THE NUCLEAR MATTERS HANDBOOK

EXPANDED EDITION

2011 — ATSD(NCB) becomes ASD(NCB)

2010 — New START Treaty signed and ratified by the U.S. Senate
— Third NPR released

2009 — ANWFZ and CANWFZ Treaties enter into force
— North Korea conducts second UGT
— President Obama's Prague speech

2008 — 50th Anniversary of U.S.-UK MDA

2006 — North Korea conducts first UGT

2005 — Final Peacekeeper ICBM decommissioned

2004 — NCCS CoP established

2003 — Libya halts its "unconventional" weapons program
— Moscow Treaty (SORT) enters into force
— North Korea withdraws from NPT

2002 — U.S. withdraws from ABM Treaty

2001 — Second NPR completed
— Terrorist attack against the U.S.

1999 — NNSA created as semi-autonomous agency within DOE

1998 — Pakistan conducts five UGTs
— India conducts three UGTs

1997 — U.S. conducts its first "subcritical" experiment at NTS
— Bangkok Treaty enters into force

1996 — CTBT opens for signature
— ATSD(AE) becomes ATSD(NCB)

1995 — U.S. Army relinquishes its last nuclear weapon to the DOE for dismantlement
— NPT extended indefinitely

1994 — START I enters into force
— First NPR completed
— NWCSSC established

1993 — DOE directed to establish U.S. Science-Based Stockpile Stewardship Program
— South Africa declares dismantled nuclear weapons capability
— START II Treaty signed

1992 — U.S. conducts its last underground nuclear test

1991 — USSR dissolved
— Nunn-Lugar Cooperative Threat Reduction Act signed
— PNIs announced

1990 — TTBT and PNET enter into force

1989 — Berlin Wall comes down

1988 — INF Treaty enters into force

1986 — MLC replaced by NWC
— Chernobyl nuclear reactor accident
— Treaty of Rarotonga enters into force

1983 — Strategic Defense Initiative announced

1981 — Israel bombs Iraq's Osirak nuclear reactor

1939 Albert Einstein sends a letter to President Roosevelt informing him of the German atomic research program and the potential for a bomb

1940 Otto Frisch and Rudolph Peierls conclude that only about 1kg of U-235 is needed to create a nuclear weapon

1942 Manhattan Project initiated

1943 LANL is established in New Mexico

Quebec Conference is held between the U.S., Britian, and Canada

1945 "Trinity" detonated, first test of a nuclear explosive device

Atomic bombings of Hiroshima and Nagasaki

1946 Atomic Energy Act of 1946 establishes the AEC

1948 Z-Division's growth prompts its designation as SNL

AEC directed to build atomic bomb stockpile

1949 USSR detonates its first atomic weapon

NATO created

1952 U.S. detonates its first full-scale thermonuclear weapon

UK detonates its first atomic weapon

LLNL is established in California

1953 ATSD(AE) position established

1954 Atomic Energy Act amended

1955 USSR detonates its first genuine thermonuclear device

1957 Sputnik is launched into orbit by a Soviet SS-6

U.S. conducts first contained UGT

1958 U.S.-UK MDA signed

1960 France tests its first nuclear weapon

1961 Berlin Wall erected

Antarctic Treaty enters into force

1962 Soviet nuclear weapons deployment leads to the Cuban Missile Crisis

1963 LTBT enters into force

U.S./USSR "Hot-Line" established

Polaris Sales Agreement signed between the U.S. and the UK

1964 PRC detonates its first atomic weapon

1968 Treaty of Tlatelolco enters into force

1970 NPT enters into force

1972 SALT I and ABM Treaty enter into force

1974 India conducts its first atomic test explosion

AEC replaced by NRC and ERDA established

1977 DOE established, replacing ERDA

1979 SALT II Treaty signed

Three Mile Island nuclear reactor accident

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Preface

The Nuclear Matters Handbook is an expanded and revised version of the earlier *Nuclear Matters: A Practical Guide*. Originally published in 1991 for the use of Action Officers associated with the Nuclear Weapons Council, previous editions have been modified over time to meet the needs of the larger U.S. nuclear community as well as those outside the community who seek a better understanding of the subject area. Since the early 1990s, the U.S. nuclear program has evolved significantly as a result of unilateral and bilateral arms reductions, the end of underground nuclear testing in the United States, and in response to the growing threats of nuclear proliferation and nuclear terrorism.

This revised and expanded handbook can be read cover to cover for those who seek to understand the U.S. nuclear program in its entirety, and can also be used as a reference source to look up useful facts and information concerning specific areas. The book is divided into chapters and appendices; the chapters present an overview of the U.S. nuclear program as a whole, while the appendices provide supplementary information on related topics for those less familiar with the subject matter.

