, and maintenance.

DOE SECURITY PROGRAM AUTHORITIES

DOE O 452.1E, Nuclear Explosive and Weapon Surety Program, outlines the Nuclear Explosive and Weapon Surety (NEWS) Program and the five DOE surety standards.

DOE O 452.2E, Nuclear Explosive Safety, addresses security regarding the safety of NNSA nuclear explosive operations.

DOE Policy 470.1A, Safeguards and Security Program, outlines the DOE Safeguards and Security Program, which provides the basis for security for all DOE/NNSA activities related to nuclear weapons.
10 CFR Part 712, Human Reliability Program, establishes the policies and procedures for implementation of the HRP within the DOE, including the NNSA. This document 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, establishes the design basis threat which facilities that possess nuclear weapons must protect against.

DOE O 472.2 Chg 2, Personnel Security, establishes requirements that enables 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, establishes performance objectives, metrics, and requirements for developing, implementing, and maintaining a nuclear material control and accountability program, including nuclear weapons, within DOE/NNSA.

DOE O 473.3, Protection Program Operations, establishes requirements for the management and operation of the 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.

7.6 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).

Coded Control Device

A coded control device (CCD) is a use control component that may be a part of the overall weapons system coded control.

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.

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 7.6** shows an individual entering a PAL authorization code into a bomb during an exercise.


Figure 7.6 Entering PAL Authorization Code

7.6.1 DoD Use Control Program

The 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.

7.6.2 DOE/NNSA Use Control Program

Use control responsibilities of the DOE/NNSA include the design and testing of new use control features and their installation into the nuclear weapon. Additionally, the national laboratories provide technical support to reinforce DoD use control efforts. The DOE/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 DOE/NNSA 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, and reliability of nuclear weapons and components in coordination with the DoD. The DOE/NNSA conducts research and development on a broad range of use control methods and devices for nuclear weapons and assists the DoD in developing, implementing, and maintaining plans, procedures, and capabilities to store and move nuclear weapons. The DOE/NNSA also assists other departments in developing, implementing, and maintaining plans, procedures, and capabilities to recover lost, missing, or stolen nuclear weapons or components.

Chapter 8
Countering Nuclear Threats

8.1 Overview

At the end of the Cold War, there was hope that the fall of the Soviet Union would herald a new era of peace and security. To some extent, this vision has materialized insofar as the threat of global nuclear war has been greatly diminished. However, the potential for nuclear use due to threats from nuclear terrorism and nuclear proliferation over the past two and half decades has increased. The uncertainty of a world with an increasing number of nuclear players has replaced the relative stability of a bipolar balance. Now there are state and non-state actors whose risk calculus does not deter them from conducting a nuclear attack against the United States, its allies, partners, or interests regardless of the cost to themselves.

> *"No threat poses as grave a danger to our security and well-being as the potential use of nuclear weapons and materials by irresponsible states or terrorists."*
>
> National Security Strategy
> February 2015

In development of the Presidential Policy Directive final draft for *Preventing and Countering Weapons of Mass Destruction (WMD) Proliferation, Terrorism, and Use*, the National Security Council and departmental leaders reaffirmed "the proliferation and use of WMD and their delivery systems is among the most serious threats facing the United States and the international community." 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, to an improvised nuclear device (IND), a radiological dispersal device (RDD), or a radiological exposure device (RED), to a weapon from one of the established nuclear states that has fallen out of state control.

8.2 Efforts to Counter Nuclear Threats

The primary goal of countering nuclear threats (CNT) is to prevent a nuclear attack against the United States and its interests or, in the event of an attack, to respond effectively, avoiding additional attacks and providing the President with a range of options to hold the responsible parties accountable.

More specifically, the term CNT refers to the integrated and layered activities across the full range of U.S. Government efforts to prevent and counter radiological and nuclear incidents. Failing successful prevention of a radiological or nuclear incident, CNT also includes activities to manage the consequences of these incidents and to support the attribution process. Prevention and protection activities encompass all actions and programs that take place prior to detonation, while response activities are actions and programs that prepare for post-detonation response.

The primary goal of Countering Nuclear Threats is to prevent a nuclear attack against the United States and its interests.

CNT efforts are diverse and require the involvement of many agencies within the federal government and include partnerships throughout public and private domains. Most issues are national in scope, with implications for international security. Some aspects of CNT, such as accident response, are relatively mature, as they are based on historical and current work related to the U.S. nuclear weapons program. Others, including nuclear forensics and nuclear detection capabilities, are evolving as the threats of nuclear terrorism and nuclear proliferation continue to emerge.

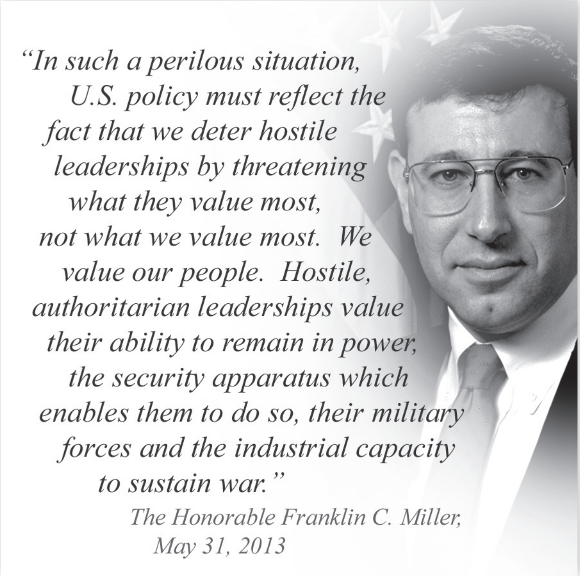
8.3 Nuclear Event Pathway

There are a number of generic steps that must be achieved for a potential adversary to be successful in carrying out an attack. These “nuclear event pathway” steps are illustrated in **Figure 8.1.** Terrorists do not share the same goals or need the same capabilities as governments. For a fabricated nuclear device, any yield production would be a success in a terrorist context. Weight and size constraints may not be important to a terrorist; unsafe designs may be acceptable, as are hazardous materials and higher dose rates. Finally, a wide variety of delivery methods could be used.

Figure 8.1 Nuclear Event Pathway

A pathway to an attack begins with motivation, planning, and intent. Next, for a credible threat, the acquisition of nuclear materials, nuclear components, or device is an essential step. This is unique for nuclear threats and is the key to a terrorist’s success.

In March 2014, international partners convened a third Nuclear Security Summit in The Hague. Over 45 nations participated, representing a diverse set of regions and expertise on nuclear materials and energy. The goals of the Nuclear Security Summit were to strengthen nuclear security, reduce the continuing threat of nuclear terrorism, and assess the progress made since the Washington Summit in 2010. The summit affirmed a common goal of strengthening the international nuclear security architecture. The White House announced the fourth summit will be held in Washington, DC, in March-April 2016.



“In such a perilous situation, U.S. policy must reflect the fact that we deter hostile leaderships by threatening what they value most, not what we value most. We value our people. Hostile, authoritarian leaderships value their ability to remain in power, the security apparatus which enables them to do so, their military forces and the industrial capacity to sustain war.”

The Honorable Franklin C. Miller,
May 31, 2013

If successful in acquisition of materials, a potential adversary must design and fabricate a 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 a NTD. Failing successful interdiction, rendering the device safe or unusable is necessary in responding effectively to the emergency. Finding and correctly interpreting indicators are keys to the prevention mission. In a post-detonation environment, the focus of the CNT 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 CNT activities is illustrated in **Figure 8.2**. The figure highlights activities beginning well before a potential nuclear event. Materials security, including the efforts embodied by the Nuclear Security Summit series, 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 that the production of weapons-usable materials is

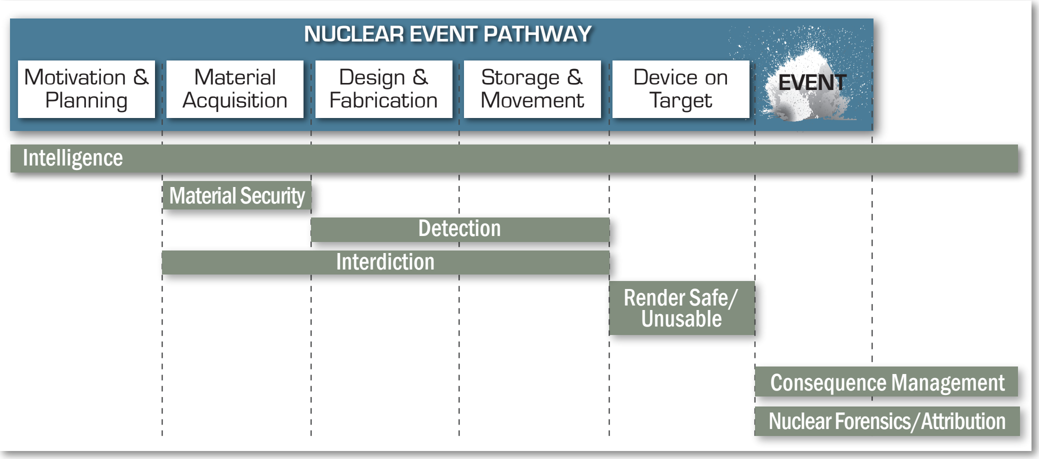


Figure 8.2 The Spectrum of CNT Activities

limited; and achieve this by instituting new processes and procedures to minimize the proliferation risks inherent in the use of nuclear power for peaceful purposes.

8.4 Understanding the Threat

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 a nuclear yield. As a result, there is no fixed set of NTD concepts or designs and our understanding of possibilities continue 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 8.3** illustrates the intimate relationship between technical understanding of NTD designs and elements of a strong program for CNT.

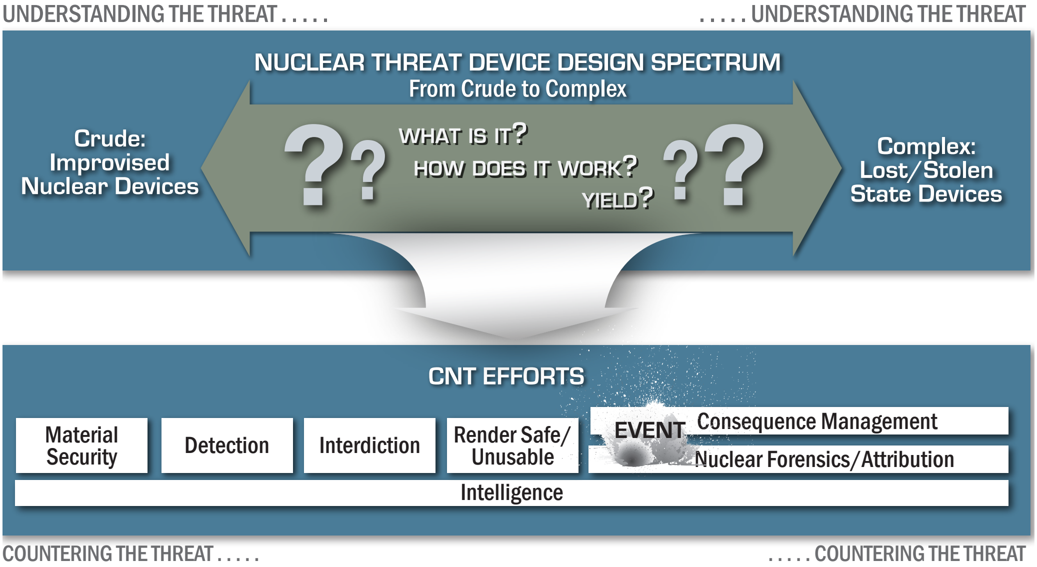


Figure 8.3 Understanding the Threat

The DOE, through the NNSA, works 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, thus, help to perform render safe functions in a timely and effective manner.

8.5 Actions to Counter the Nuclear Threat

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.

8.5.1 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 are multiple instances of collaboration among countries to minimize the threat of nuclear terrorism, including collaborations between the United States and Russia.

The Material Protection, Control, and Accounting (MPC&A) program is part of the DOE/NNSA nonproliferation program and seeks to improve the security of nuclear weapons and material accounting for 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 1991 Nunn-Lugar *Cooperative Threat Reduction Act*, the United States and Russia worked to build the Mayak storage facility in Russia. The

Fissile Material Storage Facility (FMSF),
Mayak, Russia

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.

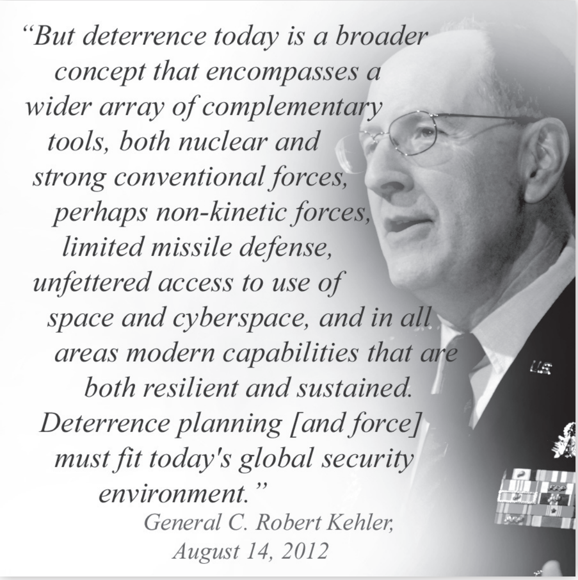
On July 15, 2006, President George W. Bush and Russian President Vladimir Putin launched the Global Initiative to Combat Nuclear Terrorism (GICNT). The initiative aims to broaden and enhance international partnership to strengthen global capacity to prevent, detect, and respond to nuclear terrorism. Currently, 85 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, the DoD and the DOE/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 DOE/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.

8.5.2 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 will degrade 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 Domestic Nuclear Detection Office (DNDO) within the Department of Homeland Security (DHS) 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 DNDO 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, DNDO conducts research, development, testing, and evaluation of detection technologies; acquires systems to implement the domestic portions of the architecture; and coordinates international detection activities. The DNDO also provides support to other U.S. Government agencies through the provision of standardized threat assessments, technical support, training, and response protocols. The DOE/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.



"But deterrence today is a broader concept that encompasses a wider array of complementary tools, both nuclear and strong conventional forces, perhaps non-kinetic forces, limited missile defense, unfettered access to use of space and cyberspace, and in all areas modern capabilities that are both resilient and sustained. Deterrence planning [and force] must fit today's global security environment."

General C. Robert Kehler, August 14, 2012

8.5.3 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 established by presidential directive that is 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 Department of State (DOS), the DHS, and the DOE/NNSA while the DoD provides support to each of the civil authorities, as requested. This process ensures the response is integrated and coordinated. The DOE/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. The DoD has responsibility for interdicting a nuclear weapon in transit outside the United States. For this reason, the DoD maintains the capabilities to interdict a weapon in the maritime, aerial, and terrestrial domains. The 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 weapon.

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.

8.5.4 Render Safe

The ability to render a nuclear weapon 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. 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. The DoD and the FBI maintain specific teams trained in rendering safe these types of ordnances.

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 the DoD or the DOE/NNSA. The DoD, the FBI, and the DOE/NNSA execute training exercises individually and jointly to streamline the render safe process and to build relationships and share technologies across the interagency.

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, radiological medical triage capabilities, and increasing population resilience and recovery capabilities.

8.5.5 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 following a successful render safe mission. National-level guidance, such as the National Response Framework (NRF) and other documents, outline interagency roles and responsibilities and guide U.S. efforts in response planning, exercises, and 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 minimize the disastrous effects desired by the adversary, demonstrated preparedness can serve as a deterrent effect.

The FBI is the lead federal agency for the crisis management response (interdiction), while the Federal Emergency Management Agency (FEMA) is the federal lead for consequence management and is an agency within the DHS. 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 specialized DOE/NNSA emergency response assets fall under DHS operational control when they are deployed in response to a potential nuclear incident in the United States.

The DOE/NNSA provides scientific and technical personnel and equipment during all aspects of a nuclear or radiological terrorist incident, including consequence management. The DOE/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.

8.5.6 Nuclear Forensics

Nuclear forensics provides information outside the scope of traditional forensics on interdicted materials or devices before detonation and on postdetonation debris to facilitate attribution. Attribution is an interagency effort requiring coordination of law enforcement, intelligence, and 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.

Nuclear forensics provides information on interdicted materials and devices before detonation and on debris post detonation to facilitate the attribution of the event.

The nuclear forensics and attribution capabilities are part of the broader CNT mission within the 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, DOE/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 bilateral and multilateral activities with foreign partners.

Attribution

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 8.4**). 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.

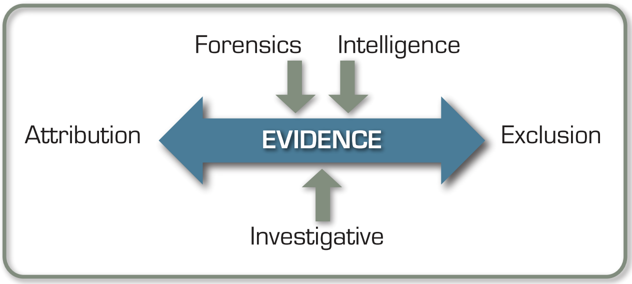


Figure 8.4 The Attribution Calculus

8.6 The Future of CNT

Nuclear threat reduction efforts and international work to counter nuclear threats is informed by a thorough scientific and technological understanding of the full range of NTD. Understanding the nuclear threat is the key to mitigation. The goal of preventing and responding to the loss of control of a nation-state nuclear weapon or to a nuclear terrorist attack is best accomplished through an integrated, whole-of-government approach and close cooperation and collaboration with international partners.

Policies and guidance for nuclear threat reduction and countering nuclear threats must be underpinned by accurate and timely technical knowledge. Sound technical knowledge is a product of research and development related to understanding NTD designs and how these affect all aspects of countering nuclear threats, including material protection and security, detection, intelligence, interdiction, diagnostics, emergency response or disablement, nuclear forensics, and attribution.

CNT encompasses a broad spectrum of activities, performed by numerous agencies and organizations. The United States is working with other nations around the world to increase partner capacities and find solutions to technical and other challenges. International cooperation across the spectrum of CNT activities is vital to successfully addressing the nuclear threat.

Chapter 9
International Nuclear Cooperation

9.1 Overview

The threat of global nuclear war has become remote but the risk of nuclear attack against the United States and our allies and partners has increased.

As stated in the 2010 *Nuclear Posture Review*, the threat of global nuclear war has become remote but the risk of nuclear attack against the United States and our allies and partners has increased. Nuclear terrorism and nuclear proliferation are global problems requiring cooperation among the United States and international partners and allies. The United States engages cooperatively 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. Additionally, the United States works closely with certain allies to ensure the common use of best practices and to benefit from independent peer review. 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.

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.[1] This MDA serves as a bilateral treaty between the United States and United Kingdom and is renewed every ten years, most recently extending the agreement to December 31, 2024 (**Figure 9.1**).

According to the AEA, all international information exchanges are predicated on the existence of an Agreement for Cooperation, such as a mutual defense agreement, with the individual nation or organization.

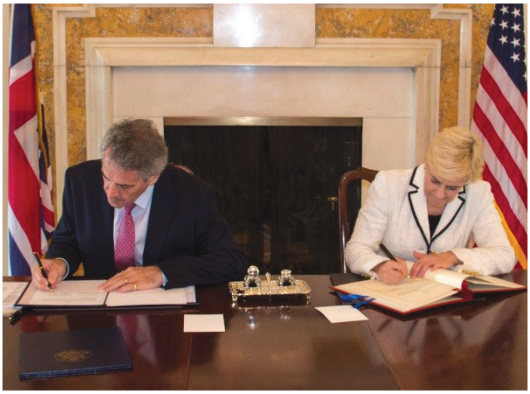


Figure 9.1 UK Ambassador Sir Peter Westmacott and State Department Principal Deputy Assistant Secretary for Nuclear and Strategic Policy Ms. Anita E. Friedt, sign the 10-year update to the U.S.-UK MDA, July 22, 2014

Given the existence of a formal MDA, the AEA further stipulates that all exchanges conducted under the auspices of the 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

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[1] *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.

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.

Today, SDs are still the mechanism for authorizing specific information exchanges 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 for communication. Most SDs relate to weapons design information, although increasingly SDs are also being developed and approved to share nuclear information to counter the threats of nuclear terrorism and nuclear proliferation.

9.2 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 guaranteed the mutual defense of its 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 the area of military doctrine and procedure, combined training exercises, and intelligence sharing.

The Nuclear Planning Group (NPG), established in 1967, provides a forum for NATO member nations to exchange information on nuclear forces and planning. 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.

NATO
Nuclear Planning Group
Members

The role of the NPG is to review the Alliance's nuclear policy in the 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 the Alliance's nuclear policy and in decisions on NATO's nuclear posture, regardless of whether or not they maintain 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.

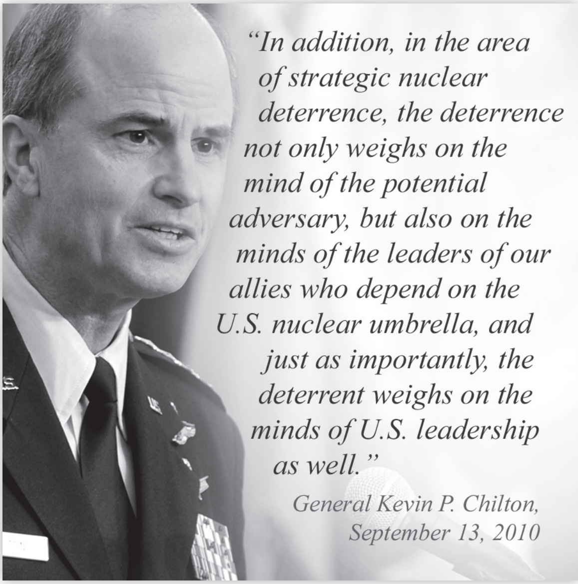
The senior advisory body to the NPG on nuclear policy and planning issues, and nuclear weapons safety, security, and survivability matters, is the High Level Group (HLG). The HLG is chaired by the United States and is composed of national policy makers and experts. The HLG meets approximately twice a 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 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, 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 session four times annually and in plenary session twice annually.

In the new *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's overall capabilities. As a contributor to the strategic nuclear forces of the NATO alliance, U.S. nuclear cooperation with NATO will remain important into the future.

9.3 U.S.-UK International Program of Cooperation

The United States and the 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 resulted in the decision to pursue the Manhattan Project, thereby leading to the beginning of the nuclear age. For more information on the history of nuclear weapons, see *Chapter 2: Evolution of the Nuclear Deterrent – A History*.



"In addition, in the area of strategic nuclear deterrence, the deterrence not only weighs on the mind of the potential adversary, but also on the minds of the leaders of our allies who depend on the U.S. nuclear umbrella, and just as importantly, the deterrent weighs on the minds of U.S. leadership as well."

General Kevin P. Chilton, September 13, 2010

Apart from a period of restriction from 1946 to 1958, under 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 a level appropriate to the evolving strategic situation and the nations' developing cooperation. Today the relationship between the United States and the United Kingdom is the strongest it has been for decades, as both nations face, together with NATO, 21st century security challenges and the common threats of nuclear terrorism and nuclear proliferation. 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 very visible, shared commitment to NATO's security. To facilitate this cooperation, both nations maintain liaison officers assigned within their respective nuclear oversight organizations. The closeness of the relationship and the

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.

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 Trident missile.

Under the U.S.-UK International Program of Cooperation, there are regular exchanges of information and experience 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 nuclear weapons programs.

MUTUAL
DEFENSE
AGREEMENT
1958 - 2008
50

Since the MDA was first signed, 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 weapon information.

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

Under the terms of the AEA, the DoD and the 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, depending on the medium involved. These mechanisms include Management Arrangements, Administrative Arrangements, Joint Atomic Information Exchange Group (JAIEG), Joint Working Groups (JOWOGs), Exchanges of Information by Visit and Report (EIVRs), and Channels.

9.3.1 Management Arrangements

Management arrangements detail the means of supervisory oversight over the cooperation effort. The two management levels are known as Stocktake and Second Level, depicted in **Figure 9.2.** The Stocktake principals, which include the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs (ASD(NCB)), the NNSA Administrator, and the UK Ministry of Defence's Director General Security Policy, meet approximately every 18 months to take stock of the enterprise, referred to as Stocktake. 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 is responsible for oversight of the exchanges. 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, manage the bulk of the day-to-day business of the collaborations, and prepare materials for the Stocktake meetings.

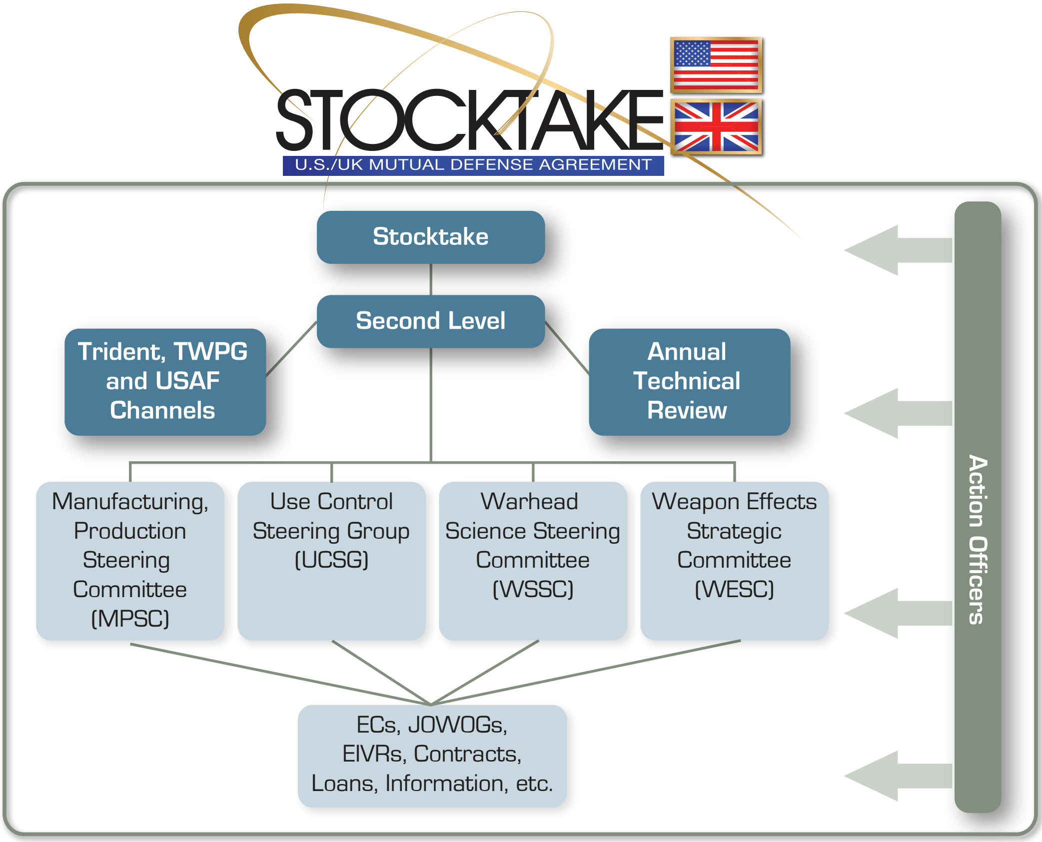


Figure 9.2 Management Arrangements

9.3.2 Administrative Arrangements

Administrative arrangements with the various nations and regional defense organizations lay out specific mechanisms for information exchange, whether in person, in written form, or electronically. The administrative arrangements supporting the MDA between the United States and the United Kingdom is a document detailing administrative procedures to be followed by the two countries in the implementation of the MDA. The arrangements cover topics such as transmission channels, visit requests, requests for information, marking of documents, reproduction, classification, reports, transmission to third nations, and dissemination.

9.3.3 Joint Atomic Information Exchange Group

The JAIEG is the U.S. entity responsible for reviewing and making determinations on the transmissibility of atomic information related to U.S. nuclear weapons sponsored for disclosure in light of the policy provided by the DoD, through the ASD(NCB), and the DOE, through the NNSA Administrator. The JAIEG is also responsible for providing support to the 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, DC, act for the UK Ministry of Defence in these matters as they pertain to the MDA.

9.3.4 Joint Working Groups

The JOWOGs are administrative bodies established to facilitate the oral and visual exchange of technical information between representatives of the United States and the United Kingdom who are engaged in cooperation and research pursuant to the MDA. JOWOGs are co-chaired by the United States and the United Kingdom. JOWOG members are appointed by participating U.S.-UK laboratories and agencies dedicated to the advancement of research in a designated field. 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 technology, nuclear warhead physics, nuclear warhead accident response technology, and methodologies for nuclear weapon safety assurance.

9.3.5 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 the 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 have included nonproliferation and arms control technology, safety and security, and nuclear intelligence.

9.3.6 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 may be granted. Therefore, a final 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 and the Trident Warhead Project Group Channel.

9.3.7 U.S.-UK Nuclear Threat Reduction

In recent years, the United States and the 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. As part of this work, the United States and the United Kingdom are jointly working to further develop the nations' capabilities in nuclear forensics to identify sources of radioactive material, improve capabilities to detect nuclear material, and improve abilities to respond to a terrorist nuclear incident. The United States and the United Kingdom are also working together on techniques to verify nuclear disarmament.

Appendix A
Nuclear Weapons Council and Annual Reports

A.1 Overview

The Nuclear Weapons Council (NWC) serves as the focal point for interagency activities to maintain the U.S. nuclear weapons stockpile. The NWC is a joint DoD-DOE activity responsible for facilitating cooperation and coordination, reaching consensus, and establishing priorities between the two Departments as they fulfill their dual-agency responsibilities for U.S. nuclear weapons stockpile management.

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 NWC meets regularly to discuss status, path forward, and resolve issues between the DoD and the DOE/NNSA regarding strategies for stockpile management.

The NWC is responsible for a number of annual and biennial reports that garner senior-level attention on important nuclear weapons matters. 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 testing to preserve the credibility of the U.S. nuclear deterrent. The NWC also ensures any significant threats to the continued credibility of the U.S. nuclear capability will be identified quickly and resolved.

A.2 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 the DOE/NNSA.[1]

A.2.1 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 the DoD, the present day organization) and the AEC (hereafter referred to as the DOE, the present day organization).

The MLC was an executive- or flag-level (one-, two-star) military organization that served as the authorized channel of communication between the DoD and the DOE on all atomic energy matters related to the military application of atomic weapons or atomic energy, as determined by the 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 the 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, the Joint Staff (JS), and the Defense Nuclear Agency (DNA) participated as observers. An

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[1] In 1974, an administrative reorganization transformed the AEC into the Energy Research and Development Agency (ERDA). A subsequent reorganization in 1977 created the DOE. In 2001, the NNSA was established as a semi-autonomous agency within the DOE.

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 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 the DOE to the DoD. Under this proposal, the DOE would then execute its nuclear weapons-related activities, using funds provided by the 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 (FY) 1985*, Public Law (Pub. L.) 98-525, directed the President to establish a Blue Ribbon Task Group to examine the issue.

A.2.2 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 the DoD and the 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 the DoD and the 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 the 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)[2] 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 the 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

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[2] The POGs are joint DoD-DOE/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.

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)).

A.3 Nuclear Weapons Council Today

Acting on the recommendations of President Reagan's Blue Ribbon Task Group, Congress established the NWC in the FY 1987 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 the DoD and the DOE with respect to nuclear weapons production. The NWC was created when the U.S. plans for continued nuclear weapons production were indefinite and 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.

As nuclear weapons stockpile management has evolved over time, particularly since the end of the Cold War and the demise of the Soviet Union, so have the responsibilities and administrative procedures of the NWC.

A.4 Organization and Members

As dictated by *Title 10, Section 179 of the United States Code* (10 USC 179), the NWC has five voting members as illustrated in **Figure A.1**, the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)); the Vice Chairman of the Joint Chiefs of Staff (VCJCS); the Under Secretary for Nuclear Security of the DOE and NNSA Administrator; the Under Secretary of

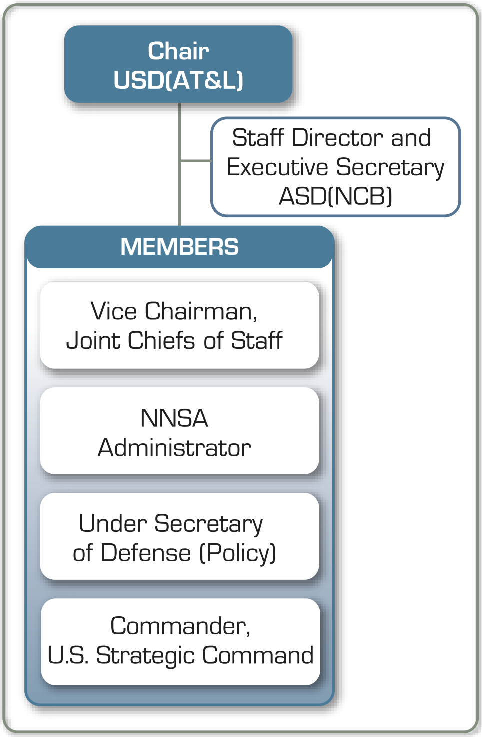


Figure A.1 NWC Membership per 10 USC 179

Defense for Policy (USD(P)); and the Commander of the U.S. Strategic Command (CDRUSSTRATCOM). The USD(AT&L) serves as the chairman of the NWC. The ASD(NCB) is designated as the NWC staff director.

The law directs the DoD and the DOE/NNSA to provide personnel to serve as the NWC staff. From the beginning, the ASD(NCB) performed the role of NWC executive secretary, in addition to the legally mandated staff director function. Now, as the executive secretary, the ASD(NCB) manages the agendas and facilitates the activities of the NWC. As NWC staff director, the ASD(NCB) also has oversight responsibilities for the NWC staff and the other subordinate organizations of the NWC.

NWC membership includes several advisor organizations, in addition to its official members. Though not voting members, these organizations make valuable technical contributions to NWC deliberations. NWC advisors include:

- Chief of Staff, U.S. Air Force;
- Chief of Naval Operations, U.S. Navy;
- Director, Cost Assessment and Program Evaluation (CAPE);
- Under Secretary of Defense, Comptroller (USD(C));
- U.S. Navy (Strategic Systems Programs (SSP));
- U.S. Air Force (Strategic Deterrence and Nuclear Integration (AF/A10));
- Office of the Assistant Secretary of Defense for Acquisition (OASD(A));
- Office of the Assistant Secretary of Defense for Legislative Affairs (OASD(LA));
- Department of State (DOS); and
- National Security Council (NSC).

A.5 Responsibilities and Activities

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 DOE/NNSA budget request to meet the NWC stockpile requirements. The NWC currently fulfills four annual reporting requirements: the NWSM and Requirements and Planning Document

(RPD), the NWC Report on Stockpile Assessments (ROSA), the NWC Joint Surety Report (JSR), and the NWC Budget Certification Letter. The NWC also has a biennial requirement to assess the DOE/NNSA long-range Stockpile Stewardship and Management Plan (SSMP). Additionally, the DoD members of the NWC prepare the Annual Report on 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 serves as the coordination point for these reports.

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). 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-DOE/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 authority within the DoD and the DOE/NNSA;
- receiving information and recommendations from advisory committees on nuclear weapons issues and recommending appropriate actions to the DoD and the DOE/NNSA;
- providing broad guidance to the DoD and the DOE/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 reporting requirements as provided in 10 USC 179.

A.6 Procedures and Processes

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 nuclear weapons stockpile management issues 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 voting process in which members' 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.

In theory, each member of the NWC could veto any action or decision. In practice, however, the NWC works to achieve consensus among members before it issues official decisions or recommendations. Documents reflecting NWC findings and decisions, including NWC reports, memoranda, and letters, are coordinated until all NWC members concur.

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 the DoD, the DOE/NNSA, and the national 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, in person to provide an opportunity for members, advisors, and observers to solicit additional information as required for clarity or completeness.

Decisions and recommendations made at the subordinate levels are always communicated to the NWC through items such as meeting minutes and memoranda.

These decisions and recommendations are theoretically subject to modification or repeal by the NWC itself. However, in practice this does not usually occur.

A.7 Subordinate Organizations

The NWC conducts day-to-day operations and coordinates issues through its subordinate organizations. NWC subordinate organizations are not codified in 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 the DoD and the DOE developed nuclear weapons requirements processes within their own Departments. For these reasons, the NWRWG members voted 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 the vote.

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 nuclear security enterprise. New committees are created, as needed, by the NWC to respond to issues of the day. **Figure A.2** provides a timeline of their establishment.

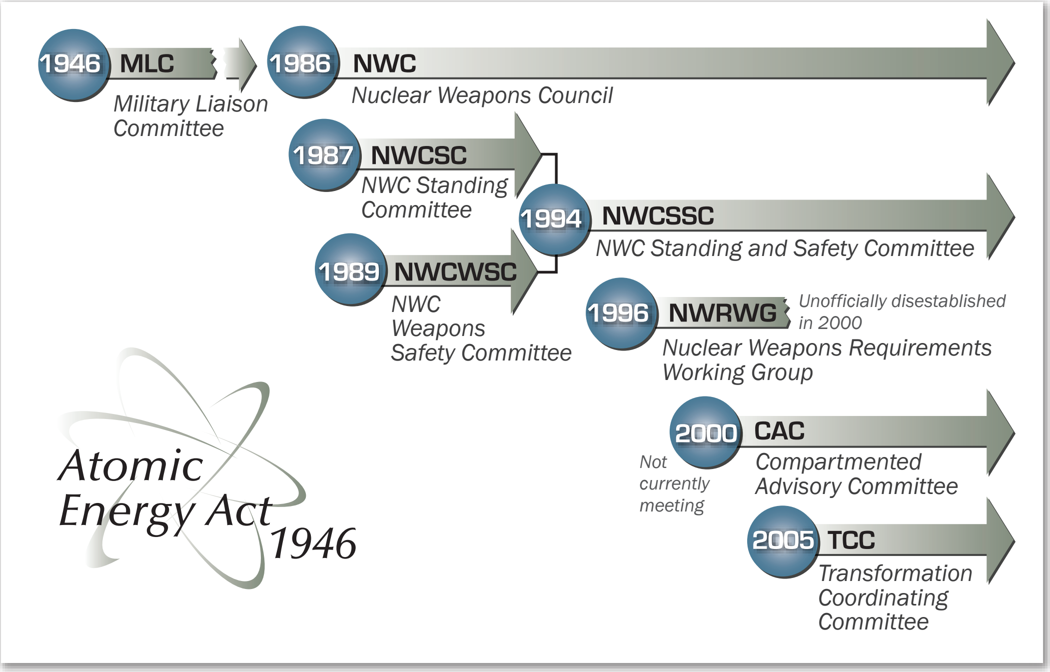


Figure A.2 Overview of the Establishment of the NWC and Its Subordinate Bodies

A.7.1 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 activities. The NWCSSC conducts transactions between the DoD and the DOE/NNSA on behalf of the NWC.

NWCSSC Organization and Members

The ASD(NCB) serves as chair of the NWCSSC and represents the USD(AT&L) as well as the OSD. A DOE/NNSA senior official in the Defense Programs (DP) office is the NWCSSC co-chair and represents the NNSA Administrator. **Figure A.3** is a representation of NWCSSC membership.

The NWCSSC is composed of one flag-level representative or the civilian equivalent from the DOE/NNSA, Office of the USD(P), Joint Staff, U.S. Strategic Command, Navy, Air Force, U.S. Army Nuclear and Combating Weapons of Mass Destruction Agency (USANCA), DoD Chief Information Officer (CIO), and Defense Threat Reduction Agency (DTRA).

Given the disparate nature of the Committee's responsibilities and other important demands on members' schedules, each member organization may appoint one or more alternates to attend meetings when the principal is unavailable or when the alternate's skills are appropriate to the topic of discussion.

Figure A.3 NWCSSC Membership and Advisors

NWCSSC MEMBERS

Chair
ASD(NCB)

Co-Chair
NNSA DP

DOE/NNSA
OUSD(P)
JS
USSTRATCOM
USN
USAF
USANCA
DTRA
DoD CIO

NWCSSC ADVISORS

ODASD(NM)
LANL
LLNL
SNL
NSA
OUSD(C)

DoD CAPE
NSC
USEUCOM
USN-SSP
NCCS SPT STAFF
OASD(LA)
OASD(A)

The NWCSSC is also supported by a group of technical advisors from both within the DoD and the interagency, as shown in **Figure A.3.**

NWCSSC Responsibilities and Activities

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.

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 refurbishments for existing weapon systems and production activities for new systems. As recommended by the POGs, the NWCSSC reviews and approves the military characteristics (MCs) and stockpile-to-target sequence (STS) for major modifications of existing weapons and new systems. The NWCSSC is informed on a wide variety of issues related to nuclear weapons stockpile management through informational briefings and other channels of communication. **Figure A.4** depicts the summary of NWCSSC responsibilities.

NWCSSC Procedures and Processes

The NWCSSC generally meets once per month. The majority of the work performed by the NWCSSC involves issues related to DoD military requirements in relation to DOE/NNSA support plans and capacity, as well as issues regarding consideration and monitoring of all nuclear surety issues and nuclear weapons refurbishments.

During meetings, NWCSSC members usually hear briefings from various organizations involved with nuclear stockpile management issues. These organizations include the nuclear weapons POGs, the national laboratories, as well as individual components within the DoD and the DOE/NNSA.

The NWC staff is responsible for coordinating meeting times and places as well as developing meeting agendas, drafting briefings the DASD(NM) may provide, and drafting the minutes of each meeting. The minutes describe briefings and record NWCSSC key points and actions assigned. NWCSSC minutes are then formally coordinated with AOs and signed by the NWCSSC chairman, co-chairman, and executive secretary.

A.7.2 NWC Action Officers Group

The NWCSSC is supported by an AO group, which operates in a frank and informal meeting environment to discuss issues, receives pre-briefings in preparation for NWCSSC or NWC meetings, and coordinates actions for consideration by their principals at the NWCSSC and NWC levels.

AO Group Organization and Members

The AO group is composed of action officers representing NWCSSC member organizations, observer organizations, NWC advisor organizations, and other stakeholders within the nuclear enterprise. Though most organizations have specific focal points for AO activities, membership is open to those who must keep apprised of NWC activities. The NWC staff supports the AO group. When responsible for NWC actions in progress, other agencies and

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 the DOE/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 the DOE/NNSA.

Request weapon program status information from the DoD and DOE/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 A.4 Summary of NWCSSC Responsibilities organizations, such as the POGs and the national laboratories, send AOs to participate as observers or invited guests.

AO Group Responsibilities and Activities

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 nuclear weapons stockpile management issues, ensuring consistent progress, facilitating information dissemination, and preparing nuclear weapons issues for their 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.

AO Group Procedures & Processes

The NWCSSC executive secretary, who also serves as the NWC assistant staff director, chairs the AO meetings. 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 tracking and coordinating NWC reports and provides a status update at each AO meeting. Frequency of meetings is adaptable to the workload and is flexible to the needs of the NWCSSC executive secretary and AOs.

During the coordination of official reports, documents, or correspondence, the AO group may comment on initial drafts. This input is considered in the development of subsequent drafts. This process is repeated until a final draft is completed. Generally, the AOs complete an action when the AO group reaches consensus on an issue and forwards it to the NWCSSC. If consensus cannot be reached, the issue may move to the NWCSSC for resolution.

A.7.3 NWC Staff

The NWC staff provides 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 the DoD and the DOE/NNSA assign personnel to provide necessary support services to the entire NWC organization.

NWC Staff Organization and Members

The NWC staff is located within the ODASD(NM) at the Pentagon. The NWC staff is comprised of the DOE/NNSA representative (NWCSSC executive secretary, who serves as the lead), national laboratory personnel, plant personnel, DoD employees, and government contractors. The NWC staff reports through the DASD(NM) to the NWC staff director.