This book is intended to be an **unofficial** reference and is, therefore, neither authoritative nor directive. Every effort has been made to ensure that it is accurate and comprehensive. Please refer to the applicable statute, regulation, Department of Defense Directive/Instruction, or Department of Energy Order for definitive guidance in all areas related to U.S. nuclear matters.

The content of *The Nuclear Matters Handbook* is the sole responsibility of the Office of the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs.

An electronic version of this handbook can be downloaded at
www.acq.osd.mil/ncbdp/nm

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Nuclear Matters History and Policy

1.1 Overview

Nuclear power is unique. The ability to harness nuclear energy has changed the world. The peaceful applications of nuclear power for the developed and developing world have been an unprecedented game changer and have accelerated the development timeline of many nations through increased access to energy resources and advanced technologies. Similarly, the ability to use nuclear energy for military purposes has fundamentally altered the international security environment since the employment of nuclear weapons by the United States during World War II.

The U.S. nuclear deterrent, with its unique attributes, is a central element of U.S. national security policy.

The U.S. nuclear deterrent, with its unique attributes, is a central element of U.S. national security policy for several reasons. First, the U.S. nuclear deterrent reduces the probability that 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 so that these nations do not need to develop and field their own nuclear weapons. This helps to minimize nuclear proliferation. Third, the U.S. nuclear arsenal deters nuclear or radiological attack against the United States, its allies, and its partners by state-sponsored terrorist organizations or proliferant nations. These 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 current policy of the United States to retain and maintain its nuclear deterrent indefinitely until verifiable worldwide nuclear disarmament is achieved.

1.2 The Changing International Security Environment

During an April 5, 2009 visit to Prague, Czech Republic, President Barack Obama described his vision for a new direction for U.S. nuclear forces in the world: "I state clearly and with conviction America's commitment to seek the peace and security of a world without nuclear weapons...As long as these weapons exist, the United States will maintain a safe, secure, and effective arsenal..." Concrete steps toward achieving this vision were described and outlined in the results of the 2010 Quadrennial Defense Review (QDR) and the 2010 Nuclear Posture Review (NPR). Both reviews acknowledge 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. Both the QDR and the NPR Reports note that the most immediate and extreme danger for the United States are the dual threats of nuclear proliferation and nuclear terrorism. Additional countries—especially those that do not conform to international norms and structures—may acquire or seek to acquire nuclear weapons. Sub-state actors and terrorist organizations have also declared their intent to acquire nuclear threat devices.[1] While facing these increasingly

Figure 1.1 President Obama in Prague

[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.

urgent threats, the two reviews assert that it is important for the United States to continue addressing the more familiar challenge of ensuring strategic stability with existing nuclear powers—most notably Russia and China.

Russia remains America's only peer in the area of nuclear weapons capabilities. The nature of the U.S.-Russia relationship has changed fundamentally since the days of the Cold War. While policy differences continue to arise between the two countries and Russia continues to modernize its still-formidable nuclear forces, Russia and the United States are no longer adversaries and prospects for military confrontation have declined dramatically. The two nations have increased their cooperation in areas of shared interest, including preventing nuclear terrorism and nuclear proliferation.

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 that guide them raise questions about China's future strategic intentions.

1.3 2010 Nuclear Posture Review

NUCLEAR POSTURE REVIEW 2010

The 2010 Nuclear Posture Review Report outlines the Administration's approach to implementing the president's agenda for reducing nuclear dangers and pursuing the long-term goal of a world without nuclear weapons.

As a result of these changes in the international security environment, the United States has modified the role of U.S. nuclear weapons, retaining the benefits of the peaceful applications of nuclear power, while mitigating the concomitant risks. The 2010 Nuclear Posture Review Report outlines the Administration's approach to implementing the president's agenda for reducing nuclear dangers and pursuing the long-term goal of a world without nuclear weapons. The report also details how the United States will sustain a safe, secure, and effective nuclear deterrent as long as nuclear weapons exist.

The 2010 NPR is the third comprehensive review of U.S. nuclear policies and posture; the first two were conducted in 1994 and 2001 by the Clinton and Bush Administrations, respectively. The 2010 review was an interagency effort conducted by the Department of Defense 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, placing nonproliferation and nuclear counterterrorism as primary U.S. national security priorities for the first time.