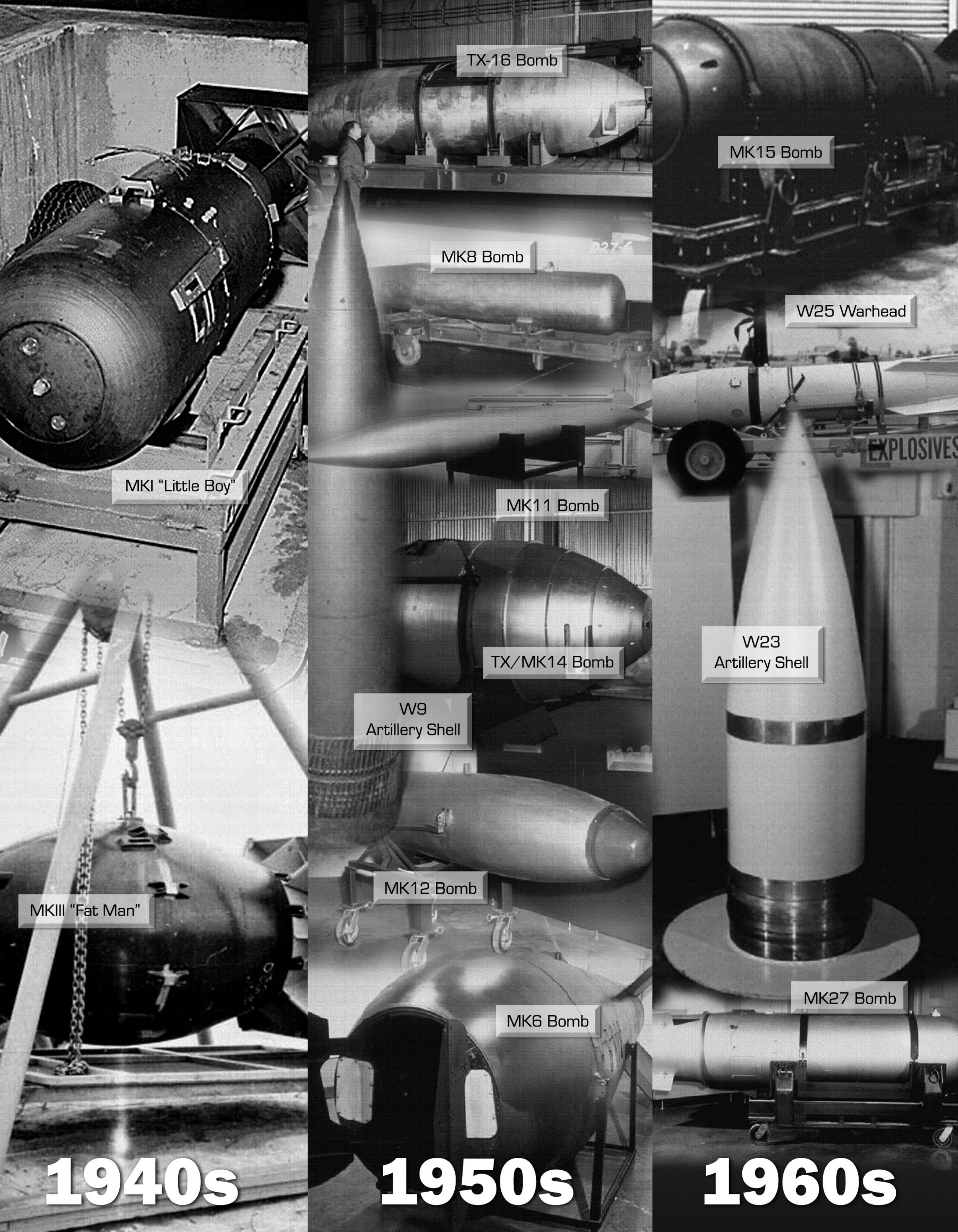
NWC Staff Responsibilities and Activities

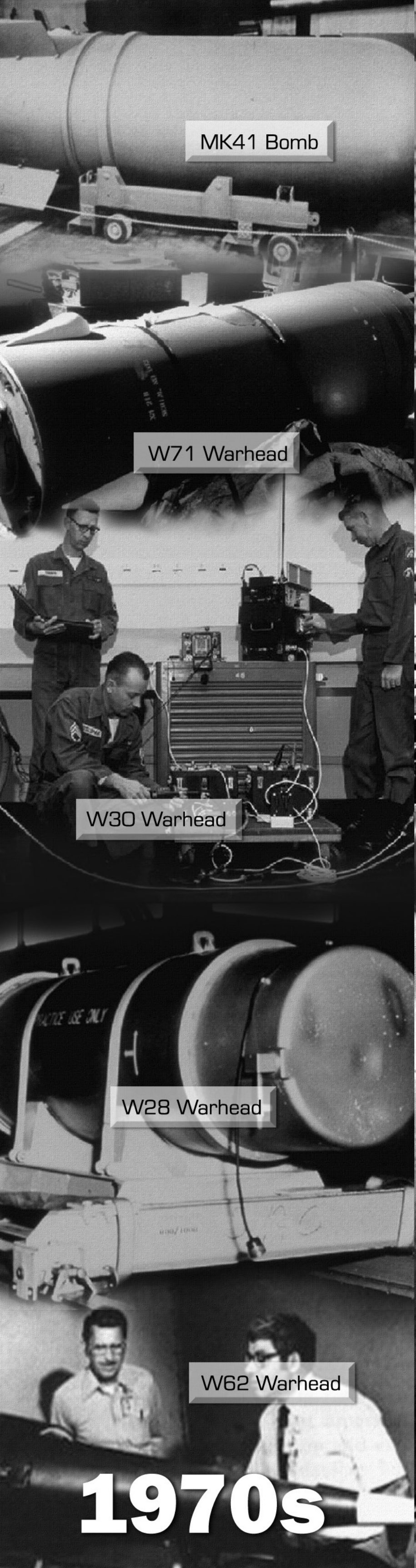
The NWC staff has a variety of responsibilities to ensure the NWC and its subordinate bodies operate as efficiently and effectively as possible. The primary responsibilities of the NWC staff are divided into meetings for planning and follow-up activities and the NWC annual reports and decision memoranda for development, drafting, coordination, and execution.

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.

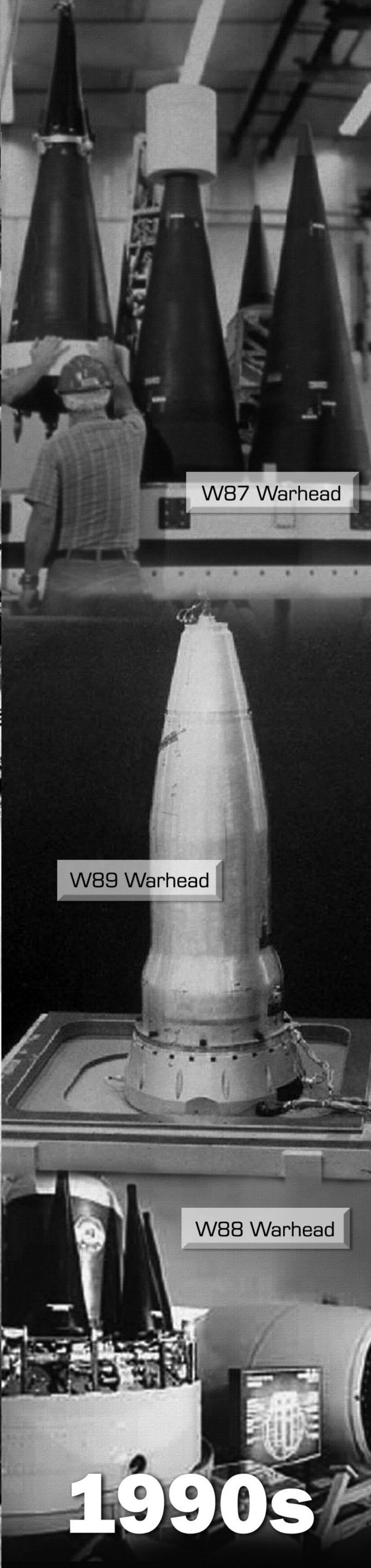
The NWC staff is also responsible for technical activities, including preparing technical content for briefings to the NWC and NWCSSC, developing reports and letters, guiding documents through coordination, and resolving issues within the interagency. Additionally, the staff works administrative issues for the NWC, including preparing and coordinating meeting minutes, developing vote packages for NWC or NWCSSC paper votes, scheduling of supplementary briefings, and developing responses to members' 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 five annual and biennial reports for which the NWC is responsible and the two DoD-only reports. The NWC staff manages the coordination of these reports with the many different representatives from the DoD and the DOE/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.


MKI “Little Boy”
MKIII “Fat Man”
1940s
TX-16 Bomb
MK8 Bomb
MK11 Bomb
TX/MK14 Bomb
W9
Artillery Shell
MK12 Bomb
MK6 Bomb
1950s
MK15 Bomb
W25 Warhead
EXPLOSIVES
W23
Artillery Shell
MK27 Bomb
1960s


MK41 Bomb
W71 Warhead
W30 Warhead
PRACTICE USE ONLY
W28 Warhead
W62 Warhead
1970s


W84 Warhead
W80 Warhead
B83 Bomb
W76 Warhead
W79
Artillery Shell
W78 Warhead
1980s


W87 Warhead
W89 Warhead
W88 Warhead
1990s

A.8 Annual Reports

Each of the NWC-responsible 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 March of each year marking the busiest time.[3]

A.8.1 Nuclear Weapons Stockpile Memorandum and Requirements and Planning Document

NWSM

Requirement:	10 USC 179
Reporting period:	Fiscal Year
Annual due date:	September 30, or as specified 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 NWSP are collectively called the "NWSM package" or "NWSM."

The coordination process for these documents serves as the key forum in which the DoD and the DOE/NNSA resolve issues concerning DoD military requirements for nuclear weapons in relation to the DOE/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

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[3] The FY 1995 amendment to 10 USC 179 required the NWC chairman to submit a report, the NWC *Chairman's Annual Report to Congress* (CARC), to Congress each fiscal year evaluating the "effectiveness and efficiency of the NWC and the deliberative and decision-making processes used." The CARC was submitted through the Secretary of Energy. The FY 2016 NDAA did not require the CARC.

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.[4] Since the early 1990s, however, the NWSM has 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 weapons stockpile. It provides detailed technical information and analyses that support the development of the NWSM and the proposed presidential directive containing the NWSP. The RPD is now linked with the NWSM to form a single NWC vote package for coordination and approval through the NWC chairman. The chairman forwards the NWSM to the Secretaries of Defense and Energy for signatures and distributes the RPD to NWC and NWCSSC members (as the RPD is an internal NWC document not required by legislation or the President).

The NWSM, which was formerly coordinated to satisfy a statutory requirement, has evolved into an instrument for programmatic authorization. This is particularly true for the DOE/NNSA, which relies on the current NWSM/RPD to direct and authorize its planning decisions and to serve as the basis for workload scheduling in the field. This workload planning is done by assigning nuclear weapons with specific warhead readiness states.

Warhead Readiness States

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

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

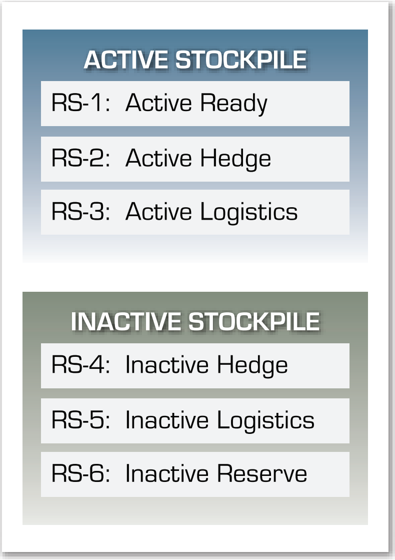

Figure A.5 Warhead Readiness States

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—modifications (Mods) or alterations (Alts). CCMD orders specify the allocation of strategic operational warheads and readiness timelines. Operational warheads are fully assembled warheads that have Gas Transfer Systems and other limited life components (LLCs) installed.

Active Ready (AR) (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 USSTRATCOM activation timelines.

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. Gas Transfer Systems, if installed, are removed and returned to the DOE/NNSA prior to their projected limited life. Hedge and logistics warheads are updated to incorporate the latest warhead refurbishment 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 life extension programs. Warheads in this category are exempt from future refurbishment Mods or Alts.

NWSM/RPD Development

When the military requirements are received from the Joint Staff in March of each year, the NWC staff develops and coordinates the NWSM/RPD package for review and comment from the NWCSSC. After coordination and approval, the NWCSSC forwards the NWSM/RPD package to the NWC for review and approval. Following NWC approval, the NWSM package is transmitted to the Secretaries of Defense and Energy for signatures and the RPD is signed out by the NWC chairman.

After it is signed by the two Secretaries, the NWSM is forwarded to the President with the proposed presidential directive and associated NWSP. The NWSM package is due annually to the President no later than September 30, unless otherwise specified by a previous presidential directive.

A.8.2 NWC Report on Stockpile Assessments

ROSA	
Requirement:	FY 2003 NDAA and FY 2013 NDAA
Reporting period:	Fiscal Year
Annual due date:	February 1
Drafted by:	DOE/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 William J. 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 safeguards 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.[5] The annual assessment process of which the NWC ROSA, formerly the Annual Certification Report, is one element, was originally developed to correspond with Safeguard F.

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 testing. The annual assessment process, originally associated with the CTBT, has evolved independently of the CTBT. 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 is regularly evaluated in the absence of underground nuclear 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 testing might be required.

The FY 2003 NDAA legally codified the requirement for an annual stockpile assessment process. Specifically, section 3141 of the FY 2003 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 FY 2013 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, if the President has not forwarded the jointly signed report.

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[5] 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.

These reports are prepared individually by the directors of the three DOE/NNSA national laboratories (Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL)) and by the CDRUSSTRATCOM, who is responsible for nuclear weapons targeting within the DoD. The reports 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 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 testing is recommended to address any issues associated with the stockpile.

While the principal purpose of annual assessment is to provide analyses of and judgments about the safety, reliability, performance, and military effectiveness of the nuclear stockpile, the process would not be used as a vehicle for notifying decision makers about an immediate need to conduct nuclear test. If an 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 immediately outside of the context of the annual assessment process.

A.8.3 Joint Surety Report

JSR	
Requirement:	NSPD-28
Reporting period:	Fiscal Year
Annual due date:	March 31
Drafted by:	DOE/NNSA and NWC Staff
Coordinated through:	NWC and NWCSSC
Signed by:	Secretaries of Defense and Energy
Submitted/Transmitted to:	House and Senate Committees on Armed Services and Appropriations

National Security Presidential Directive 28 (NSPD-28), *United States Nuclear Weapons Command and Control, Safety, and Security*, dated June 20, 2003, requires the DoD and the DOE/NNSA 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 DOE/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.

Currently, the DOE/NNSA prepares the preliminary inputs to the JSR. The NWC staff is then responsible for further drafting and coordinating the JSR with additional input from the DoD and the DOE/NNSA. When all preliminary comments are received and incorporated, the JSR is then reviewed by the NWCSSC. This is followed by an NWC vote to approve the report before it is forwarded to the Secretaries of Defense and Energy for signatures. The NSC staff requires joint transmittal of the JSR along with the *U.S. Nuclear Command and Control System (NCCS) Annual Report*, as developed by the NCCS Support Staff (NSS) and signed out by the director, NSS (CDRUSSTRATCOM). The reports are due to the President by March 31 each year.

A.8.4 NWC Budget Certification Letter

Budget Certification	
Requirement:	FY 2013 NDAA
Reporting period:	Fiscal Year
Annual due date:	First Tuesday of February (with 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

Section 1039 of the FY 2013 NDAA amended 10 USC 179 by incorporating a new responsibility for the NWC to certify the funding request for the upcoming fiscal year and that which is anticipated for the following four fiscal years, sufficiently meet the NWC stockpile requirements. This certification is sent to Congress in the form of a short letter from the NWC chairman that represents the opinion of each NWC member.

The DoD and the DOE/NNSA function on different budget request cycles, with the DOE/NNSA preparing its budget later in the calendar year than the DoD. The budget certification is an NWC agenda topic, usually beginning in November, and the members discuss how the DOE/NNSA is forming its request to meet DoD needs, as laid out in the current endorsed stockpile profile. Annually the DOE/NNSA provides a line-by-line breakout of its budget for the members to review while the DoD-CAPE 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.

A.8.5 Stockpile Stewardship and Management Plan Assessment

SSMP Assessment	
Requirement:	FY 2013 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 DOE/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, the DOE/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 FY 2013 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; and 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 members. 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.

A.8.6 Annual Report on the Nuclear Weapons Stockpile of the United States

Stockpile Report	
Requirement:	FY 2012 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 FY 2012 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 the DoD and, therefore, the NWC staff assists in drafting and coordinating the report. The DoD members of the NWC coordinate on the report, as well as the Secretaries of the Navy and the Air Force.

A.8.7 Biennial Report on Platform Assessments

ROPA

Requirement:	FY 2012 NDAA
Reporting period:	Two fiscal years
Annual due date:	Biennial (FY); March 1
Drafted by:	Director Navy SSP, Commander Air Force Global Strike Command, and CRDUSSTRATCOM
Coordinated through:	ODASD(NM) and NWC
Signed by:	Secretary of Defense
Submitted/Transmitted to:	President and Congress

Section 1041 of the FY 2012 NDAA created a new DoD-only, biennial reporting requirement similar to the construct of ROSA. The ROPA comprises assessments from the Director of Navy SSP, the 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 NCCS. The "covered officials" coordinate through the ODASD(NM) and submit these assessments to the NWC and the Secretary of Defense by December 1 of each 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 not coordinated through the NWC process. However the ODASD(NM) is the responsible coordinating office for the DoD. The DoD members of the NWC coordinate on the report, as well as the Secretaries of the Navy and the Air Force.

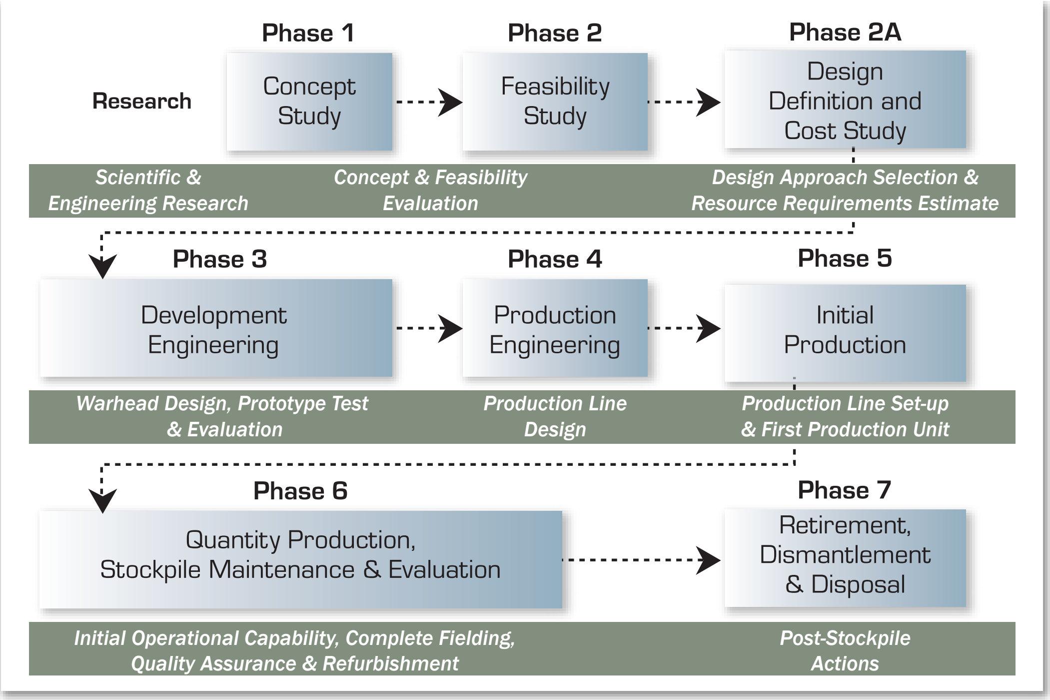
Appendix B

U.S. Nuclear Weapons Life-Cycle

B.1 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. As a part of nuclear weapons stockpile management, the DoD and the DOE, through the NNSA, have specific responsibilities related to nuclear weapons life-cycle activities. This chapter describes the most significant activities and decision points during the life-cycle of a nuclear warhead. The information presented in this chapter is a summary version of the formal life-cycle process codified in the *1953 Agreement Between the AEC and the DoD for the Development, Production, and Standardization of Atomic Weapons*, commonly called the 1953 Agreement. U.S. nuclear weapons have not undergone the full life-cycle phase process since the completion of the W88 Phase 5 in 1991. The United States has not produced new nuclear weapons since 1991. **Figure B.1** depicts the traditional joint DoD-DOE/NNSA nuclear weapons life-cycle phases.

Figure B.1 Joint Nuclear Weapons Life-Cycle Phases



Historically, life-cycle phases 1 through 7 established activities associated with the acquisition of nuclear weapons into the stockpile through their eventual retirement. Since 1999, the phased life-cycle process has evolved to focus on key elements in weapon stockpile sustainment. Today, the 6.X Process provides the framework for nuclear weapon stockpile sustainment activities. The 6X Process is not intended to replace established Phase 6 activities such as routine maintenance, stockpile evaluation, enhanced surveillance, and annual assessment. Rather, 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 weapons stockpile. The 6.X Process activities are for non-routine nuclear weapon alterations (Alts) at the system, sub-system, or component level; life extension programs (LEPs); and other warhead modernization activities. Stockpile sustainment activities conducted under the 6.X Process follow current policy to utilize warhead remanufacturing, component reuse, and component replacement, excluding limited life component exchange (LLCE) (e.g., tritium gas bottle replacement which is managed under normal weapon maintenance programs). Nuclear weapon alterations are assessed on a case-by-case basis to determine applicability of the Phase 6.X Guideline. Depending on the specific stockpile sustainment activity some portions of the 6.X Process may be merged, deferred, modified, or omitted, as approved by the Nuclear Weapons Council (NWC). Additionally, the NWC may authorize the weapon Project Officers Group (POG) to coordinate Alts as routine weapon sustainment activities.