1.3.1 Preventing Nuclear Proliferation and Nuclear Terrorism

The 2010 NPR stressed the prevention of nuclear proliferation and nuclear terrorism and outlined steps for the United States to lead expanded international efforts to strengthen the global nonproliferation regime. Specifically the NPR recommended:

- Bolstering the nonproliferation regime, including increasing funding for DOE nonproliferation programs;
- Accelerating efforts to implement the president's initiative to lock down all vulnerable nuclear materials against theft or seizure, and increasing the United States' ability to detect and interdict nuclear materials; and
- Pursuing arms control to support the Treaty on the Nonproliferation of Nuclear Weapons (NPT) Article VI obligations, including the New Strategic Arms Reduction Treaty (START), the Comprehensive Nuclear Test Ban Treaty (CTBT), and a verifiable Fissile Material Cutoff Treaty (FMCT).

The NPR Report also addressed the renewed U.S. commitment to hold fully accountable any state, terrorist group, or other non-state actor that supports or enables terrorist efforts to obtain or use weapons of mass destruction, either by facilitating, financing, or providing expertise or safe haven for such efforts.

1.3.2 Reducing the Role of Nuclear Weapons

Since the end of the Cold War, the United States has reduced the role of nuclear weapons in deterring non-nuclear attacks on itself and its allies and partners. The United States is continuing to strengthen conventional military capabilities, missile defenses, and counter-WMD capabilities so that 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 Report also explained changes in U.S. declaratory policy to include the strengthening of negative security assurances. Specifically, the United States declared that it will not use or threaten to use nuclear weapons against non-nuclear weapons states that are party to the NPT and in compliance with their nuclear nonproliferation obligations.[2]

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[2] In making this strengthened assurance, the United States affirmed that any state eligible for the assurance that uses chemical or biological weapons against the United States or its allies and partners

1.3.3 Maintaining Strategic Deterrence and Stability at Reduced Nuclear Force Levels

As the United States and Russia reduce their nuclear forces, maintaining stability remains a priority. As a first step, the 2010 NPR analytically derived U.S. positions for New START negotiations with Russia:

- 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. The Treaty does not constrain U.S. missile defenses and allows the United States to pursue conventional global strike systems.
- Under New START, the United States will retain a nuclear triad and "deMIRV"[3] its ICBMs to one warhead each.

The NPR also proposed pursuing high-level, bilateral dialogues with Russia and China aimed at promoting more stable and transparent strategic relationships. With Russia, this includes a discussion of future bilateral nuclear weapons reductions, including strategic and non-strategic, deployed and non-deployed. With China, the United States seeks to address each side's concerns about the other's strategic forces and policies. The goal of such a dialogue is to enhance confidence, improve transparency, and reduce mistrust.

1.3.4 Strengthening Regional Deterrence and Reassuring U.S. Allies and Partners

The United States remains committed to strengthening bilateral and regional security architectures and to adapting these relationships to emerging twenty-first century requirements. The United States will continue the forward deployment of U.S. forces in key

would face the prospect of a devastating conventional military response and that any individuals responsible for the attack, whether national leaders or military commanders, would be held fully accountable. Given the catastrophic potential of biological weapons and the rapid pace of biotechnology development, the United States reserves the right to make any adjustment in the assurance that may be warranted by the evolution and proliferation of the biological weapons threat and U.S. capacities to counter that threat. In the case of countries not covered by this assurance—states that possess nuclear weapons and states not in compliance with their nuclear nonproliferation obligations—there remains a narrow range of contingencies in which U.S. nuclear weapons may still play a role in deterring a conventional or a chemical or biological weapon attack against the United States or its allies and partners.

[3] "MIRV" stands for multiple independently targetable reentry vehicle. Using a MIRV warhead, a single launched missile can strike several targets or fewer targets redundantly.

regions, the strengthening of U.S. and allied non-nuclear capabilities, and the provision of extended deterrence in order to deter potential threats, demonstrate to neighboring states that the pursuit of nuclear weapons will only undermine their goal of achieving military or political advantages, and reassure non-nuclear U.S. allies and partners that 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 and through U.S. intercontinental and submarine-launched ballistic missiles (ICBMs and SLBMs). The United States plans to retain the capability to forward deploy U.S. nuclear weapons on tactical fighters and heavy bombers and to proceed with a full-scope life extension of the B61 bomb, which will be able to be carried by these aircraft.

1.3.5 Sustaining a Safe, Secure, and Effective Nuclear Arsenal

The United States will sustain a safe, secure, and effective nuclear arsenal as long as nuclear weapons exist. The United States is modernizing its nuclear weapons infrastructure, sustaining the science, technology, and engineering base, investing in human capital, and ensuring senior leadership focus. The NPR Report outlined several principles guiding future U.S. stockpile management decisions:

- The United States will not conduct nuclear testing and will seek ratification and entry into force of the Comprehensive Nuclear Test Ban Treaty.
- The United States will make decisions on how to sustain specific warheads on a case-by-case basis.
- The United States will not develop new nuclear warheads; life extension programs (LEPs) will be based on designs that are, or have been, in the U.S. stockpile and will not provide new military capabilities or support new military missions.
- LEP decisions will be made on a case-by-case basis with strong preference given to refurbishment or reuse. Replacement of nuclear components with redesigned components will require presidential and congressional approval.

1.4 Nuclear Weapons from 1939-1945

An understanding of the unique status of nuclear weapons is integral to understanding their role. Nuclear weapons are distinct from other weapons; they are in a class by themselves. 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 talk about 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 produced. Because of their tremendous power, the U.S. military did not have peacetime physical custody of nuclear weapons until 1959, almost fifteen years after the first successful nuclear detonation.

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 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, the Austrian Otto Frisch and the 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 to fission, 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 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 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*.[4]

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

[4] 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.

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 he 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 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. Several scientists from Canada also joined the project. 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.

Figure 1.2 "Enola Gay"


Figure 1.3 "Little Boy"

On July 16, 1945, the United States detonated its first nuclear explosive device called the "Gadget" at the Trinity Site, located within the current White Sands Missile Range, near the town of Alamagordo, New Mexico. Twenty-one days later, on August 6, President Harry S. Truman authorized a specially equipped B-29 bomber called *Enola Gay* (Figure 1.2) to drop a nuclear bomb, *Little Boy* (Figure 1.3), on Hiroshima, Japan. Soon after Hiroshima was attacked, President Truman called for Japan's surrender. With no response from the Japanese after three days, on August 9, another B-29 bomber, *Bockscar* (Figure 1.4), dropped a second U.S. atomic weapon, *Fat Man* (Figure 1.5), on Nagasaki.

Figure 1.4 “Bockscar”


Figure 1.5 “Fat Man”

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. Their use permanently altered the global balance of power.

1.5 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 device, followed nine months later by the Soviet Union’s first thermonuclear test.[5] 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 that 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 deterrence for both nations. 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

[5] 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.

the prospect of an attack against the North Atlantic Treaty Organization (NATO) in Western Europe was a very real possibility.

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—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 exchange. Throughout the late 1950s, the United States was committed to increasing its nuclear weapons quantities to enhance flexibility in the types of nuclear-capable military delivery vehicles and the bombs and warheads available for delivery.

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.

By 1965, the U.S. nuclear weapons stockpile had grown to more than 31,000 warheads (see Chapter 3: *U.S. Nuclear Forces*, for a discussion of historical and current stockpile quantities). Most of these warheads had relatively low yields and were for short-range, non-strategic (then called "tactical") systems. At the time, many weapons were forward deployed in Europe within the territories of NATO allies.

Beginning in the mid-1960s, the United States shifted its priorities from quantity to quality, and U.S. 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 that included building and subsequently replacing the weapons in the U.S. nuclear stockpile with newer, more modern designs. In addition to warheads that were simpler[6] for the military operator, modern characteristics included greater yield, smaller size,[7] better employment characteristics,[8] and more modern safety, security, and control

6 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.

7 Smaller warhead size allowed strategic missiles to carry a larger number of re-entry 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.

8 Some of the features that provided increased operational capability included selectable yields, better

features. A key part of this process was the use of nuclear testing for a wide variety of purposes,[9] 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 that were already fielded; and
- certify the design modification required to correct those problems.

Until 1992, the United States utilized a complementary combination of underground nuclear testing (UGT)[10] 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. During and after fielding, stockpile activities included exchanging limited life components (LLCs),[11] detecting components with design or aging defects and replacing them, conducting periodic validations for safety, and updating reliability estimates. Eventually, as the weapon aged, and additional modern safety, security, and operational design features became available, the United States would begin development of a newer, better, and

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fuzing (for a more accurate height of burst), increased range (for cannon-fired warheads), and shorter response times.

9 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 1958-1960. The moratorium was broken by France in 1960, and the United States and the Soviet Union resumed testing in 1961.

10 The United States conducted above ground and undersea testing until 1963, when the Limited Threshold Test Ban Treaty entered into force, banning nuclear tests in the atmosphere, outer space, and under water. (For more information on the Threshold Test Ban Treaty, see Appendix B: *International Nuclear Treaties and Agreements.)*

11 Some age-related changes affecting nuclear warhead components are predictable and well understood. LLCs in any given warhead-type might include power sources, neutron generators, tritium reservoirs, and gas transfer systems. LLCs are replaced at pre-determined times during scheduled limited life component exchanges (LLCEs). In a similar manner to that in which one replaces components of an automobile—such as oil filters, brake pads, and tires—so too must LLCs be replaced before their deterioration adversely affects warhead function or personnel safety.