B.2 Phase 6.X Process

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 testing. To manage and facilitate the stockpile sustainment process, the NWC approved the *Procedural Guideline for the Phase 6.X Process* in April 2000. This guideline has been revised and the revision is in the NWC approval process. The revision takes into account the evolution of the stockpile since 2000 and draws on the experience from a number of LEPs, Alts, and modifications (Mods) conducted in this timeframe. **Figure B.2** is an illustration of the Phase 6.X Process.

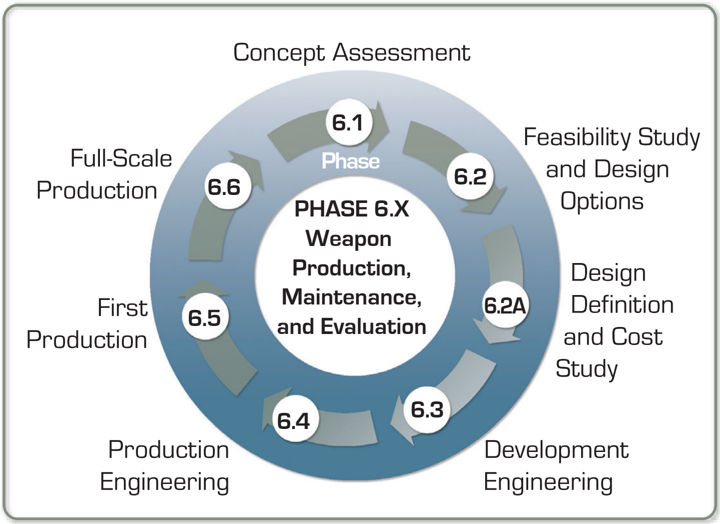


Figure B.2 Phase 6.X Process

The Phase 6.X Process is based on the original *Joint 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 Phase 7 Process. The phased life-cycle process was used to develop a complete warhead, whereas the 6.X Process is intended to develop and field only those components that must be replaced as a part of the approved stockpile sustainment program for a legacy warhead-type. Each stockpile sustainment program is different; some involve the replacement of only one or two key components, while others may involve the replacement of many key components. 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 DOE/NNSA requirements.

B.2.1 Phase 6.1 – Concept Assessment

The DoD and the DOE/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. The DoD and the DOE/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 DOE/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 NWC Standing and Safety Committee (NWCSSC). This notification, at a minimum, includes an overview of the study's purpose, scope, objectives, and deliverables.

Key Tasks and Deliverables

At the completion of the Concept Assessment phase, the POG provides:

- 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;
- initial assessment of supply chain protection considerations;
- proposed potential changes to the military characteristics (MCs), stockpile-to-target sequence (STS), or other DOE/NNSA requirements drivers; and
- 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.

B.2.2 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 system 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 the DoD and analyzed by the DOE/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 (ICDs). If updates are required, the POG coordinates any STS changes while approval of ICD updates are controlled between the DOE/NNSA and the appropriate Military Department.

The DOE/NNSA prepares a Major Impact Report (MIR), as necessary, reflecting any major impacts due to the down-selected option(s).[1] The POG includes the DOE/NNSA 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 operation 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 options considered and associated analyses. It documents criteria used to down-select from the options considered (e.g., the extent to which each concept meets DoD and DOE/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 and STS documents are also included in the Phase 6.2 study report.

The POG down-selects design options to be analyzed for cost in Phase 6.2A. These options are presented to the NWC for approval prior to commencing Phase 6.2A.

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[1] Down-selected option(s) are those selected from a field of options to continue to the next phase.

B.2.3 Phase 6.2A – Design Definition and Cost Study

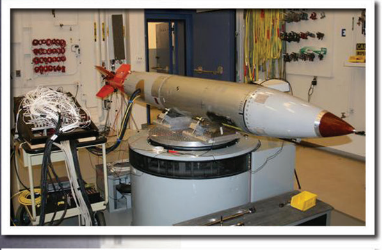
Phase 6.2A continues upon successful completion of Phase 6.2 activities. During Phase 6.2A, the POG refines the down-select options by updating the down-select criteria developed in Phase 6.2, developing design and qualification plans, identifying production needs, and creating a preliminary life-cycle 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 of the Joint Integrated Project Plan (JIPP) from the POG and the Weapon Design and Cost Report (WDCR) from the DOE/NNSA.

Key Tasks and Deliverables

The POG creates the JIPP based on DoD and DOE/NNSA input to implement the proposed down-selected 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-DOE/NNSA milestones, planned management briefings and reviews, and certification schedules);
- cost analysis;
- configuration management;
- qualification and certification plans;
- supply chain protection program plan;
- Military Department test and evaluation plans;
- MCs, STS, and ICD changes;
- system memoranda of understanding between the DoD and the DOE/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;

The lathe is used to machine high explosives parts for use in weapon life extension programs at Pantex



- 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.

The DOE/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;
- 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 (SEP) plan;
- platform requirements, to include any changes;

- risk management strategy;
- requirements management process;
- configuration management process; and
- cost analysis, to include trade-off decisions.

B.2.4 Phase 6.3 – Development Engineering

During Phase 6.3, the DOE/NNSA, in coordination with the DoD, conducts experiments, tests, and analyses to develop and validate the selected design option. The national 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 down-select option. The recommendation for Phase 6.3 entry includes updated MCs and STS documents, as appropriate. Prior to executing Phase 6.3 activities, the POG acquires written authorization to proceed from the NWC.

Key Tasks and Deliverables

Following its authorization to enter Phase 6.3, the NWC prepares a letter requesting Military Department and DOE/NNSA participation in Phase 6.3. The DOE/NNSA and the appropriate Military Department generate and approve interagency agreements, as required, to cover technical and financial responsibilities for product-specific or joint activities. The DoD and the DOE/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.

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

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

B.2.5 Phase 6.4 – Production Engineering

During Phase 6.4, the DOE/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. The DOE/NNSA updates production cost estimates based on preliminary experience gained in PPI and product qualification. Finally, the DoD and the DOE/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, the DOE/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.

The DoD and the DOE/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 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 the DOE/NNSA updates the BCR. Prior to entry into Phase 6.5, the POG provides written notification to the NWC that the DOE/NNSA is prepared to transition to Phase 6.5.

B.2.6 Phase 6.5 – First Production

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

Key Tasks and Deliverables

The DOE/NNSA makes a final weapon evaluation of the design and production processes. The national laboratories, in coordination with the DOE/NNSA, prepare the final draft addendum to the FWDR, and then submit the draft FWDR and addendum, and the draft MIR 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 the DOE/NNSA whether the weapon meets MCs, STS, and other applicable requirements.

The national 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 requalification for system deployment.

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

The first production unit (FPU) milestone occurs when the Military Department and/or the NWC accepts the design and the DOE/NNSA verifies the first produced weapon(s) meets the design. Phase 6.5 terminates with DoD acceptance actions, as conveyed in a letter from the Military Department and/or the NWC chairman to the NNSA Administrator.

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 operation that affect safety. The NWSSG also validates 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.

B.2.7 Phase 6.6 – Full-Scale Production

The DOE/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

The DOE/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 at 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.

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

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

B.3 Phase 7 – Retirement and Dismantlement

Phase 7 begins with the first warhead retirement of a particular warhead-type. At the national level, retirement is the reduction in quantity of a warhead-type in the Nuclear Weapons Stockpile Plan for any reason other than to support surveillance activities. However, the DOE/NNSA may be required to initiate Phase 7 activities to perform dismantlement and disposal activities for surveillance warheads that are destructively tested under surveillance activities. This phase initiates a process that continues until all warheads of a specific 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 the DOE/NNSA is dismantling and disposing of the warheads, if appropriate, the DoD is engaged in the retirement, dismantlement, and disposal of associated nuclear weapons delivery systems and platforms.

Appendix C
Basic Nuclear Physics and Weapons Effects

C.1 Overview

This appendix offers a basic overview of nuclear physics, proliferation considerations, the effects of nuclear detonations, nuclear targeting, and the physics of countering nuclear threats. It is information useful in understanding the basic technical aspects of the U.S. nuclear stockpile and efforts to counter nuclear threats.

C.2 Nuclear Physics

C.2.1 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 are combined to form atoms, they are called elements. An element is one of more than 110 known chemical substances, 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. The smallest unit of a given amount of an element is called an atom. Atoms are composed of electrons, protons, and neutrons.

Nuclear weapons depend on the potential energy that can be released from the nuclei of atoms. In the atoms of heavy elements, which serve as fissile material in nuclear weapons, the positively charged protons and electrically neutral neutrons, collectively known as nucleons, form the enormously dense nucleus of the atom that is located at the center of a group of shells of orbiting, negatively charged electrons. See **Figure C.1** for an illustration of the structure of an atom.

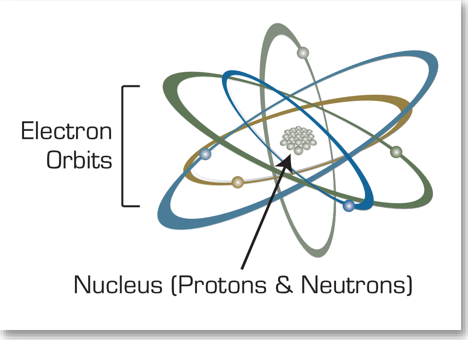


Figure C.1 Diagram of an Atom

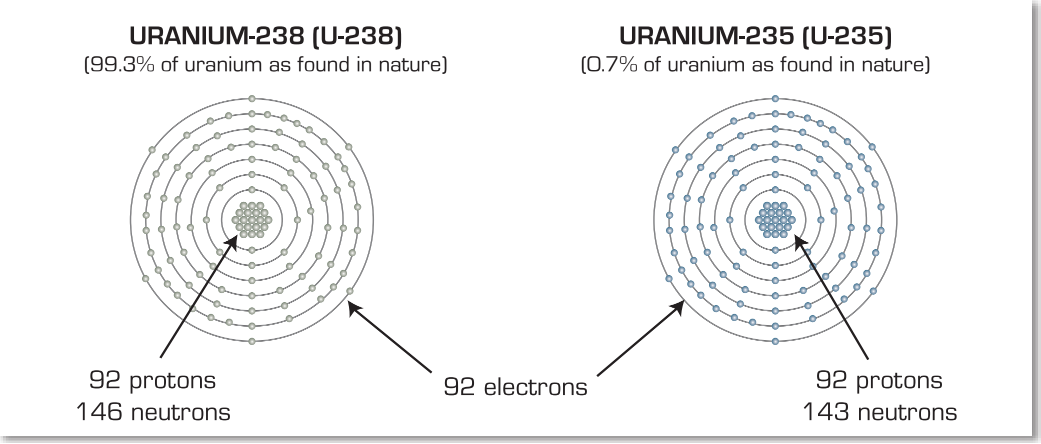
Electron interactions determine the chemical characteristics of atoms whereas nuclear activities depend on the characteristics of the nucleus. Examples of *chemical characteristics* include the tendency of elements to combine with other elements (e.g., hydrogen and oxygen combine to form water), the 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, 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 there can neither be a loss nor a gain of mass during a chemical reaction, but mass can be converted to energy in a reaction at the nuclear level. This change of mass into energy is what is responsible for the tremendous release of energy during a nuclear detonation.

Isotopes are atoms that have identical atomic numbers (same number of protons) but a different atomic mass (different number of neutrons). Different isotopes of the same element have different nuclear characteristics, for example uranium-235 (U-235) has significantly different nuclear characteristics than U-238. **Figure C.2** is an illustration of the two primordial isotopes of uranium. There are currently 23 known isotopes of uranium.

C.2.2 Radioactive Decay

Radioactive decay is the process of nucleus change and 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.

Figure C.2 Isotopes of Uranium



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 very small fraction of a second to billions of years. The rate of decay is also characterized as activity, or the number of decay events or disintegrations that occur in a given time.

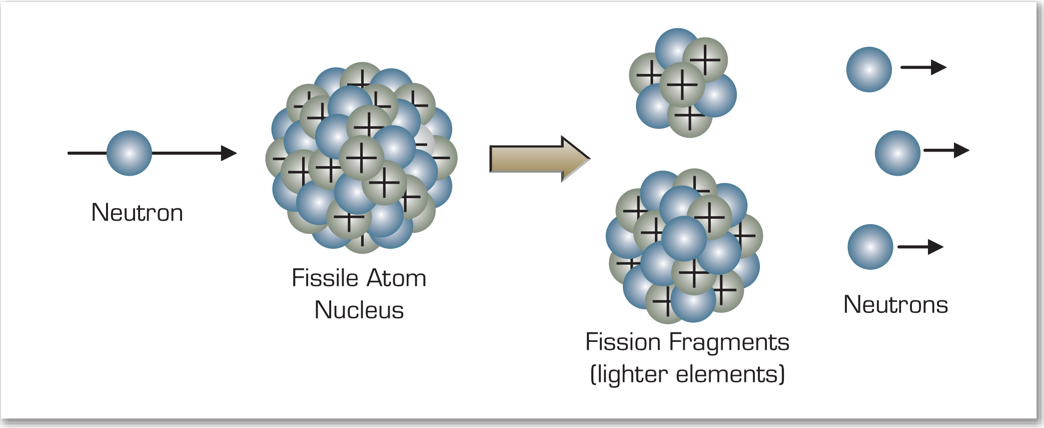
C.2.3 Nuclear Reactions

Fission, the splitting apart of nuclei, and *fusion* the 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 sub-atomic 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 (**Figure C.3**) can interact with the nuclei of other fissile atoms and produce other fission events, referred to as a *chain reaction*.

Figure C.3 Fission Event



Criticality describes whether the rate of fission is increasing (supercritical), remaining constant (critical), or decreasing (subcritical). See **Figure C.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.

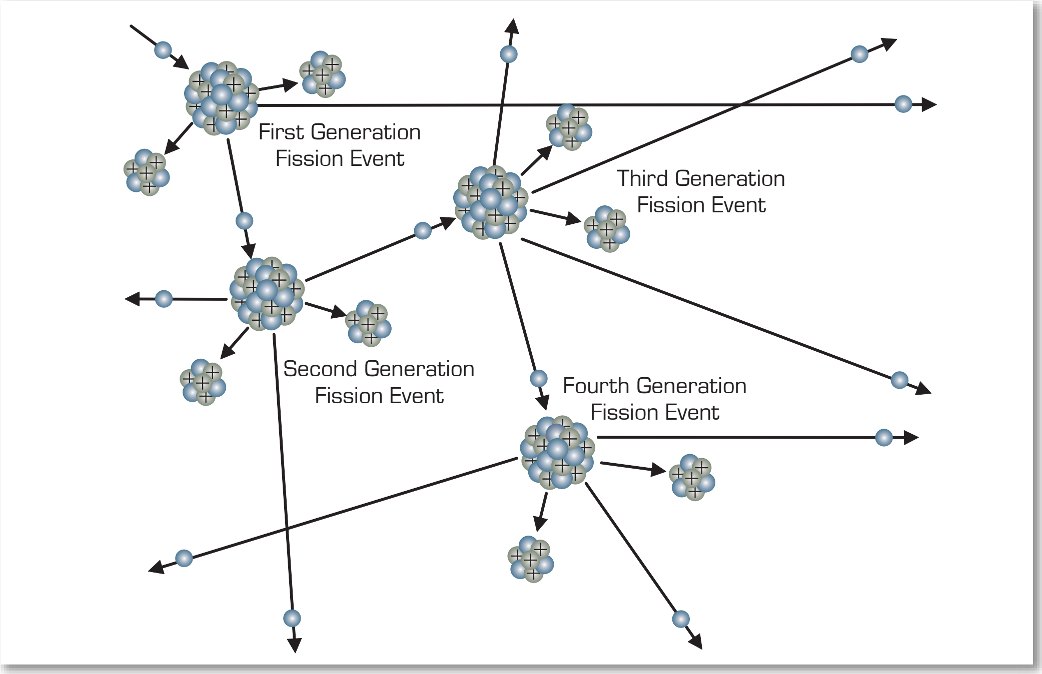


Figure C.4 Chain Reaction of Fission Events

Fissile material is called a subcritical mass, or subcritical component, when the amount is so small and the configuration with atoms is so spread-out that any fission event 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.

Different types of fissile isotopes have different probabilities of fission when nuclei are struck with a neutron. 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. Generally, the larger the amount of fissile material in one mass, 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.

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 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 to achieve fusion. In almost all cases, a fusion event produces one high-energy free neutron, which can be used in a nuclear weapon to cause another fission event. Fusion also releases significantly more energy than a chemical reaction does. **Figure C.5** is an illustration of a fusion event.

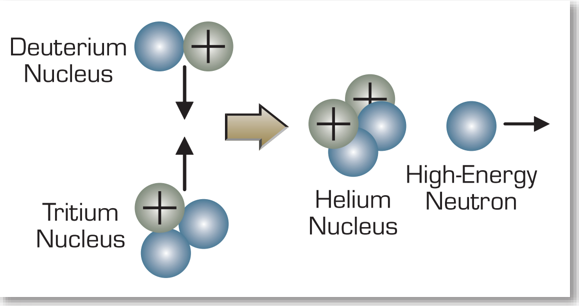


Figure C.5 Fusion Event

C.2.4 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 due to the primary energy release coming 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,* due to the high temperatures and pressure required for the fusion reactions to occur.[1]

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. 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 super-criticality, the first generation of fission events in the multiplying chain reaction is a larger number of fission events.

Currently, nuclear weapons use one of four basic design approaches: gun assembly, implosion, boosted, or staged.

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[1] The term *thermonuclear* is also used to refer to a two-stage nuclear weapon.

Gun Assembly Weapons

Gun assembly (GA) weapons (**Figure C.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 a nuclear detonation. In general, the GA design is less technically complex than other designs and is also the least efficient.[2]

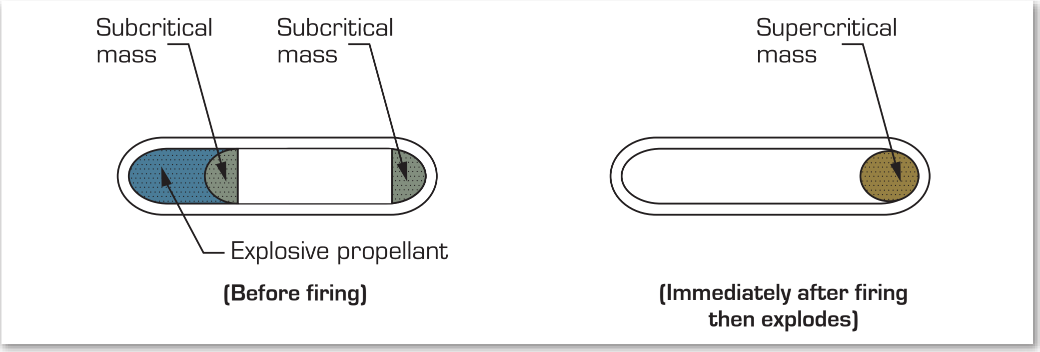

Figure C.6 Unclassified Illustration of a GA Weapon
(Source: *Joint DOE/DoD Topical Classification Guide for Nuclear Assembly Systems* (TCG-NAS-2), March 1997)

Implosion Weapon

Implosion weapons (**Figure C.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, thereby compressing it. The increased density achieves

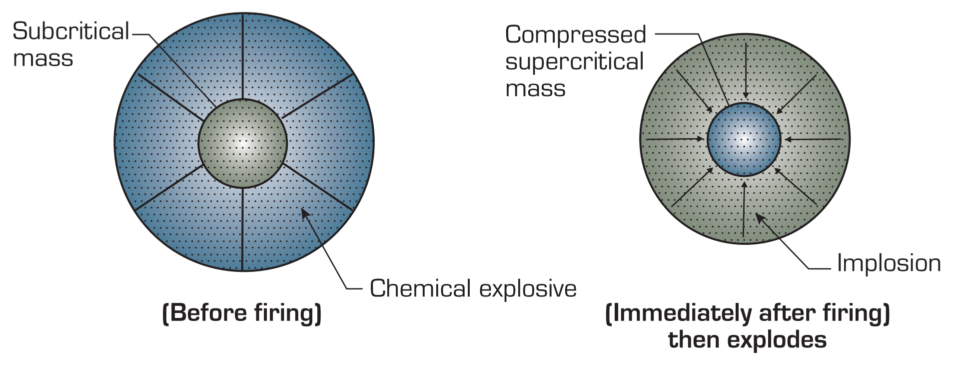

Figure C.7 Unclassified Illustration of an Implosion Weapon
(Source: TCG-NAS-2, March 1997)

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[2] Technical efficiency is measured by the amount of energy produced for a given amount of fissile material. Less efficient devices require more material to produce the same energy yield.

super-criticality since the fissile nuclei are 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.

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 C.8**) normally uses a boosted primary stage and a secondary stage to produce a significantly increased yield. In the first stage, a 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

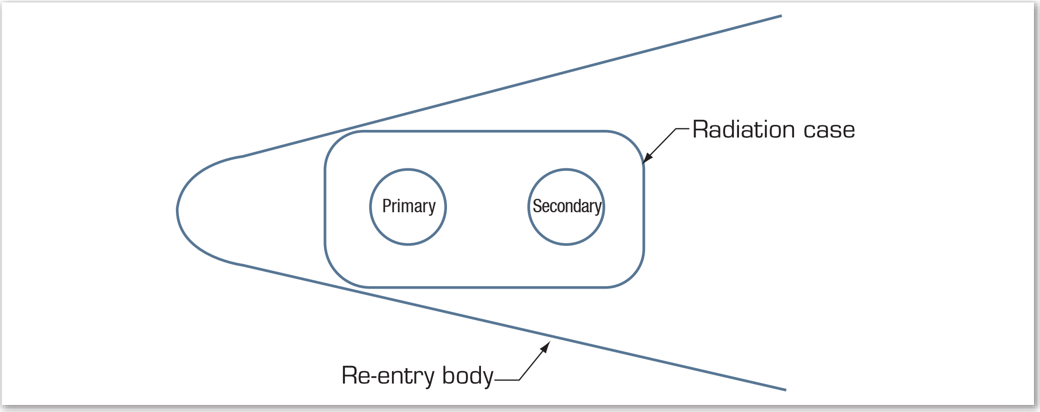

Figure C.8 Unclassified Illustration of a Staged Weapon
(Source: TCG-NAS-2, March 1997)

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.