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 a period of 15-20 years, a period known as the "protected period." During the protected period, required operational quantities of existing warheads were preserved, even though quality assurance testing would usually consume one weapon per year for each type of weapon. At the end of the protected period, the older weapon would begin the retirement process; at the same time, the replacement system would be in the production and fielding process. In this way, the U.S. nuclear arsenal was continually replenished by weapons with better safety and security features that met the required effectiveness with less collateral damage and fewer undesirable effects. This ensured that the United States had an extremely modern, sophisticated stockpile predicated on a substantial nuclear and non-nuclear component production capacity and the continuation of underground nuclear testing.

1.6 The End of Underground Nuclear Testing

Because of congressional pressure, the United States voluntarily suspended its program of nuclear testing in 1992. Public Law 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.[12] With a limit of 15 tests within less than four years, however, 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.[13] Therefore, the decision was made to forgo the 15 additional tests permitted under the new law, and no other tests were conducted.[14]

[12] Public Law 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).

[13] 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.

[14] 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.

This nuclear test prohibition impacted the stockpile management process in several significant ways. First, the legislation was too restrictive to achieve the objective of improving the safety of those already-fielded warhead-types lacking all available modern safety features. Second, the moratorium on UGT also resulted in suspending production of weapons being developed with new, untested designs—including those with newer safety and security improvements beyond those specified in the legislation. 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 UGT 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 that 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.)

1.7 Stockpile Management Since 1992

In response to these new circumstances and the resulting paradigm shift, the Fiscal Year 1994 National Defense Authorization Act (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." 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 "science-based" approach, which has served as a substitute for nuclear testing since 1992, has developed and matured significantly since its inception, and now includes computer simulations, experiments, and the data from more than 1,000 previous nuclear tests. The capabilities of this integrated analytical computation system are maturing constantly with the expectation that, over time, the system will provide the same level of confidence that was achieved through nuclear testing in 1992. As U.S. weapons continue to age, however, innovative solutions to evolving problems must continue to be developed.

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. weapons, with periodic reductions in quantities corresponding with the U.S. reductions in strategic forces associated with strategic force reduction treaties.

As a result of the 2010 Nuclear Posture Review, plans are currently in place to refurbish and modernize the U.S. nuclear weapons infrastructure to continue to sustain a safe, secure, and effective nuclear deterrent. Additionally, the United States nuclear program, both independently and in cooperation with foreign partners, is actively engaged in nuclear threat reduction activities to enhance international stability and national security.

1.8 Summary

The Departments of Defense and Energy are cooperating as partners in the plan to retain and maintain the U.S. strategic deterrent with safe, secure, and reliable nuclear weapons now and in the future, as the nation cooperates with Russia and other nuclear weapons states to reduce nuclear forces and moves toward a verifiable global elimination of all nuclear weapons. The president has acknowledged that until such a world exists, however, the United States will maintain a safe, secure, and effective nuclear deterrent. The goal of this volume is to provide an understanding of the current U.S. actions associated with maintaining this safe, secure, and effective nuclear deterrent while effectively countering the nuclear threats of nuclear proliferation and nuclear terrorism.

Chapter 2

Stockpile Management, Processes, and Organizations

2.1 Overview

Stockpile management is the 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. It ensures that the stockpile is safe, secure, and reliable to perform as the nation's nuclear deterrent. Stockpile management involves the care of the weapons from cradle to grave, including concept development, design engineering, manufacturing, quality assurance, maintenance, and repair. Because of the sophistication and intricacy of U.S. nuclear weapons and the numbers of weapons and components involved, stockpile management is a complex undertaking, and the consequences of error in its execution could be very significant.

The stockpile management process is dynamic. Programs and activities must be properly coordinated to ensure that all U.S. nuclear weapons will work how and when they are supposed to and that they remain safe and secure at all times. For example, weapon surveillance,[1] scheduled maintenance, refurbishment programs, and assembly/disassembly activities must all be coordinated against significant funding constraints and within the bounds of the physical infrastructure and human capital available to the mission. Ensuring that each process is completed on time, in sequence, and within budget is a monumental undertaking that is further complicated by the need to coordinate all stockpile management activities between two federal departments, the Department of Defense (DoD) and the Department of Energy (DOE) through the National Nuclear Security Administration (NNSA).

2.2 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 1945-1991, the United States utilized a design-produce-retire-replace sequence for nuclear warheads; warheads were designed, developed and 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 enhanced military capabilities and better safety and security features. Figure 2.1 illustrates U.S. stockpile management during the Cold War. This continuous replacement cycle was used throughout the Cold War to ensure U.S. stockpile weapons exploited technological advances and achieved the greatest military performance possible.

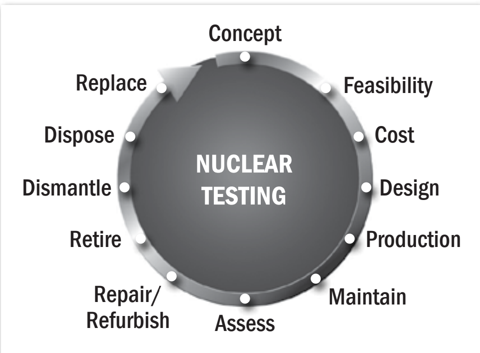

Figure 2.1 U.S. Stockpile Management during the Cold War

During the Cold War, a primary goal of U.S. nuclear weapons was to get the most yield into the smallest possible package (meaning maximum yield-to-weight ratio) as warheads were designed to be carried by increasingly more sophisticated and more capable delivery

[1] *Surveillance* is the term used to describe the activities involved in making sure the 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.

systems.[2] A second objective was to incorporate modern safety and security features in the warheads, which also added to the design complexity and the level of sophistication required to produce them. 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 force structure categories. This offered the president a wide range of options in the event that nuclear weapons would need to be used. For a list of these options, see Figure 2.2. As shown, the number of different weapon-types in the stockpile was larger than it is today. The weapons produced during this period were highly sophisticated with designs that pushed the technological envelope in every way. These weapons were designed with very little margin for error, meaning every component had to work independently and together exactly as specified for proper functioning of the weapon. The current U.S. nuclear stockpile is comprised 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.

STRATEGIC, OFFENSIVE
- **Intercontinental Ballistic Missiles***
- **Strategic Heavy Bombers***
- **Submarine-Launched Ballistic Missiles***

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

TACTICAL, OFFENSIVE
- **Dual-Capable Aircraft***
- **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
- **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

Figure 2.2 Cold War Nuclear Weapon Delivery Vehicles

In the period between the mid-1980s and 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] With the end of the Cold War, the United

[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 what is known as the "nuclear triad" for strategic systems. (For additional information on nuclear delivery systems, see Chapter 3: *U.S. Nuclear Forces*.)

[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 its capacity to mass produce pits. As recognized by the Nuclear Posture Review, reestablishing a pit production capability (including plutonium processing) and building a modern secondary production facility are necessary steps for the NNSA to achieve a modernized and responsive capacity to produce nuclear components for stockpile life extension. U.S. nuclear component production capability is extremely limited at the present time and has been almost non-existent since the end of the Cold War. When this

States adjusted its national security priorities and reconsidered the appropriate role for its 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 H.W. Bush announced the immediate termination of additional nuclear weapons production in 1991 and a moratorium on nuclear testing that 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 (UGT). To fulfill this mandate, stockpile management strategies evolved to maintain an established stockpile of aging weapons without UGT that were originally programmed to last no more than twenty years when supported with nuclear testing.

2.2.1 Stockpile Life Extension from 1992 - 2010

By 1992, when warhead production and UGT 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 (composed of weapons designed and built during the Cold War) 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 practical, 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. Figure 2.3 illustrates the U.S. approach to stockpile management during this time.

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

capability is achieved and there are plans in place to reconstitute U.S. nuclear component production, it will mark the beginning of a new stockpile support paradigm whereby the 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 re-creation of this capability will be the eventual reduction in the total number of warheads retained in the stockpile. For a more in-depth discussion of this subject, see Chapter 3: *U.S. Nuclear Forces*.

to that weapon. For refurbishment LEPs, nuclear and non-nuclear components are produced as closely as possible to the original designs for that warhead. Deviations from original designs generally occur only as a result of "sunset" technologies (where there are no longer technologies in existence to produce items) or manufacturing processes that cannot be replicated because of environmental or health hazards.

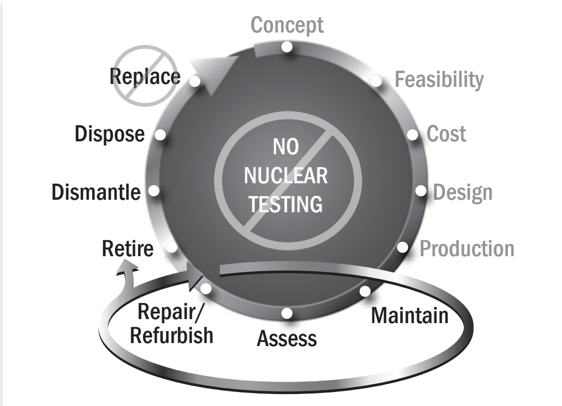

Figure 2.3
U.S. Approach to Stockpile Management, 1992-2010

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 that these weapons continue to meet safety, security, and yield standards.

Today, the United States has the technical capacity to produce safety and security features that are superior to those in the current warheads.