C.3 Proliferation Considerations

Generally, the smaller the size (e.g., volume, dimensions, and weight) of the warhead, the more difficult it is to get the nuclear package to function to produce a nuclear detonation and the harder it is to achieve a higher yield. The simplest and easiest design is the GA design followed by the implosion design. Since the boosted and staged designs are significantly more difficult, they are not practical candidates for any nation's first generation of nuclear weapons.

Most proliferating nations have focused on the implosion design for a number of reasons. The GA design is the least efficient producing yield in a weapon-sized device and has inherent operational disadvantages not associated with the other designs. Highly enriched uranium (HEU), which can be used in either a GA or implosion design, is very expensive due to the cost of the enrichment process. Since plutonium is produced in a reactor that can also be used for the simultaneous production of electrical power, the cost is partially or completely offset by the value of the electricity produced. However, in a GA design, plutonium is susceptible to *preinitiation*, a significantly reduced yield due to the early initiation of fission events that destroys the weapon before it reaches its designed super-criticality. For this reason, a GA design cannot use plutonium.

Up to this time, nations that have pursued a nuclear weapons capability have been motivated to design warheads small enough to be delivered using missiles or high-performance jet aircraft.[3] This is probably because, unlike the situation in the early 1940s, many nations today, and even some non-government actors, possess some type of effective air-defense system, which render non-stealth, large cargo, or passenger aircraft ineffective at penetrating a potential adversary's target. Due to this size limit,

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[3] Typically, the maximum weight for a warhead to be compatible with a high-performance jet aircraft would be approximately 1,000 to 1,500 kilograms (kg) (2,200 to 3,300 pounds) and approximately 750 to 1,000 kg (1,650 to 2,200 pounds) for the typical missile being proliferated (e.g., Nodong or SCUD-variant missiles).

First Thermonuclear Test, Ivy Mike (10.4 MT) it is very likely that the first generation weapons developed by proliferating nations are low-yield weapons, typically between one[4] and 10 kilotons (kt).[5]

C.4 The 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 nuclear detonation differs from a conventional explosion in several ways. A typical nuclear detonation[6] 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, electromagnetic pulse (EMP), thermal radiation, prompt nuclear radiation, air blast wave, residual nuclear radiation, interference with communications signals, and, if the fireball interacts with the terrain, ground shock. **Figure C.9** depicts the overarching energy distribution for a typical nuclear detonation.

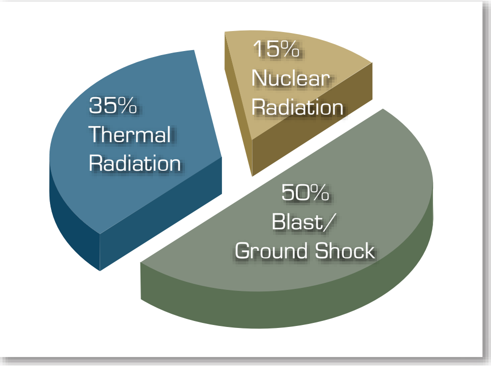

Figure C.9 Energy Distribution for a Typical Nuclear Detonation

C.4.1 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 C.10** shows Hiroshima after being attacked with a nuclear weapon on August 6, 1945.

Figure C.10 Hiroshima After the Nuclear Detonation

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[4] A 1-kt detonation releases the energy equivalent to 1,000 tons of TNT.

[5] The *Fat Man* and *Little Boy* weapons had respective yields of 21 and 15 kt but were almost 10,000 pounds each with dimensions much larger than today's modern warheads.

[6] For the purposes of this appendix, a typical nuclear detonation is one that occurs on the Earth's surface or at a height of burst (HOB) low enough for the primary effects to cause damage to surface targets. Detonations that are exo-atmospheric, high altitude, or deeply buried underground have different effects.

Nuclear detonation effects for people or objects close to GZ are devastating. However, the distances that effects can travel away from GZ are limited.

C.4.2 Overall Effects

The yield of the weapon 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, HOB, terrain, or objects in the area that could interfere with various effects moving away from GZ and the weather in the target area.

If properly employed,[7] 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 produces total devastation in an area large enough to produce tens of thousands, and possibly more than 300,000 fatalities. Yet, it does not wipe-out the entire major metropolitan area. The survival of thousands of people who are seriously injured or exposed to a moderate level of nuclear radiation depends on the response of various federal, state, and local government agencies and non-governmental organizations.

C.4.3 Casualty and Damage Distances for Populated Areas

A very low-yield, 1-kt detonation produces severe damage effects approximately one quarter of a mile from GZ. Within the severe damage zone, almost all buildings collapse and 99 percent of persons become fatalities quickly. Moderate damage extends approximately one half mile and includes 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 includes 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.

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[7] Proper employment includes using the required yield at the required location with an effective HOB (e.g., a high-altitude detonation does 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.

A low-yield, 10-kt detonation produces severe damage effects approximately one half mile from GZ. Moderate damage extends approximately one mile and light damage ranges approximately three miles.

A high-yield, strategic 1-megaton (MT) detonation[8] produces severe damage effects slightly beyond two miles from GZ. Moderate damage extends out beyond four miles and light damage encompasses beyond 12 miles.

C.4.4 Nuclear Fireball

A typical nuclear weapon detonation produces 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 of a second. The size of the immediate fireball is a function of yield and the surrounding environment. **Figure C.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 C.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.

C.4.5 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

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[8] A 1-MT detonation releases the energy equivalent to one million tons of TNT.

some protection against thermal burns or the ignition of objects. **Figure C.12** shows types of burns and approximate maximum distances for selected yields.[9]

			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 C.12 Thermal Radiation Burns

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. Since 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.

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 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

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[9] The distances in **Figure C.11** 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.

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.

C.4.6 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 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.[10] 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 ground zero, 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).

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[10] 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.

This is the beginning of the negative phase of dynamic pressure. The vacuum effect, or negative overpressure, can cause a wood frame 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 C.13** shows the overpressure in pounds per square inch (psi) and the approximate distances associated with various types of structural damage.[11]

		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 C.13 Air-Blast Damage to Structures

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 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

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[11] The distances in **Figure C.12** 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 one psi.

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, making it 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.

C.4.7 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.

Subsidence Craters at Yucca Flat on the Nevada National Security Site

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 to distances usually two to five times deeper than those destroyed through the employment of a surface burst.[12] 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 routes, as well as communications lines connected to ground-level equipment, can be hardened or made redundant.

C.4.8 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.[13] 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 testing, the expanding fireball creates a spherical volume of hot radioactive gases. As

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[12] The amount of increased depth of damage is primarily a function of the yield and the soil or rock type.

[13] 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 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.

A crater produced by a recent detonation near 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 does not use crater formation to attack targets. Though at the height of the Cold War, the North Atlantic Treaty Organization (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.

C.4.9 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 their hull. 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. Normally, nuclear weapons are not used to target enemy naval forces.

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.

C.4.10 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.[14] Gamma rays are high-energy photons of electromagnetic radiation with frequencies higher than visible light or ultraviolet rays.[15] 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.[16]

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[14] 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.

[15] 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.

[16] 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.

Since 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 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. For a description of the biological damage mechanisms, see section C.4.12 on the biological/medical effects of ionizing radiation. The unit of measurement for radiation exposure is the Centi-Gray (cGy).[17] The 450 cGy exposure dose level is considered to be the lethal dose for 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 C.14** shows selected levels of exposure, the associated near-term effects on humans, and the distances by yield.[18]

		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 C.14 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

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[17] 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).

[18] For the purposes of this appendix, 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.

this risk by approximately 10 to 15 percent and lethal cancer by approximately six to eight percent.[19]

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. Some non-strategic or terrorist targets may include people as a primary target element. 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).

Individuals can do very little to protect themselves against initial nuclear radiation after a detonation has occurred since initial radiation is emitted and absorbed in less than one minute. The 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.

C.4.11 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 exo-atmospheric

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[19] Calculated from data in *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII - Phase 2*, National Academy of Sciences, Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, 2006.

detonation creates a cloud in orbit that could remain significantly radioactive for many months.

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.[20] These atoms become radioactive isotopes capable of emitting, among other things, gamma radiation. The induced radiation is generally created in a circular pattern, 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. This could cause first responders who are not trained to understand induced radiation to move into an area still radioactively hot because, without radiation detectors, they would not be aware of the radioactive hazard.

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 to three 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 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

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[20] Neutrons induced into typical soil are captured primarily by sodium, manganese, silicon, and aluminum atoms.

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 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 the 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 exo-atmospheric 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.

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).[21] 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 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.

C.4.12 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 exposure, there are near-term consequences, including impaired performance that can cause casualties and death. **Figure C.15** 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 C.15 Biological Damage from Ionization

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[21] PPE for first responders includes a sealed suit and self-contained breathing equipment with a supply of oxygen.

At low levels of exposure, ionizing radiation does not cause any near-term medical problems. However, at the 75 cGy level, approximately five 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 C.16** shows healthy adults' increased risk 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 C.16 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 C.17** 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]

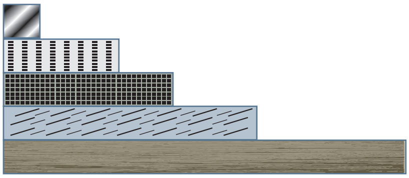

Figure C.17 Radiation Shielding

C.4.13 Electromagnetic Pulse

EMP is a very short duration pulse of low-frequency, or long-wavelength, electromagnetic radiation (EMR). EMP is produced when a nuclear detonation occurs in a non-symmetrical environment, especially at or near the Earth's surface or high altitudes.[22] The interaction of gamma and X-rays with the atoms in the air generates an instantaneous flow of electrons. These electrons immediately change direction, primarily due to the Earth's magnetic field and velocity, emitting a large number of low-frequency EMR photons. This entire process occurs almost instantaneously.

Any unprotected equipment with electronic components could be vulnerable to EMP. A large number of low-frequency photons can be absorbed by any antenna or any component acting as an antenna. This energy moves within the equipment to unprotected electrical wires or electronic components and generates a flow of electrons. The electron flow becomes voltage within the electronic component or system. Modern electronic equipment using low voltage components can be overloaded with a voltage beyond its designed capacity. At low levels of EMP, this can cause a processing disruption or a loss of data. At increased EMP levels, certain electronic components can be destroyed. EMP can damage unprotected electronic equipment, including computers, vehicles, aircraft, communications equipment, and radars. EMP does not result in structural damage to buildings or bridges, for example, and is not a direct hazard to humans. It is possible the effects of electronics failing instantaneously in items such as vehicles, aircraft, and life-sustaining equipment in hospitals could cause injuries or fatalities.

A high-altitude detonation, or an exo-atmospheric detonation within a certain altitude range, generates an EMP that could cover a very large region of the Earth's surface, as large as one thousand kilometers across. A surface or low-air burst produces local EMP with severe intensity, traveling through the air out to distances of hundreds of meters. Generally, the lower the yield, the more significant the EMP is compared with air blast. Unprotected electronic components are vulnerable and electrical lines as well as telephone wires carry the pulse to much greater distances, possibly 10 kilometers, and could destroy any electronic device connected to the power lines.

Since electronic equipment can be hardened against the effects of EMP, it is not considered in traditional approaches for damage estimation. The primary objective of EMP hardening is to reduce the electrical pulse entering a system or piece of equipment to a level that

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[22] EMP can also be produced by using conventional methods.

does not cause component burnout or operational upset. It is always cheaper and more effective to design EMP protection into the system during design development. Potential hardening techniques include the use of certain materials as radio frequency shielding filters, internal enclosed protective “cages” around essential electronic components, and enhanced electrical grounding and shielded cables. Additionally, equipment can be hardened if it is kept in closed protective cases or in EMP-protected rooms or facilities. Normally, the hardening that permits equipment to operate in intense radar fields (e.g., helicopters operating in front of a ship’s radars) also provides a significant degree of EMP protection.

Because EMP is so fast, circuit breakers, surge protectors, and power strips are not effective against EMP since these are designed to protect against a lightning strike, whereas EMP is at least one thousand times faster than a bolt of lightning.

C.4.14 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 exo-atmospheric 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. Since 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.

C.4.15 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 exo-atmospheric 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.

C.5 Nuclear Weapons Targeting Process

C.5.1 Nuclear Weapons Targeting Overview

Nuclear weapons targeting is based on nuclear weapons effects and accounts for the characteristics of U.S. nuclear weapons, predictable effects of those weapons, and resulting damage expectancy. It is a process by which the United States calculates how well it meets damage requirements to defeat adversary targets. The nuclear weapons targeting process is cyclical, beginning with guidance and priorities issued by the President, the Secretary of Defense, and the Chairman of the Joint Chiefs of Staff (CJCS) in conjunction with appropriate combatant command guidance and priorities. These objectives direct joint force and component commanders and the targeting process continues through the combat assessment phase. **Figure C.18** illustrates the U.S. nuclear targeting cycle.

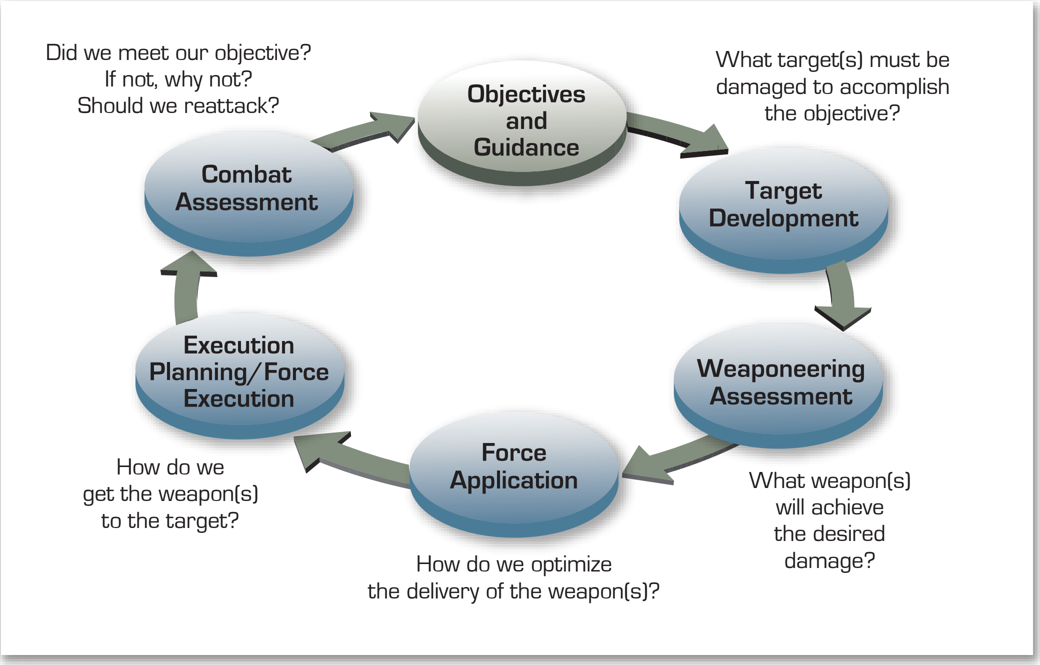

Figure C.18 U.S. Nuclear Targeting Cycle

Objectives and Guidance: Guidance and objectives are issued by the President and the CJCS while joint force and component commanders initiate the targeting cycle.

Target Development: Targets are developed focused on identifying and nominating critical elements of enemy military forces and their means of support for attack.

Weaponeering Assessment: Planners analyze each target nominated for a nuclear strike to determine the optimal means of nuclear attack. During this process, planners consider the employment characteristics of available weapons including yields, delivery accuracy, and fuzing. Damage prediction, consequences of execution, and collateral damage preclusion are additional factors considered in this analysis. Target analysts use target information including location, size, shape, target hardness, and damage criteria (moderate or severe) as inputs to nuclear targeting methodologies.

Force Application: Information is integrated concerning the target, weapon system, and munitions types in addition to non-lethal force options to select specific weapons to attack specific targets.

Execution Planning and Force Execution: The final tasking order is prepared and transmitted; specific mission planning and material is received at the unit level; and presidential authorization for use is issued.

Combat Assessment: A joint effort determines if the required target effects meet the military campaign objectives. Nuclear combat assessment is composed of two segments, battle damage assessment and a re-attack recommendation.

C.5.2 Nuclear Weapons Targeting Terminology

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's 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 (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 HOB of the nuclear weapon.

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 aim-point.

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 (PA) is the likelihood the weapon arrives and detonates in the target area, calculated as a product of weapon system reliability (WSR), pre-launch 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 (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 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. Since 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 aim-point, 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 (DGZ)**—moving the DGZ away from target center may achieve the desired effects while avoiding or minimizing collateral damage.

Counterforce targeting plans to destroy the military capabilities of an enemy force. Typical counterforce targets include bomber bases, ballistic missile submarine bases, intercontinental ballistic missile (ICBM) silos, air-defense installations, command and control centers, and weapons of mass destruction storage facilities. Since these types of targets are harder and more protected, the forces required to implement this strategy need to be numerous and accurate.

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. Since these targets tend to be softer and less protected, weapons required for this strategy need not be as numerous or as accurate as those required to implement a counterforce targeting strategy.

Layering is a technique that plans 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.

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.

C.6 Physics for Countering Nuclear Threats

While the technical challenges to building advanced designs such as staged nuclear weapons are significant, the relative simplicity of a GA design raises the possibility non-state actors with sufficient fissile material could assemble a supercritical mass and produce a nuclear detonation using an improvised nuclear device (IND). The physical effects of a nuclear detonation demonstrate 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 (CNT) is paramount.

C.6.1 Fission Yield and Nuclear Forensics

The fission process produces isotopes with a wide range of atomic mass and atomic number, 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. **Figure C.19** compares fission yield curves for U-235 and plutonium-239 (Pu-239). Fission from Pu-239 results in relatively more heavy nuclei than from U-235, as well as higher yield in the atomic mass range 100-120.

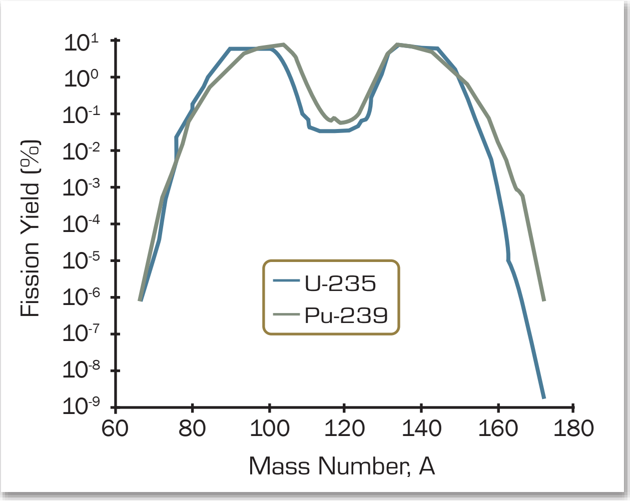

Figure C.19 Fission Product Yield by Mass for U-235 and Pu-239

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 what the device used as fissile material.

C.6.2 Detection of Nuclear Material

The same principles of 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 in 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. Since 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 C.20** compares the penetration of various types of radiation.

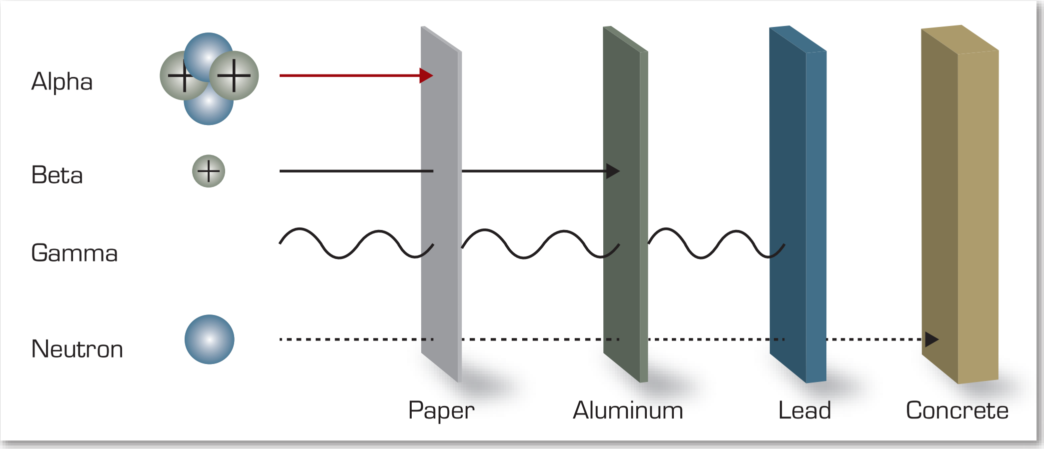

Figure C.20 Penetrating Power of Various Types of Radiation

Appendix D

Nuclear and Non-Nuclear Testing

D.1 Overview

From 1945 to 1992, the United States conducted both nuclear and non-nuclear testing. After 1992, the United States developed a robust program to certify the continued safety, security, and effectiveness of nuclear weapons without the use of nuclear explosive testing.

D.2 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 the *Fat Man* implosion design weapon 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. Nuclear testing resumed in 1961 and the United States 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 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 U.S. from conducting an underground nuclear test and led to the current policy restriction on nuclear explosive testing.

D.2.1 Early Years of the U.S. Nuclear Testing Program

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, very crude test measurement equipment and computational

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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 a great benefit to the United Kingdom—especially following the atmospheric testing moratorium of 1958—because the nation 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 9: International Nuclear Cooperation*, 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).

capabilities. Because of this, only limited amounts of scientific data were gained in 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 Nevada Test Site (NTS), Enewetak Atoll, Bikini Island, the Pacific Ocean, and Nellis Air Force Range in Nevada. 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 D.1** shows the *Bravo* fireball shortly after detonation.