The second major issue with a refurbishment-only approach to life extension is that refurbishment offers very little opportunity to enhance safety or security performance by introducing technological improvements that have been developed over the past twenty years. 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. The refurbishment LEP process does not allow for incorporating these more effective safety and security features without underground nuclear testing to ensure that they do not corrupt the functioning of other safety, security, and yield characteristics of the weapon.

2.2.2 The Advancement of Stockpile Life Extension

To take advantage of innovations in safety and security and to preclude the need to resume UGT, the Obama Administration has decided on, and the 2010 Nuclear Posture Review (NPR) Report reflects, a strategy to ensure the continued safety, security, and effectiveness (consistent with the congressionally mandated Stockpile Management Program) of the U.S. nuclear arsenal through the expansion of life extension options beyond a refurbishment-only approach. This expanded LEP approach seeks to:

- Address the issue of aging nuclear weapons;
- Prevent the need to resume underground nuclear testing; and
- Enhance the safety, security, and reliability of the weapons of the U.S. nuclear stockpile.

Every LEP involves the potential use of existing and newly manufactured nuclear and non-nuclear components. LEPs do not provide new military capabilities for warheads, nor do they support new military missions. LEPs do not, therefore, 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 UGT 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 had never been fielded in any U.S. weapon (but would not require UGT 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.

[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 not 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.

- Each LEP will be certified—without underground nuclear testing—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 approaches described above. (For more detailed information about the Phase 6.X Process, see Appendix D: *U.S. Nuclear Weapons Life-Cycle*.)
- The use of the third approach (use of a previously tested, but never-before-fielded, nuclear component design) requires presidential approval and congressional authorization.

2.3 Dual Agency Responsibility for Stockpile Management

The U.S. nuclear weapon stockpile is co-managed by the Departments of Defense and Energy. Because of the special nature of the weapons, the management process is very complicated. Stockpile management is governed by laws, Presidential Directives, and joint agreements. Additionally, both the DoD and the DOE have rules, processes, and documentation governing stockpile management, and neither department is bound by the internal rules and regulations of the other. To further complicate the process, the DoD and the DOE are appropriated funds to pay for nuclear weapon activities through different congressional committees. (For more information on the programming, planning, budget, and execution process, see Appendix I: *Programming, Planning, and Budgeting.*)

2.3.1 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 that 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 National Nuclear Security Administration was established as a semi-autonomous agency within the DOE responsible for the U.S. nuclear weapons complex and associated nonproliferation activities. Figure 2.4 illustrates the evolution of the AEC to the NNSA, and Figure 2.5 is a timeline of basic DoD-DOE nuclear-related agreements.

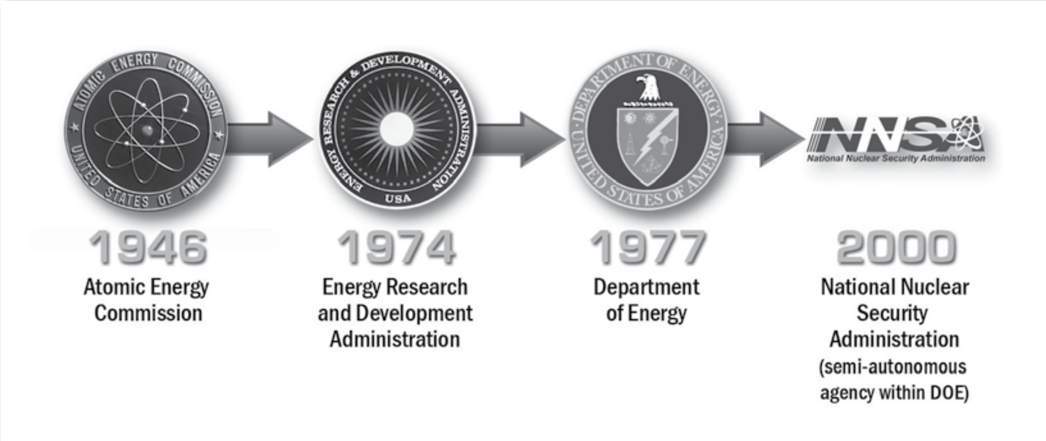

Figure 2.4 AEC to NNSA

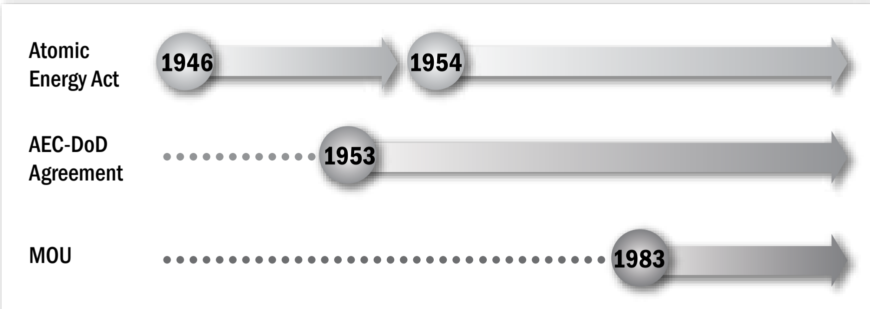

Figure 2.5 Timeline of DoD-DOE Nuclear-Related Agreements

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)).