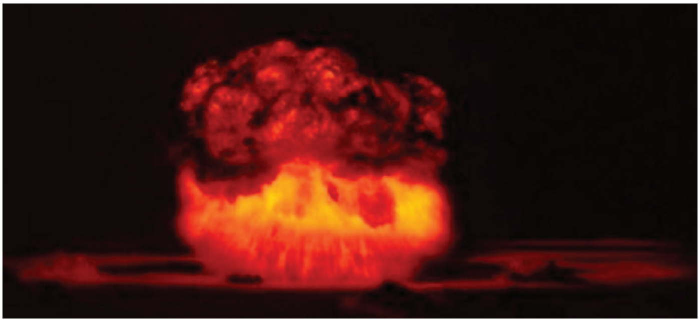

Figure D.1 Bravo Nuclear Test

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 data base expanded and computing technology evolved.

D.2.2 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 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 1968 *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)[3] 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).[4] The locations for these tests included the NTS, Nellis Air Force Range in Nevada, and the vicinities of Fallon, Nevada; Hattiesburg, Mississippi; Amchitka, Alaska; Farmington, New Mexico; Grand Valley, Colorado; and Rifle, Colorado.[5] 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.[6] 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 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

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[3] 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).

[4] Four of these were surface experiments, without a nuclear detonation, to study plutonium scattering.

[5] After May 17, 1973, all U.S. nuclear tests were conducted at the NTS.

[6] 81 of the 90 tests are listed in the unclassified record with a yield between 20 and 200 kt.

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. 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.[7] See **Figure D.2** for a photograph of a preparation site for an underground nuclear test.


Figure D.2 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

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[7] 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.

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 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.[8] 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 were 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 X-ray 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

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[8] 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.

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) to certify several different secondary stage designs, which would produce yields greater than 150 kt. See **Figure D.3** for a summary of U.S. nuclear tests by yield.

	Yield					
Time Period	**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 D.3 U.S. Nuclear Tests by Yield

The second change was that, 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, the newest strategic warheads would not have a nuclear test, in its new configuration, for any yields above 150 kt.

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. 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 six 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 component. 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.

D.2.3 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 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 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.[9] 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 the computational modeling capabilities.

D.2.4 End of Underground Nuclear Testing

In 1992, in anticipation of a potential comprehensive test ban treaty, the United States voluntarily suspended underground nuclear testing. Public Law (Pub. L.) 102-377, the legislation prohibiting U.S. underground nuclear testing, had several key elements.

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[9] 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.

Preparation for Divider, the Last U.S. Underground Nuclear Test

These included a provision for 15 additional nuclear tests to be conducted by the end of September 1996 for the primary purpose of applying three modern safety features (enhanced nuclear detonation safety (ENDS), insensitive high explosive (IHE), and fire-resistant pit (FRP)) to those warheads planned for retention in the reduced stockpile under the proposed *Strategic Arms Reduction Treaty (START) II*.

With a limit of 15 tests within less than four years, 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. Therefore, the legislation was deemed too restrictive to achieve the objective of improving the safety of those warhead-types lacking all of the available safety enhancements and it was decided the United States would not conduct any further tests. The last U.S. underground nuclear test, *Divider*, was conducted on September 23, 1992.

The *National Defense Authorization Act* (*NDAA*) *for Fiscal Year (FY) 1994* (Pub. L. 103-160) called on the Secretary of Energy to "establish a stewardship program to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons." The Stockpile Stewardship Program, a science-based approach to ensure the preservation of competencies as mandated by the FY 1994 NDAA, has served as a substitute for underground nuclear testing since 1992. For more information on the Stockpile Stewardship Program, see *Chapter 4: U.S. Nuclear Weapons Infrastructure*.

D.3 Quality Assurance and Non-Nuclear Testing

The goals of the U.S. nuclear weapons quality assurance (QA) 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 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. The DOE/NNSA Stockpile Evaluation Program (SEP) has evolved over decades and currently provides the information to support stockpile decisions and assessments of the safety, reliability, and performance of the stockpile. This program is designed to detect stockpile defects, understand margins at a component level, understand and evaluate changes (e.g., aging), and, over time, predictably assess the stockpile. The overall QA program includes laboratory tests, flight tests, component and material evaluations, other surveillance evaluations and experiments, the reported observations from DoD and DOE/NNSA technicians who maintain the warheads, continuous evaluation for safety validation and reliability estimates, and the replacement of defective or degrading components as required.

No new replacement warheads have been fielded by the United States for over two decades. During that time, sustaining the nuclear deterrent has required the United States to retain warheads well beyond their originally designed life. As warheads in the stockpile age, the stockpile evaluation has detected an increasing number of problems, primarily ones associated with non-nuclear components. This led to an expanded program of refurbishments, as required for each warhead-type.

Because the warheads of the stockpile continue to age beyond any previous experience, it is anticipated the stockpile will reveal age-related problems unlike any other time in the past. As part of proactive QA management, the DOE/NNSA maintains a surveillance program to ensure effectiveness of the U.S. stockpile. These surveillance activities take place in multiple DOE/NNSA locations, including the Pantex Plant in Amarillo, Texas (**Figure D.4**).

Figure D.4 Pantex Plant

D.3.1 Evolution of Quality Assurance and Sampling

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 QA program and no safety standards or reliability requirements to be met. Rather, QA resulted from all precautions thought of by weapons scientists and engineers and the directives of Dr. J. Robert Oppenheimer and his subordinate managers. History proves the Manhattan Project approach to quality was successful in that it accomplished an extremely difficult task without a catastrophic disaster.

The first nuclear weapons required in-flight insertion (IFI) of essential nuclear components, until which time the weapons were unusable. Once assembled in flight, the weapons had none of the modern safety features to preclude an accidental detonation. The early focus was on ensuring the reliability of the weapons because 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.[10] See C*hapter 7: Nuclear Surety*, for a detailed discussion of nuclear detonation safety and surety 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. Initially, this was called the New Material and Stockpile Evaluation Program (NMSEP). New material referred to weapons and components evaluated during a warhead's development or production phase. See *Appendix B: U.S. Nuclear Weapons Life-Cycle*, for a description of nuclear weapon life-cycle phases. New material tests were conducted to detect and repair problems related to design and/or production processes. The random sample warheads 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, the program was reduced to random sampling of 44 warheads of each type. 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 and remained constant for approximately a decade. Over time, the random sample number was once again reduced to 11 per year to reflect fiscal and logistical realities. Each weapon system was re-evaluated with respect to the approach to sampling, accounting for the specific technical needs of each system, and new approaches to evaluation tests being implemented. As a result, some system samples were reduced from 11 per year to lower numbers.

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[10] 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.

In the mid-1980s, the DOE strengthened the significant finding investigation (SFI) process. Any anomalous finding or suspected defect that might 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, random sample warheads drawn from the fielded stockpile are considered part of the Surveillance Program. Under the this program, additional efficiencies are gained by sampling and evaluating several warhead-types as a warhead "family" if there are enough identical key components. Until 2006, each warhead family had 11 random samples evaluated each year under what was called the Quality Assurance and Reliability Testing (QART) program. The sample size enabled the QA program to provide an annual safety validation, supply a reliability estimate semi-annually, and sample any randomly occurring problem that was present in 10 percent or more of that warhead-type (with a 90 percent assurance, within two years).

Weapons drawn for surveillance sampling are returned to the DOE/NNSA 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 (CME). Surveillance testing and evaluation may be conducted at Pantex or at other DOE/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 (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.

D.3.2 Stockpile Surveillance

The Surveillance Program is composed of the Stockpile Evaluation Program and the Enhanced Surveillance Subprogram. The SEP conducts evaluations of both the existing stockpile (stockpile returns) and new production (i.e., Retrofit Evaluation System Test Units). The Enhanced Surveillance Subprogram provides diagnostics, processes, and other tools to the SEP to enable prediction and detection of initial or age-related defects, reliability assessments, and component and system lifetime estimates. These two program elements work closely together to execute the current Surveillance Program and develop new surveillance capabilities at the system, component, and material levels.

The evaluations conducted as part of the SEP 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. These JTAs are flown on the respective DoD delivery platform to gather the requisite information to assess the effectiveness and reliability of both the weapon and the launch or delivery platform and the associated crews and procedures. Stockpile laboratory tests conducted at the component level assess major assemblies and components and, ultimately, the materials that compose 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 SEP consists of four elements:

- **Disassembly and Inspection**—Weapons sampled from the production lines or returned from the 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.
- **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.
- **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 Air Force JILT facility, located at Hill Air Force Base in Utah, also conducts evaluations of joint test beds to obtain information regarding delivery platform-weapon interfaces.

- **Component Testing and Material Evaluation**—Components and materials from the disassembly and inspection process undergo further evaluations to assess component functionality, performance margins and trends, material behavior, and aging characteristics. The 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).

Surveillance requirements, as determined by the national laboratories for the weapon systems, in conjunction with the Air Force and the Navy for joint testing, result in defined experiments to acquire the data that support the Surveillance Program. The national laboratories, in conjunction with the DOE/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 Enhanced Surveillance Subprogram assesses the impact of material behavior changes on weapon performance and safety. This joint science and engineering effort provides material, component, and subsystem lifetime assessments and develops predictive capabilities for early identification and assessment of stockpile aging issues. The Subprogram identifies aging issues with sufficient lead time to ensure the DOE/NNSA has the refurbishment capability and capacity in place when required. Typically, the lifetime assessments include efforts to understand basic aging mechanisms and interactions of materials in components, assemblies, and subassemblies. Accelerated aging experiments are used to obtain data beyond that available from traditional stockpile surveillance. Experiments are also used to validate broader, more age-aware models developed to support lifetime assessments and predictions pertinent to life extension programs. In addition, the subprogram provides new or improved diagnostic techniques and technologies to detect and quantify aging degradation mechanisms in the stockpile. The capabilities and knowledge gained are applied to assess and develop candidate replacement materials, through separate technology and component maturation program efforts, for future stockpile insertion.

Appendix E
Nuclear Survivability

E.1 Overview

It is common to confuse *nuclear weapon effects survivability* with *nuclear weapon system survivability*.

Nuclear weapon effects survivability applies to the ability of any and all personnel and equipment to withstand the blast, thermal radiation, nuclear radiation, and electromagnetic pulse (EMP) effects of a nuclear detonation and thus 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 vast 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
- the initial effects of a nuclear detonation.

See **Figure E.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 E.2** illustrates the intersection between nuclear effects survivability and system survivability.

Put simply, nuclear weapon effects survivability refers to the ability of any and all personnel, equipment, and systems, including, but not limited to, nuclear systems, to survive nuclear weapon effects. Nuclear weapon system survivability refers to nuclear weapon systems being survivable against any threat, including, but not limited to, the nuclear threat.

Figure E.1 Nuclear Weapon Effects versus System Survivability

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

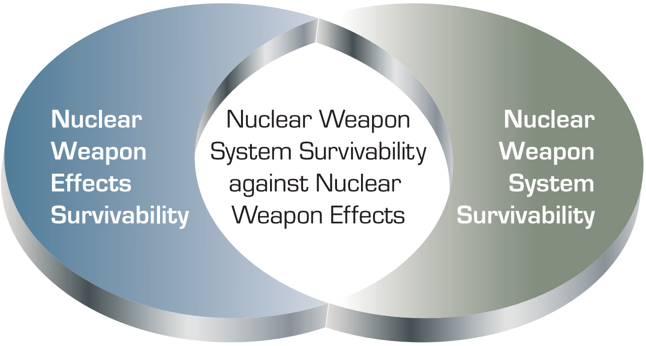
Survivability of **NUCLEAR FORCES**
- Nuclear Weapons
- Nuclear Force Personnel
- Nuclear Force Equipment

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

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, energy absorbed, and electrical stress. This 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 appendix does not address residual nuclear weapon effects such as fallout nor does it discuss nuclear contamination survivability.[1]

E.2 Governance

Figure E.2 Intersection of Nuclear Weapon Effects Survivability and System Survivability



Department of Defense Instruction (DoDI) 3150.09, *The Chemical, Biological, Radiological, and Nuclear (CBRN) Survivability Policy*[2] establishes the CBRN Survivability Oversight Group (CSOG) to oversee implementation of DoD-CBRN survivability policy; ensure 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; refer recommendations for action by the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) or others; and conduct 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)), but the day-to-day implementation activities are overseen by two principal-level working groups. The CSOG-CBR on contamination survivability is chaired by the Deputy Assistant Secretary of Defense for Chemical and Biological Defense; the CSOG-N on nuclear survivability is chaired by the Deputy Assistant Secretary of Defense for Nuclear Matters.

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 CBR, nuclear, or combined CBRN environments specified.

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[1] For information on fallout and nuclear contamination, see Samuel Glasstone and Philip Dolan, *The Effects of Nuclear Weapons*, 3rd Edition, United States Department of Defense and the Energy Research and Development Administration, 1977.

[2] DoDI 3150.09 was first issued in September 2008 and subsequently updated in 2015.

The process for reporting those systems is conducted annually and run by the Office of the ASD(NCB). The mission-critical reports (MCRs) identify the Military Departments' and Missile Defense Agency (MDA) MCS and CBRN MCS, 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 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 the DoD to operate successfully in CBR environments and nuclear environments, and (2) if necessary, written guidance to the Military Departments and the MDA on which systems should be added to the MCRs.

E.3 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.

E.3.1 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 very large area that may damage equipment containing vulnerable electronics on the ground and in the air. **Figure E.3** shows the nuclear environments that dominate the survival for typical systems based on various heights of burst from space to below the Earth's surface.

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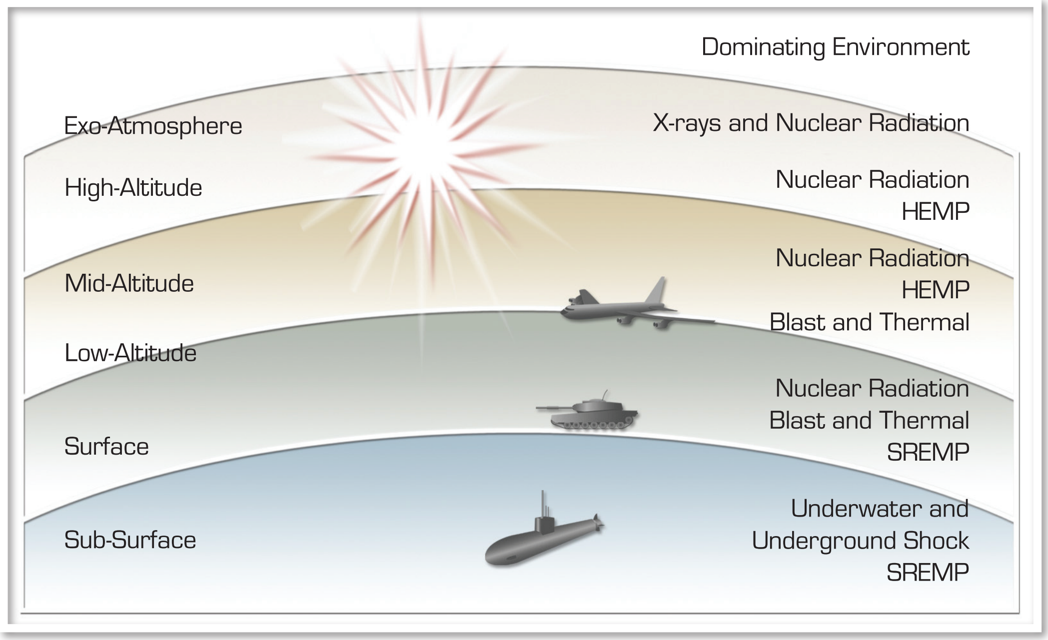
[3] The survival range measures the distance from the detonation necessary to survive nuclear weapon effects.

Figure E.3 Dominant Nuclear Environments as a Function of Altitude



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 very low (i.e., more susceptible to these radiation sources) compared with 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.

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 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 in 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 significantly affects 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 are 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 for buildings in urban environments can be used to provide higher-fidelity estimates of damage and casualties. Surface-launched missiles and associated buses and payloads are the most challenging systems to design for survivability. They typically are 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.

E.3.2 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 impact and roll a vehicle causing personnel injuries. EMP does not cause injuries directly but can cause casualties indirectly (e.g., 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.

Systems with operators outside in the open air have a less stringent nuclear survivability requirement than do systems such as armored vehicles or tanks where the operators are in a hardened shelter. At distances from the detonation where a piece of equipment might survive, an individual outside and unprotected might become a casualty. Therefore, the equipment would not be required to survive either. Conversely, because an individual in a tank could survive at a relatively close distance to the detonation, the tank would be required to survive. The equipment need not be any more survivable than the crew.

E.3.3 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, and hardening.

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). For a description of these effects, see *Appendix C: Basic Nuclear Physics and Weapons Effects*. 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 and 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 weapon effects. The exposure level equipment tolerates 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.

E.4 Nuclear Weapon System Survivability

Nuclear weapon system survivability refers to the capability of a nuclear weapon system to withstand exposure to a full spectrum of threats without suffering a loss of ability to accomplish its designated mission. Nuclear weapon system survivability applies to a nuclear weapon system in its entirety including, but not limited to, the nuclear warhead. The entire nuclear weapon system includes all mission-essential assets, the nuclear weapon and delivery system or 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.

E.4.1 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.”

In addition to 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.

It is often difficult to separate measures to enhance survivability from those that provide 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.

E.4.2 Nuclear Command and Control Survivability

Nuclear weapon systems include the nuclear weapons and the associated Nuclear Command and Control System (NCCS). 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*, which establishes policy and assigns responsibilities related to the U.S. NCCS. The policy states that the command and control of nuclear weapons shall be ensured through a fully survivable and enduring NCCS. The 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(AT&L), in conjunction with the Military Departments, establishes survivability criteria for related nuclear weapon equipment.

E.4.3 Missile Silos

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

E.4.4 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. In the past, considerable research and development was devoted to enhancing the efficacy of containers for use with nuclear weapons for artillery systems.

E.4.5 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.

E.5 Nuclear Effects Testing and Evaluation

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 through the use of simulators and not actual nuclear detonations, remains essential to the development of nuclear-survivable systems while test and evaluation of nuclear hardness is considered throughout the development and acquisition process. 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 DOE/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. Analysis is limited, however, due to inherently numerous, non-linear responses often encountered in both nuclear weapon effects and digital electronics.

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 tests are notable exceptions because these can be tested, in many cases, at the system level. Additionally, in certain situations, at its fast burst reactor (FBR) the Army can test full systems.

Figure E.4 lists the types of simulators commonly used for nuclear weapon effects testing. The Defense Threat Reduction Agency (DTRA) maintains a *Guide to Nuclear Weapon Effects Simulation Facilities and Applications – Support for the Warfighter,* currently the 2014 Edition, which includes comprehensive descriptions of all available facilities in the United States for nuclear survivability testing.

Test	Type of Simulator	Size of Test
X-rays Effects (Hot)	▪ Low-Voltage Flash X-ray Machines	▪ Components and small assemblies
X-rays Effects (Cold)	▪ Plasma Radiators	▪ Components
Gamma Ray Effects	▪ Flash X-ray Machines ▪ Linear Accelerator ▪ Fast Burst Reactor (FBR)	▪ Components, circuits, and equipment
Total Dose Gamma Effects	▪ Cobalt 60 ▪ FBR	▪ 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
Thermal Effects	▪ Thermal Radiation Source (TRS) ▪ Flash Lamps and Solar Furnace	▪ Equipment, large components ▪ Components and materials
Shock Effects (Dynamic pressure)	▪ Large Blast Thermal Simulator (LBTS) ▪ Explosives	▪ Equipment, large components ▪ Systems

Figure E.4 Simulators Commonly Used for Effects Testing

E.5.1 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 underground 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 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 soft (cold) X-rays.

FXRs consume large amounts of electric power, which is converted into intense, short pulses of energetic electrons. The electrons are normally accelerated into a metal target that converts a small portion of its energies 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. The rapid discharge of this much energy in a short time period results in power levels ranging from billions to trillions of watts.

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 that reach components inside enclosures. The machine’s output energy and power usually determines the exposure level and test area and volume. Most X-ray tests in FXRs are limited to components and small 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 gas puff to create irradiating plasma. The energy of the photons produced by the PRS is a function of the wire material or gas and tends to be in the one to three 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.

Larger test objects can be subjected to blow-off impulse testing using light-initiated high explosives (LIHE) or magnetically driven flyer plates. 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.

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

E.5.2 Gamma Dose-Rate Effects Testing

All solid-state components are affected by the rapid ionization produced by prompt gamma rays. Gamma dose-rate effects dominate TREE in non-space-based electronics and the effects do not lend themselves to strict analyses since 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 dose-rate effects tests operate at significantly higher voltages than FXRs used for X-ray effects tests and produce gamma radiation that is equivalent, in most respects, 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 pulses of very energetic electrons. The electron pulses may be used to irradiate test objects or to generate bremsstrahlung radiation.[4]

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

Most dose-rate tests are active, that is, it requires the test object to be powered up and operating for testing. Effects, such as component latch-up, logic upset, and burnout, can

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[4] 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.

E-4 airborne command post on the EMP simulator for testing 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 the DOE/NNSA. The DoD currently operates smaller gamma ray facilities used to test systems at lower levels, including the PulseRad 1150 at L3 Communications Titan Corporation in California and the LINAC Facility at White Sands Missile Range in New Mexico.

E.5.3 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.

E.5.4 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 as neutron sources and techniques using Dense Plasma Focus (DPF); these could potentially provide pulsed neutron capability for future effects testing.

E.5.5 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 antenna, 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.

E.5.6 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 DTRA Large Blast Thermal Simulator (LBTS), currently in caretaker status, 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 with the same positive phase-time duration as the actual 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.

E.5.7 Thermal Radiation Effects Testing

The majority of thermal radiation effects testing is performed with high intensity flash lamps, solar furnaces, liquid oxygen, or powdered aluminum flares, 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 frequently used in conjunction with the large HE tests. The DTRA LBTS features a thermal source that allows test engineers to examine the combined effects of thermal radiation and air blast.

E.5.8 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 with 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.

E.6 Military Standards

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 other systems 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 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 with nuclear EMP survivability at three hardness levels. 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 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 utilizing test results from EMP simulators.

MIL-STD-4023, Maritime EMP Standard 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 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.

Appendix F
Nuclear-Related Treaties and International Agreements

F.1 Overview

The size and composition of the U.S. nuclear weapons stockpile has been influenced by several arms control initiatives and international treaties. For example, the 1987 Intermediate-Range Nuclear Forces (INF) Treaty eliminated an entire class of weapons; in compliance with the INF Treaty, the United States retired all Pershing II missiles and all U.S. ground-launched cruise missiles (GLCMs). In 1991, the United States unilaterally eliminated all Army tactical nuclear weapons and most Navy non-strategic nuclear systems.

There are a number of arms control agreements restricting the deployment and use of nuclear weapons, but 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. See **Figure F.1** for a timeline of nuclear-related treaties.

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 (The United States withdrew from the ABM Treaty in 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 Social 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

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 Treaty or START I)
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 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 | At the date of this publication, the CTBT has not yet 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)
Signed: 2010 | Entry into force: 2011

Figure F.1 Nuclear-Related Treaties

F.2 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 F.2**) established by treaty: Antarctica, Latin America, the South Pacific, Southeast Asia, Africa, and Central Asia.

F.2.1 The 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 that cannot be handled by direct talks, mediation,

Figure F.2 Map of Nuclear Weapon-Free Zones

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

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.

F.2.2 The 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.

F.2.3 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.[1] 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). On May 3, 2010, Secretary of State Clinton announced that the United States would submit the protocols for Senate ratification.

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.

F.2.4 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

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[1] The Compact of Free Association defines the relationship into which these three sovereign states have entered with the United States. As part of this compact, the United States is allowed to move nuclear submarines through the countries' waters.

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.

F.2.5 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 U.N. 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 have all signed the relevant protocols to the treaty. The United States submitted Protocols I and II on May 3, 2011 for Senate ratification.

F.2.6 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. On April 27, 2015 President Obama submitted the Protocol to the CANWFZ for Senate ratification.

F.3 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.

F.4 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, Russia, 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 or periods. 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.

F.5 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 Soviet Union negotiated the first agreements to place limits and restraints on some of their most important nuclear armaments.

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 M. Nixon and General Secretary Leonid

Brezhnev signed the Anti-Ballistic Missile Treaty and the Interim Agreement on strategic offensive arms.

F.5.1 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 provides 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 its 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 ballistic missile defense program.

F.5.2 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 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 ICBMs, with none under construction, and the Soviet Union had an estimated 1,618 ICBMs, including operational missiles and missiles 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, in effect, 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.

F.5.3 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 equal 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 the SALT II. The terms of the treaty were intended to remain in force through 1985.

The completed SALT II agreement was signed by President James E. 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.

F.6 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 PNE Treaty both entered into force on December 11, 1990.

F.7 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.

F.8 Intermediate-Range Nuclear Forces Treaty

The T*reaty 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, DC. The INF Treaty requires 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 and ensures 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 secured full continuation of the INF Treaty regime through the multilateralization of the INF Treaty with the 12 former Soviet Republics considered to be INF Treaty successor states. 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 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 has since renewed these calls, citing concerns that, without other countries joining the treaty, it may no longer prove useful.

F.9 Strategic Arms Reduction Treaty I

After nine years of negotiations, the *Treaty on the Reduction and Limitation of Strategic Offensive Arms*, or START I, 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 START I, signed on May 23, 1992, Belarus, Kazakhstan, Russia, and Ukraine became parties to START I as legal successors to the Soviet Union. In December 1994, the parties to START I exchanged instruments of ratification and START I 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 Weapon States.

START I 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), 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 final START I requirements. This completed the largest arms control reductions in history.

START I 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 follow-on to START I were ongoing, and the agreement, called New START, was signed in Prague on April 8, 2010.

F.10 1991 Presidential Nuclear Initiatives

On September 17, 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. In addition, President Bush declared that U.S. strategic bombers would be taken off alert and that ICBMs, scheduled for deactivation under START I, would also be taken off alert. These unilateral arms reductions are known as the 1991 Presidential Nuclear Initiatives.

In October 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 mobile ICBMs and building new mobile launchers for existing ICBMs. He also pledged to eliminate an additional 1,000 nuclear warheads beyond the numbers required by START I and stated that the country would observe a 1-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.

F.11 START II

Negotiations to achieve a follow-on to START I 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 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.

F.12 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 William J. 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 testing since 1992.

F.13 Strategic Offensive Reductions Treaty

On May 24, 2002, U.S. 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 strategic nuclear warheads to a level between 1,700 and 2,200 by December 31, 2012, nearly two-thirds below levels at the time. 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 considers 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 located at heavy bomber bases

The Moscow Treaty entered into force in 2003. When New START entered into force in 2011, the Moscow Treaty was terminated.

F.14 New START

Negotiations for a new follow-on agreement to START I began in May 2009. A *Joint Understanding for a Follow-on Agreement to START I* 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 Vladimir Medvedev in Prague, Czech Republic, on April 8, 2010.

Under New START, 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 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 combines elements of START I with new elements tailored to the limitations of the New START. 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.

F.15 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 or counterproliferation activities in addition to those designed to account for and monitor reductions in existing nuclear stockpiles, or stockpile monitoring activities. There are some technologies and procedures that apply to both counterproliferation activities and stockpile monitoring activities.

F.15.1 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 International Atomic Energy Agency (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, to verify facility design information, and to 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 8: Countering Nuclear Threats*.)

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.

F.15.2 Stockpile Monitoring Activities

Stockpile monitoring activities include those designed to ensure compliance with nuclear weapons reduction or stockpile monitoring treaties, for instance, 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 within 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 strategic systems. During the inspections, inspectors will be 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 tamper-resistant identifiers will be assigned to each nuclear weapon and each nuclear weapons system. These are confirmed against data exchange and notification figures, which list the numbers, location, and technical characteristics of weapons systems and facilities.

National technical means, while largely similar to satellite surveillance activities covered in the counterproliferation section of this appendix, are further strengthened by New START in its prohibition of interference, to include concealment measures. Telemetric information is compiled during ICBM and SLBM flight tests. These measurements, which gauge missile performance, are shared under the auspices of the treaty to increase transparency and supplement verification provisions.

F.16 Nuclear Security Summits

In 2009, U.S. President Barak Obama delivered a speech in Prague in which he characterized nuclear terrorism as “the most immediate and extreme threat to global security”. He called for a “new international effort to secure vulnerable nuclear material around the world”, and just one year later, in April 2010, the United States hosted the first Nuclear Security Summit to address the issue of nuclear terrorism at an international level. Since President Obama’s 2009 speech, a total of four international organizations and 53 countries, including the P5 nations (nuclear weapons states) and states not party to the NPT, have convened through the Nuclear Security Summit held:

- April 12-13, 2010: Washington, DC, United States
- March 26-27, 2012: Seoul, South Korea
- March 24-25, 2014: The Hague, Netherlands
- March 31-April 1, 2016 *(anticipated)*: Washington, DC, United States

The summit series addresses 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 has 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.

F.16.1 Washington, DC (2010)

At the Nuclear Security Summit held April 12-13, 2010 in Washington, DC, leaders from 47 countries and three international organizations advanced a cooperative approach to strengthening nuclear security. Leaders expressed their commitment to ensure the security of all nuclear materials under their control, to consolidate or reduce employment of weapons-usable materials in civilian applications, and to work cooperatively as an international community to advance nuclear security, requesting and providing assistance as necessary.

One significant outcome of the Summit was the issuance of the Washington Work Plan, which provides detailed guidance for concrete national and international actions to implement the pledges in the Washington Communiqué. The plan includes:

- ratifying and implementing treaties on nuclear security and nuclear terrorism;
- cooperating through the United Nations to implement and assist others in connection with Security Council resolutions;
- working with the International Atomic Energy Agency to update and implement security guidance and carry out advisory services;
- reviewing national regulatory and legal requirements related to nuclear security and nuclear trafficking;
- converting civilian facilities that use HEU to non-weapons-usable materials;
- research on new nuclear fuels, detection methods, and forensics techniques;
- development of corporate and institutional cultures that prioritize nuclear security;
- education and training to ensure that countries and facilities have the people they need to protect their materials; and,
- joint exercises among law enforcement and customs officials to enhance nuclear detection approaches.

In addition to the commitments made in the Communiqué and Work Plan, many participating countries presented national statements in which they pledged to take specific actions in support of the Summit's objectives; 32 countries made over 70 actionable commitments to enhance nuclear security. Reflecting the sense of urgency galvanized by the threat of nuclear terrorism and the occasion of the Summit, most of these commitments were implemented prior to the 2012 Summit, resulting in tangible improvements to global security.

Participants:

47 Countries: Algeria, Argentina, Armenia, Australia, Belgium, Brazil, Canada, Chile, China, the Czech Republic, Egypt, Finland, France, Georgia, Germany, India, Indonesia, Israel, Italy, Japan, Jordan, Kazakhstan, Malaysia, Mexico, Morocco, the Netherlands, New

Zealand, Nigeria, Norway, Pakistan, the Philippines, Poland, the Republic of Korea, the Russian Federation, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States, and Vietnam.

3 International Organizations: The European Union, the International Atomic Energy Agency, and the United Nations.

F.16.2 Seoul (2012)

In addition to the 47 countries that participated in the Washington Summit, six new countries -- Azerbaijan, Denmark, Gabon, Hungary, Lithuania, and Romania -- joined the Seoul Summit held March 26-27, 2012. Expanding upon the 2010 Summit in Washington, the 2012 Summit directed efforts at three main issues: cooperative measures to combat the threat of nuclear terrorism; protection of nuclear materials and related facilities; and prevention of illicit trafficking of nuclear materials.

The Seoul Communiqué identified key priority areas for strengthening nuclear and expanded upon the Washington Communiqué and Work Plan by:

- encouraging participating countries to announce specific actions to minimize the use of HEU by the end of 2013;
- urging participating countries to ratify the 2005 Amendment to the Convention on the Physical Protection of Nuclear Material by 2014;
- recognizing a need to increase synergy between nuclear safety and nuclear security;
- emphasizing the need to improve the security of spent nuclear fuel and radioactive waste; and,
- establishing specific measures to ensure the protection of radioactive sources.

The 2012 Summit also introduced the concept of joint statements made by groups of participating countries. Such statements included pledges to take collective action towards advancing specific aspects of nuclear security, such as the security of radioactive materials, nuclear information security, transportation security, and the development of high-density LEU fuel. A total of thirteen joint statements were presented in Seoul, which, when combined with the commitments enshrined in the Communiqué and the respective national statements of many participating countries, resulted in over 100 new commitments made at the 2012 Summit.

Participants:

53 Countries: Algeria, Argentina, Armenia, Australia, Azerbaijan, Belgium, Brazil, Canada, Chile, China, the Czech Republic, Denmark, Egypt, Finland, France, Gabon, Georgia, Germany, Hungary, India, Indonesia, Israel, Italy, Japan, Jordan, Kazakhstan, Lithuania, Malaysia, Mexico, Morocco, the Netherlands, New Zealand, Nigeria, Norway, Pakistan, the Philippines, Poland, the Republic of Korea, Romania, the Russian Federation, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States, and Vietnam.

4 International Organizations: The European Union, the International Atomic Energy Agency, Interpol, and the United Nations.

F.16.3 The Hague (2014)

The third Nuclear Security Summit held in The Hague from March 24-25, 2014 assembled leaders from 53 unique countries and four international organizations to discuss three key objectives:

- strengthening the global nuclear security architecture to bolster accountability measures imposed on states and to prevent nuclear procurement by terrorists;
- elevating the importance of cooperation between governments and nuclear industry; and
- developing a concrete and actionable plan for implementing objectives enunciated (but not yet enacted) through the Seoul Communiqué and Washington Work Plan.

As was the case with the two prior Summits, extensive preparations and consultations among senior-level experts from each participating country were held leading up to the 2014 Summit. These experts, known as sherpas and sous-sherpas, met to develop consensus on the priorities and specific actions that would form the basis for commitments made by world leaders in the Summit Communiqué. For the 2014 Summit, this process began in November 2012, with the first preparatory meeting held in Istanbul, and ended with a final meeting in The Hague just prior to the Summit in March.

Three official side events also took place on the margins of The Hague Summit in an effort to involve key actors from the nuclear industry, the scientific community, nongovernmental organizations, and the general public. The first, titled @tomic 2014, was a table-top exercise on decision-making in the event of an incident of nuclear terrorism. This exercise took place in Maastricht from February 18-20, 2014. Additional side events included the Nuclear Knowledge Summit in The Hague on March 21-22 and the Nuclear Industry Summit in Amsterdam on March 23-24.

In addition, two thirds of summit participants agreed to join the “Strengthening Nuclear Security Implementation” initiative proposed by the United States, the Netherlands, and the Republic of Korea. Through this initiative, 35 countries pledged to conduct internal assessments and peer reviews to determine and the effectiveness of the country’s nuclear security mechanisms. Parties also agreed that their regulations would reflect or exceed the IAEA’s voluntary guidelines. Finally, participating countries committed to ensure that personnel responsible for nuclear security were competent, qualified, and professionally certified.

Participants:

53 Countries: Algeria, Argentina, Armenia, Australia, Azerbaijan, Belgium, Brazil, Canada, Chile, China, the Czech Republic, Denmark, Egypt, Finland, France, Gabon, Georgia, Germany, Hungary, India, Indonesia, Israel, Italy, Japan, Jordan, Kazakhstan, Lithuania, Malaysia, Mexico, Morocco, the Netherlands, New Zealand, Nigeria, Norway, Pakistan, the Philippines, Poland, the Republic of Korea, Romania, the Russian Federation, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States, and Vietnam.

4 International Organizations: The European Union, the International Atomic Energy Agency, Interpol, and the United Nations.

F.16.4 Washington, DC (2016)

The fourth and final Nuclear Security Summit will be held in Washington, DC. March 31-April 1, 2016. Previous Summits have resulted in concrete improvements in the security of nuclear materials and stronger international institutions that support nuclear security. Recognizing that the international community cannot risk a nuclear terrorist attack, the final Nuclear Security Summit will continue discussion on the evolving threat and address steps that can be taken together to minimize the use of highly-enriched uranium, secure vulnerable materials, counter nuclear smuggling and deter, detect, and disrupt attempts at nuclear terrorism.

Appendix G
Classification

G.1 Overview

Throughout U.S. history, national defense has required certain information be maintained in confidence in order to protect citizens, democratic institutions, homeland security, and interactions with foreign nations. Protecting information critical to U.S. national security remains a priority.

The United States has devised its own classification system for safeguarding documents and other media, which includes marking and granting access and clearance to obtain or view those documents. This appendix provides a classification reference for general issues related to nuclear matters. This includes a discussion of information classification, classification authorities, security clearances, accessing classified information, marking classified documents, For Official Use Only (FOUO)/Official Use Only (OUO), and Unclassified Controlled Nuclear Information (UCNI).

G.2 Information Classification

The two categories of classified information are national security information (NSI) and atomic energy (nuclear) information.

G.2.1 National Security Information

NSI is protected by Executive Order (EO) 13526, *Classified National Security Information*. EO 13526 prescribes a uniform 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 reasonably could 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 reasonably could 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 reasonably could be expected to cause *damage* to the national security that the original classification authority is able to identify or describe.

G.2.2 Nuclear Information

Nuclear information is protected by the *Atomic Energy Act (AEA)* of 1954*,* as Amended. The DOE implements the AEA requirements for classification and declassification of nuclear information via 10 CFR 1045, *Nuclear Classification and Declassification*. The AEA categorizes classified nuclear information as *Restricted Data (RD)*. RD is not subject to EO 13526.

Restricted Data is all data concerning the design, manufacture, or utilization of nuclear weapons; production of special nuclear material (SNM); or use of SNM in the production of energy.

Classified nuclear information can be removed from the RD category pursuant to AEA sections 142d or 142e, and, after its removal, it is categorized respectively as *Formerly Restricted Data (FRD)*.

Formerly Restricted Data is jointly determined by the DoD and the DOE to relate primarily to the military utilization of nuclear weapons and can be adequately 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.

Restricted Data information that is recategorized as NSI refers to information jointly determined by the DOE and the Director of National Intelligence to be information that concerns the nuclear programs of other nations and can be adequately safeguarded as defense information (e.g., foreign weapon yields). When removed from the RD category, this information is subject to EO 13526.

The DoD and the DOE have separate systems for granting access to nuclear information.

The DoD System for Controlling Nuclear Information

DoD policy governing access to and dissemination of RD is stated in DoD Instruction (DoDI) 5210.02, *Access to and Dissemination of Restricted Data and Formerly Restricted Data*. The DoD categorizes RD information into Confidential RD, Secret RD, and Top Secret RD. Critical Nuclear Weapon Design Information (CNWDI) is a DoD access control caveat for a specific subset of Restricted Data. CNWDI information is 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. In addition, the DoD currently recognizes the designations of Sigma 14, Sigma 15, Sigma 18, and Sigma 20, as defined by the DOE, as an additional subset of Restricted Data.

The DOE System for Controlling Nuclear Information

DOE policy of categorizing Restricted Data into defined subject areas is known as the *sigma system*. Subsets of Secret and Top Secret Nuclear Weapon Data (NWD) relating to RD and/or FRD concerning nuclear weapons, components, or explosive devices or materials has been determined to require additional protection. The categories of NWD are Sigma 14, Sigma 15, Sigma 18, and Sigma 20. This categorization system separates RD information into common work groups to enforce need-to-know limitations. Previous Sigma categories 1-13, defined by DOE Order (DOE O) 5610.2, *Control of Nuclear Weapon Data*, are no longer in use.

DOE O 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 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.[1]

Because of the extremely sensitive nature of Sigma 14 and 15 information, all individuals who are granted access to Sigma 14 and 15 must receive formal authorization by a DOE element or contractor organization with responsibility for Sigma 14 or 15 NWD.

DOE O 452.8, *Control of Nuclear Weapon Data* (cancels DOE O 5610.2) sustains Sigma 14 and 15 and establishes Sigma 18.

- **Sigma 18**: Category of NWD including 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. This information would enable the establishment or improvement of nuclear capability without nuclear testing or with minimal research and development. The DOE/NNSA determines which information is placed in the Sigma 18 category. Sigma 18 information includes complete design of a gun-assembled weapon; complete design of a primary or single stage implosion-assembled weapon; complete design of an interstage or secondary; weapon design codes with one-dimensional (1-D) hydrodynamics and radiation transport with fission and/or thermonuclear burn; and weapon design codes with two-dimensional (2-D) and three-dimensional (3-D) capabilities. DoD individuals must obtain DOE/NNSA approval to have access to Sigma 18.

DOE O 457.1A, *Nuclear Counterterrorism* provides the basis for implementing procedures regulating strict control of and access to Sigma 20.

- **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 are Sigma 20. DoD individuals must obtain DOE/NNSA approval to have access to Sigma 20.

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[1] Not all use control design information is Sigma 15.

Foreign Nuclear Information

The DOE is developing protocols to address foreign nuclear information. Foreign nuclear information begins as information on foreign nuclear programs and contains foreign design, manufacture, or utilization of nuclear weapons, the production of SNM, or the use of SNM in the production of energy and is treated as RD.

The information may be removed from RD categorization under the following conditions: no automatic declassification; DOE determines when declassified; requires special marking; access is the same as NSI; and/or is safeguarded the same as NSI at which point it is categorized as Transclassified Foreign Nuclear Information (TFNI) (DOE O 475.2A, *Identifying Classified Information)*.

TFNI is 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 AEA by past joint agreements between the DOE and the Director of Central Intelligence or past and future agreements with the Director of National Intelligence.

TFNI is stored, transmitted, and destroyed the same as NSI of the same level and does not require special read on.

Information Sharing with the United Kingdom

The DoD and the DOE agreed on joint guidance for complying with each Department's requirements on 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/NNSA management may disclose transmissible RD, FRD, and unclassified information, which includes Controlled Unclassified Information (CUI) within the nuclear weapon, to the United Kingdom. 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. The disclosure of RD and FRD external to the nuclear weapon may be made using JAIEG-approved processes. However, the disclosure of NSI, which includes Classified Military Information (CMI), external to the nuclear weapon shall not be made without approval of the respective Military Departments.

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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

Questions on these processes should be referred to the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs and the NNSA Deputy Administrator for Defense Programs.

G.3 Classifying Documents

In order to properly classify a document, an individual must have classification authority. DoD Manual (DoDM) 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 information which may be considered classified, or the combination of several unclassified data may be classified in aggregate.

G.3.1 Original Classification Authority

The authority to classify information originally 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, section 1.3, Paragraph (c). For NSI, the original classification authority (OCA) also serves as the declassification authority and sets the date for automatic declassification. A joint DoD-DOE/NNSA determination is required to declassify FRD information. Within the DoD and the DOE/NNSA, only appointed government officials can classify NSI. Further, only DOE/NNSA officials can have original classification authority for RD information. In an exceptional case, that is when an employee or government contractor of an agency without classification authority originates information believed by that person to require classification, the information must be protected in a manner consistent with EO 13526 and the AEA. The agency must decide within 30 days whether to classify the information.

G.3.2 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 the DoD and the DOE/NNSA can use derivative classification authority on NSI, RD, and FRD information.

G.4 Security Clearances

Both the DoD and the DOE/NNSA issue personnel security clearances governing access of their employees and contractors to classified information.

G.4.1 DoD Security Clearance Levels

The DoD defines a security clearance as an administrative determination by 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, assuming they have the proper need-to-know,[2] to view information classified at those levels, as defined by EO 13526.

G.4.2 DOE Security Clearance Levels

Corresponding to the information restrictions and guidelines in the AEA, the DOE established a security clearance system, implemented through DOE O 472.2, *Personnel Security* and described in DOE O 452.8, where:

- **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 COMSEC, CRYPTO, or SCI.[3]

G.4.3 Equating the Two Classification Systems

While it is not possible to directly correlate the two security clearance systems used by the DoD and the DOE/NNSA, **Figure G.1** shows the clearances and highest level of access for the two Departments.

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[2] 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.

[3] Communications Security (COMSEC), Cryptography/Cryptographic (CRYPTO), and Sensitive Compartmented Information (SCI).

G.5 Accessing Classified Information

The two basic requirements to access classified information are appropriate clearance and need-to-know. Both must be present for an individual to view classified information. Rank, position, or clearance are not sufficient criteria from which to grant access. Personnel security clearance levels correspond to the security classifications. Need-to-know is granted 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 a C, S, TS, or TS/SCI clearance in the DoD; an individual may have L, Q, or Q with TS authority in the DOE/NNSA. 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. Once the individual is given a final clearance, he or she is able to 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, these individuals have the appropriate clearance to access the information. The process is commonly referred to as being "read-in" for a caveat.

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

*Access to Sigma 14, 15, 18, & 20 requires DOE approval

[1] Outside DoD, follow owning agency procedure

DOE	**Highest Access**
L	S-NSI/FRD C-RD
Q**	TS-RD

**Access to Sigma 14, 15, & 20 requires additional approval

Figure G.1 DoD and DOE Clearance Levels and Access

To be given access to Top Secret or Q-level information a DoD individual must have a favorable single scope background investigation (SSBI). Access to Confidential RD/FRD or L-level information requires a favorable national agency check with local agency and credit check (NACLC). In both instances, only the DoD, DOE/NNSA, Nuclear Regulatory Commission (NRC), and National Aeronautics and Space Administration (NASA) have the authority to grant RD and FRD access. To access CNWDI information, individuals require authorization and a briefing.

G.6 Marking Classified Documents

Two types of documents that require classification markings are originally classified documents and derivatively classified documents.

G.6.1 Originally Classified Documents

EO 13526 requires certain essential markings on originally classified documents. DoDM 5200.01-V2 stipulates marking requirements for classified documents. The marking elements are portion marking, 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 is placed in parentheses: (U) for Unclassified, (C) for Confidential, (S) for Secret, and (TS) for Top Secret and include additional control markings, as appropriate. The subsequent paragraph underneath also has its own classification marking. The classification of the portion 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.

In the lower left-hand corner of the title page, the original classification authority is identified. Authority must be identified by name, or personal identifier, and position. If the agency of the original classifier is not readily apparent, then 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 and/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 the 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 the national security; or
- the development, production, or use of weapons of mass destruction.

The final essential marking is the “declassify on” line. One of three rules listed below is used in determining how long material is to stay classified. All documents must have a declassification date or event entered onto the “declassify on” line. The original classifying authority determines the “declassify on” date of the document using the 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, DoDM 5200.01-V2 serves as a reference.

G.6.2 Derivatively Classified Documents

Derivative classification is the act of incorporating, paraphrasing, restating, or generating in 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(s) or a classification guide issued by an OCA. It is important to note that the DoD can only derivatively classify documents containing RD.

Single Source Document 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 to be 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 except for two markings. 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, before marking the document with the "declassify on" line, it is necessary to determine which source document requires the longest period of classification. 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. The name and position should be 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.

G.6.3 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 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 subject to Administrative and Criminal Sanctions. Handle as Restricted Data in Foreign Dissemination 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.

Additionally, 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.

G.6.4 ATOMAL

RD and FRD marked materials are not cleared for release to the North Atlantic Treaty Organization (NATO) or NATO countries. Organizations that wish to transmit RD or FRD materials to NATO must clear the materials through the JAEIG. 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 paragraph 19 and in accordance with paragraphs 38-42 of the *Administrative Arrangements to Implement the Agreement Between the Parties to the North Atlantic Treaty for Co-operation Regarding ATOMAL Information* (C-M(68)41 (7th revise)). These materials, although marked as ATOMAL, have not been assigned a NATO Registry control number and, therefore, not considered NATO materials and can still be disseminated between DoD components via secure email (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.

G.7 For Official Use Only and Unclassified Controlled Nuclear Information

FOUO and OUO are terms used by the DoD and the DOE/NNSA, respectively, that can be applied to certain unclassified information. FOUO and OUO designations indicate 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 and may be exempt from mandatory release under one of eight applicable *Freedom of Information Act* (FOIA) exemptions.

- Those properly and currently classified in the interest of national defense or foreign policy.
- 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.
- 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.

- 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.
- Information, the release of which could reasonably be expected to constitute a clearly unwarranted invasion of the personal privacy of individuals.
- 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.
- Certain records of agencies responsible for supervision of financial institutions.
- Geological and geophysical information concerning wells.

The DoD and the DOE/NNSA also use the term Unclassified Controlled Nuclear Information. The 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 stated in DoDI 5210.83, *DoD Unclassified Controlled Nuclear Information*. The DOE/NNSA uses the term UCNI in a broader manner than the DoD. Designating DoD information as UCNI is governed by 10 USC 128 whereas designating DOE/NNSA information as UCNI is governed by 42 USC 2168 et seq.

Glossary

abnormal environment

Environments as defined in a weapon's stockpile-to-target sequence and military characteristics in which the weapon is not expected to retain full operational reliability.

alteration

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.

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.

atomic bomb

Term sometimes applied to a nuclear weapon utilizing fission energy only.

atomic mass

Number of protons plus neutrons in the nucleus of an atom.

atomic number

Number of protons in the nucleus of an atom.

authorization

Legislation that establishes, changes, or continues a federal program or agency. Authorizing legislation is normally a *prerequisite for appropriations. For some programs, primarily entitlements, the authorizing legislation itself provides the authority to incur obligations and make payments. Like Appropriations Acts, authorizing legislation must be passed by both Houses of Congress and must be signed by the president to become law.*

ballistic missile

Any missile that does not rely upon aerodynamic surfaces to produce lift and consequently follows a ballistic trajectory when thrust is terminated.

blast wave

Sharply defined wave of increased pressure rapidly propagated through a surrounding medium from a center of detonation or similar disturbance.

channel

Joint arrangement between the United States and a foreign government for the exchange of specific project or program-type information.

component

Assembly or any combination of parts, subassemblies, and assemblies mounted together in manufacture, assembly, maintenance, or rebuild.

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.

critical mass

Minimum amount of fissionable material capable of supporting a chain reaction under precisely specified conditions.

countering nuclear threats

To prevent a nuclear attack against the United States and its interests, or in the event of an attack, to respond effectively, avoiding additional attacks and bringing the perpetrators to justice.

cruise missile

Guided missile, the major portion of whose flight path to its target is conducted at approximately constant velocity; a cruise missile depends on the dynamic reaction of air for lift and upon propulsion forces to balance drag.

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.

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 Departments and defense agencies.

deuterium

Isotope of hydrogen with one proton and one neutron in the nucleus of each atom.

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.

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.

dynamic pressure

Air pressure that results from the mass air flow (or wind) behind the shock front of a blast wave.

electromagnetic hardening

Action taken to protect personnel, facilities, and/or equipment by filtering, attenuating, grounding, bonding, and/or shielding against undesirable effects of electromagnetic energy.

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.

Electromagnetic radiation

Radiation including visible light, radio waves, gamma rays, and X-rays where electric and magnetic fields vary simultaneously.

electron

Particle of very small mass with a negative charge.

element

Any of the more than 100 known substances (of which 92 occur naturally) that cannot be separated into simpler substances and that singly or in combination constitute all matter.

enacted appropriations

Appropriations bills in which a definite amount of money is set aside to pay incurred or anticipated expenditures.

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.

expenditure

Charges against available funds. Expenditures result from a voucher, claim, or other document approved by competent authority. Expenditures represent the presentation of a check or electronic transfer of funds to the performer of work.

fallout

Precipitation to Earth of radioactive particulate matter from a nuclear cloud; also applied to the particulate matter itself.

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.*

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.

fissile

Capable of being split by slow (low-energy) neutrons as well as by fast (high-energy) neutrons.

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.

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.

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.

fusion

The process whereby the nuclei of light elements, especially those of the isotopes of hydrogen, namely, deuterium and tritium, combine to form the nucleus of a heavier element with the release of substantial amounts of energy and a high-energy neutron.

gamma rays

Electromagnetic radiations of high photon energy originating in atomic nuclei and accompanying many nuclear reactions (e.g., fission, radioactivity, and neutron capture).

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.

half-life

Time required for the activity of a given radioactive species to decrease to half of its initial value due to radioactive decay.

height of burst

Vertical angle between the base of a target and the point of burst.

hydrogen bomb

Term sometimes applied to nuclear weapons in which part of the explosive energy is obtained from nuclear fusion (or thermonuclear) reactions.

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.

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.*

implosion assembly 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.

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).

induced radiation

Radiation produced as a result of exposure to radioactive materials, particularly the capture of neutrons.

initial nuclear radiation

Radiation resulting from a nuclear detonation and emitted from the fireball within one minute after burst. Also called prompt nuclear radiation.

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.

ion

Atom that has gained or lost an electron and thus carries an electrical charge.

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.

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.

limited life component

Weapon component that decays with age and must be replaced periodically.

major assembly

Term for a complete nuclear warhead, usually used in the process of approving or revalidating the design.

markup

Process by which congressional committees and subcommittees debate, amend, and rewrite proposed legislation.

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.

modification

Change in operational capability that results from a design change that affects delivery (employment or utilization), fusing, ballistics, or logistics.

mutual assured destruction

A U.S. doctrine of reciprocal deterrence resting on the United States and the Soviet Union being able to inflict unacceptable damage on the other in retaliation for a nuclear attack.

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.*

National Defense Authorization Act

NDAA is legislation voted on by Congress for each fiscal year to determine and permit the budget for the DoD and national security programs maintained by the DOE.

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.

near-surface burst

Detonation in the air that is low enough for the immediate fireball to touch the ground.

neutron

Neutral particle (i.e., with no electrical charge) of approximately unit mass, present in all atomic nuclei, except those of ordinary (light) hydrogen.

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.

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.

nuclear command and control

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.

nuclear command and control system

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.

nuclear command, control, and communications

Facilities, equipment, communications, procedures, and personnel that enable presidential nuclear direction to be carried out.

Nuclear Enterprise

Composite of the DoD U.S. nuclear forces and elements, to include the deterrent forces of the Air Force's nuclear capable bombers and fighters and associated nuclear weapons, as well as ICBMs; 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.

Nuclear Posture Review

Legislatively-mandated review that establishes U.S. nuclear policy, strategy, capabilities, and force posture for five to ten years into the future.

nuclear radiation

Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the nuclear weapon standpoint, are alpha and beta particles, gamma rays, and neutrons.

Nuclear Security Enterprise

Composite of the DOE/NNSA nuclear weapons complex, to include the laboratories, plants, test sites, science and technology, computing tools, and federal and contractor personnel.

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.

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.

nuclear weapon surety

Procedures and actions contributing to the physical security 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 over target.

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.

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.

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.

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.

Phase 6.X Process

Established in 2000, this process focuses on development and fielding of replacement nuclear components for the nuclear stockpile; whereas the original Nuclear

Weapons Life-Cycle Process focuses on development of a complete new warhead.

photon
Unit of electromagnetic radiation consisting of pure energy and zero mass.

project officers groups
Joint DoD–DOE groups associated with each warhead-type, created at 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).

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.

proton
Particle of mass (approximately) unit carrying a unit positive charge; it is identical physically with the nucleus of the ordinary (light) hydrogen atom. All atomic nuclei contain protons.

Quadrennial Defense Review
Legislatively-mandated review of DoD strategy and priorities.

radioactivity
Spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of unstable isotopes.

readiness state
Refers to the configuration of weapons in the active and inactive stockpiles.

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.

reliability replacement warheads
Warheads retained in the inactive stockpile that provide the assets to replace active stockpile warheads should reliability or safety problems develop.

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.

special nuclear material
Defined by the Atomic Energy Act of 1954 as plutonium, U-233, or uranium enriched in the isotopes of U-233 or U-235.

staged weapon
Weapon in which energy from the primary initiates the explosion of a secondary.

stockpile flight test
Joint DoD–DOE flight tests conducted periodically on weapon systems randomly selected from the stockpile.

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.

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.

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.

subcritical

State of a given fission system when the specified conditions are such that a less than critical mass of active material is present.

supercritical mass

Quantity of fissionable material needed to support a multiplying chain reaction.

surety

Materiel, personnel, and procedures that contribute to the security, safety, and reliability 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.

surveillance

Activities involved in making sure nuclear weapons continue to meet established safety, security, and reliability standards.

thermal radiation

1) Heat and light produced by a nuclear explosion. 2) (DoD only) Electromagnetic radiations emitted from a heat or light source as a consequence of its temperature; it consists essentially of ultraviolet, visible, and infrared radiations.

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.

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.

Transclassified Foreign Nuclear Information

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.

transient radiation effects on electronics

Effects on electronics that are exposed to transient gammas, neutrons, and X-rays.

tritium

Radioactive isotope of hydrogen, having a mass of 3 units; it is produced in nuclear reactors by the action of neutrons on lithium nuclei.

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.

underground burst

Explosion of a nuclear (or atomic) weapon with its center more than 5W0.3 feet, where W is the explosion yield in kilotons, beneath the surface of the ground.

underwater burst

Explosion of a nuclear (or atomic) weapon with its center beneath the surface of the water.

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.

warhead

That part of a missile, projectile, torpedo, rocket, or other munitions that contains either the nuclear or thermonuclear system, high explosive system, chemical or biological agents, or inert materials intended to inflict damage.

weapon surveillance

Activities involved in making sure nuclear weapons continue to meet established safety, security, and reliability standards.

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.

X-ray

Electromagnetic radiations of high energy having wavelengths shorter than those in the ultraviolet region.

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.

Acronym List

1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
10 USC 179	Title 10, Section 179 of the United States Code
ABM	anti-ballistic missiles
ADM	atomic demolition munition
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
ACRR	Annular Core Research Reactor
AF/A10	(Office of) Assistant Chief of Staff for Strategic Deterrence and Nuclear Integration, U.S. Air Force
AFB	Air Force Base
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
APS	active protection system
AR	Active Ready
AS	active stockpile
ASC	Advanced Simulation and Computing

ASD(NCB)	Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs
ATSD(AE)	Assistant to the Secretary of Defense for Atomic Energy

B	bomb
BCR	Baseline Cost Report

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
CARC	Chairman's Annual Report to Congress
CBR	chemical, biological, and radiological
CBRN	chemical, biological, radiological, and nuclear
CCD	coded control device
CCDR	Combatant Commander
CCMD	Combatant Command
CDRUSSTRATCOM	Commander, United States Strategic Command
CDS	command disablement system
CEP	circular error probable
cGy	centi-gray
CJCS	Chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CME	component and material evaluation
CMI	Classified Military Evaluation
CNT	countering nuclear threats
CNWDI	Critical Nuclear Weapon Design Information
Co-60	cobalt-60
COMSEC	Communications Security
CRYPTO	Cryptography/Cryptographic
CSOG	CBRN Survivability Group
CTBT	Comprehensive Nuclear-Test-Ban Treaty
CTR	cooperative threat reduction
CUI	Controlled Unclassified Information

D-test	destructive test
DARHT	dual axis radiographic hydrodynamic test
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
DNA	Defense Nuclear Agency
DNDO	Domestic Nuclear Detection Office

DNS	Defense Nuclear Security
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
DP	Defense Program
DPF	Dense Plasma Focus
DPG	Defense Planning/Programming Guidance
DRAAG	Design Review and Acceptance Group
DTRA	Defense Threat Reduction Agency
DUU	deliberate unauthorized use
EAM	emergency action message
EIVR	Exchange of Information by Visit and Report
EMP	electromagnetic pulse
EMR	electromagnetic radiation
ENDS	enhanced nuclear detonation safety
EO	Executive Order
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Agency
ESD	environment sensing device
FBI	Federal Bureau of Investigation
FBM	fleet ballistic missile
FBR	fast burst reactor
FEMA	Federal Emergency Management Agency
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
FXR	flash X-ray machine
FY	fiscal year
FYDP	Future-Years Defense Program
GA	gun assembly
GICNT	Global Initiative to Combat Nuclear Terrorism
GLBM	ground-launched ballistic missile
GLCM	ground-launched cruise missile
GOC	Global Operations Center
GOCO	government-owned, contractor-operated
GZ	ground zero
HE	high explosive
HEAF	High Explosives Application Facility
HEMP	high-altitude electromagnetic pulse

HERMES	high-energy radiation megavolt electron source
HEU	highly enriched uranium
HEUMF	Highly Enriched Uranium Materials Facility
HLG	High Level Group
HOB	height of burst
HRP	Human Reliability Program
ICBM	intercontinental ballistic missile
ICD	Interface Control Document
IFI	in-flight insertion
IHE	insensitive high explosive
IND	improvised nuclear device
INEL	Idaho National Engineering Laboratory
INF	intermediate-range nuclear forces
INL	Idaho National Laboratory
IOC	initial operational capability
IS	inactive stockpile
ITAR	International Traffic in Arms Regulations
ITW/AA	Integrated Tactical Warning/Attack Assessment
JAIEG	Joint Atomic Information Exchange Group
JCIDS	Joint Capabilities Integration and Development System
JIPP	Joint Integrated Project Plan
JNWPS	Joint Nuclear Weapons Publications 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
KCRIMS	Kansas City Responsive Infrastructure Manufacturing and Sourcing
keV	kiloelectron-volt
kg	kilogram
kt	kiloton
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LBTS	Large Blast Thermal Simulator
LD50	lethal dose for 50 percent of the population
LEP	life extension program
LIHE	light-initiated high explosive
LINAC	linear accelerator
LLC	limited life component
LLCE	limited life component exchange
LLNL	Lawrence Livermore National Laboratory
LTBT	Limited Test Ban Treaty

MAD	mutual assured destruction
MAR	Major Assembly Release
MBS	Modulus Bremsstrahlung Source
MC	military characteristic
MCCS	multiple-coded control switch
MCR	Mission-Critical Report
MCS	Mission-Critical System
MDA	Missile Defense Agency
MDA	mutual defense agreement
MFD	military first destination
MG	Mighty Guardian
MIL-STD	Military Standard
MIR	major impact report
MIRV	multiple independently targetable reentry vehicle
MK	mark
MLC	Military Liaison Committee
MMIII	Minuteman III
MOA	Memorandum of Agreement
Mod	modification
MOU	memorandum of understanding
MPC&A	Material Protection, Control, and Accounting
MT	megaton

NACLC	national agency check with local agency and credit check
NAOC	National Airborne Operations Center
NASA	National Aeronautics and Space Administration
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
NDB	nuclear depth bomb
NER	Nuclear Enterprise Review
NEWS	nuclear explosive and weapons surety
NIF	National Ignition Facility
NIMS	National Incident Management System
NISC	Nonproliferation and International Security Center
NLCC	National Leadership Command Capability
NMCC	National Military Command Center
NMSEP	New Material and Stockpile Evaluation Program
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)
NRC	Nuclear Regulatory Commission
NRF	National Response Framework

NSC	National Security Campus
NSC	National Security Council
NSD	National Security Directive
NSE	Nuclear Security Enterprise
NSI	national security information
NSPD	National Security Presidential Directive
NSS	Nuclear Command and Control System Support Staff
NSTCA	Nuclear Security Threat Capabilities Assessment
NTD	nuclear threat device
NTNF	national technical nuclear forensics
NTRG	Nuclear Trafficking Response Group
NTS	Nevada Test Site
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
NWPS	nuclear weapons physical security
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

OASD(A)	Office of the Assistant Secretary of Defense for Acquisition
OASD(LA)	Office of the Assistant Secretary of Defense for Legislative Affairs
OCA	original classification authority
OCR	Ohio-class replacement
ODASD(NM)	Office of the Deputy Assistant Secretary of Defense for Nuclear Matters
ODNI	Office of the Director for National Intelligence
OSD	Office of the Secretary of Defense
OUO	Official Use Only

PA	probability of arrival
PAL	permissive action link
PD	probability of damage
PDD	Presidential Decision Directive
PLS	pre-launch survivability
PNET	Peaceful Nuclear Explosions Treaty
PNI	Presidential Nuclear Initiative
POG	Project Officers Group
PPD	Presidential Policy Directive
PPE	personal protective equipment
PPI	process prove-in
PRP	Personnel Reliability Program
PRS	Plasma Radiation Source

psi	pounds per square inch
PTP	probability to penetrate
Pu-239	plutonium-239
Pub. L.	Public Law
PWDR	Preliminary Weapon Development Report
PX	Pantex Plant

QA	quality assurance
QART	Quality Assurance and Reliability Testing
QDR	Quadrennial Defense Review

RB	reentry body
RD	radius of damage
RD	Restricted Data
RDD	radiological dispersal device
RED	radiological exposure device
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
SALT I	Strategic Arms Limitation Talks
SALT II	Strategic Arms Limitation Treaty
SASC	Senate Armed Services Committee
SCI	Sensitive Compartmented Information
SCT	Stockpile Confidence Test
SD	Statutory Determination
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
SRS	Savannah River Site
SSBI	single scope background investigation
SSBN	ship, submersible, ballistic, nuclear (ballistic missile submarine)
SSGN	conventionally armed nuclear-powered submarine
SSMP	Stockpile Stewardship Management Plan
SSNS	Satellite System Nuclear Survivability
SSP	Stockpile Stewardship Plan
SSP	Strategic Systems Program
START	Strategic Arms Reduction Treaty
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
TNF	technical nuclear forensics
TNFI	Transclassified Foreign Nuclear Information
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
TTP	tactics, techniques, and procedures
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
USANCA	U.S. Army Nuclear and Combating Weapons of Mass Destruction Agency
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USD(C)	Under Secretary of Defense, Comptroller
USD(P)	Under Secretary of Defense for Policy
USEUCOM	United States European Command
USSOCOM	United States Special Operations Command
USSTRATCOM	United States Strategic Command
VCJCS	Vice Chairman of the Joint Chiefs of Staff
VHF	Very High Frequency
W	warhead
WDCR	Weapon Design and Cost Report
WESC	Weapon Effects Strategic Committee
WETL	Weapons Evaluation Test Laboratory
WMD	weapons of mass destruction
WR	war reserve
WRD&T	Weapons Research, Development, and Testing
WS3	weapon storage and security system (United States) weapon security and survivability system (NATO)
WSMR	White Sands Missile Range
WSR	weapon system reliability
WSSC	Warhead Science Steering Committee
WSV	weapon storage vault