2.3.2 Departmental Responsibilities

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

Specifically, the DOE 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; 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 facilities; accounting for individual warheads in DOE custody; participating in the joint nuclear weapons decision process; receiving and dismantling retired warheads; and disposing of components and materials from retired warheads.

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 working groups, the warhead Project Officers Group (POG), the NWC Standing and Safety Committee (NWCSSC), and the NWC); developing and acquiring the delivery vehicle and launch platform for a warhead; and storing retired warheads awaiting dismantlement in accordance with jointly approved plans.

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 organizations communicate through multiple channels, which ranges 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 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.

2.3.3 The Nuclear Weapons Council

The Nuclear Weapons Council 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 Department of Defense and Department of Energy organization that was established to facilitate cooperation and coordination, reach consensus, and establish 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 regarding concerns and strategies for stockpile management and 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 regularly 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 council is also obligated to evaluate the surety[6] of the stockpile and to report its findings to the president each year. The NWC, through its oversight and reporting functions, also ensures that any significant threats to the continued credibility of the U.S. nuclear capability will be identified quickly and resolved effectively. Figure 2.6 illustrates NWC membership as stated in Title 10, Section 179 of the U.S. Code. (For more information on the Nuclear Weapons Council and its subordinate bodies, see Appendix A: *Nuclear Weapons Council and Annual Reports*.)

2.4 Nuclear Weapon Development and Acquisition Policy

As long as nuclear weapons exist, the United States is committed to maintaining a safe, secure, and effective nuclear deterrent. Existing nuclear weapons have been maintained

[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 that there will be no nuclear weapon accidents, incidents, unauthorized weapon detonations, or degradation in performance at the target. For more on surety, see Chapter 5: *Nuclear Safety and Security*.

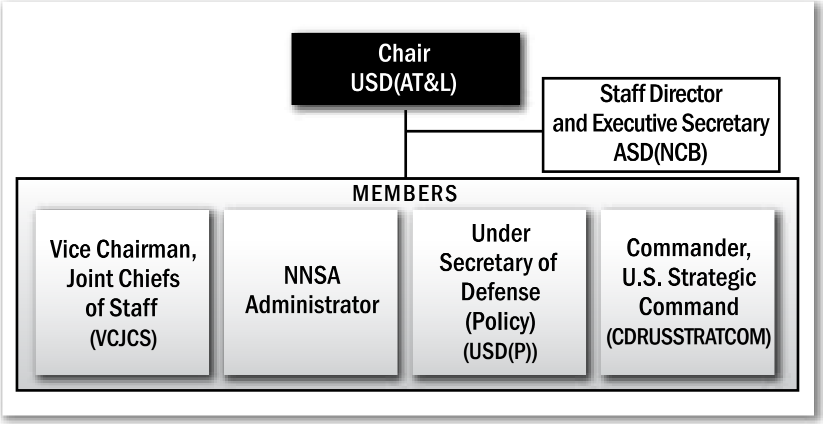

Figure 2.6 NWC Membership

well beyond their original programmed life. To ensure that these weapons remain safe, secure, and reliable, the Department of Defense and Department of Energy have developed several approaches for maintaining these weapons in an era of no nuclear testing. Until nuclear weapons are globally abolished, however, 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 Services.

2.4.1 Process Flow

The diagram in Figure 2.7 depicts the high-level process flow associated with the development and maintenance of nuclear weapons.[7] Presidential guidance, as promulgated through national documents like the 2010 Nuclear Posture Review Report, informs planning documents that Department of Defense combatant commanders use in the development of operational plans. In turn, these planning documents include requirements for capabilities and forces. These requirements create a demand for resources to ensure that the required capabilities are available to support combatant commanders. Resource requirements are consolidated and sent to the president for approval and submission into budget requests.

Figure 2.7 High-Level Process Flow

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

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 president uses the term Presidential Policy Directives (PPDs). 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 amplifies it before issuing it to the chairman of the Joint Chiefs of Staff (CJCS). These documents include the Defense Planning and Programming Guidance (DPPG) and various nuclear-related Department of Defense Directives (DoDDs).

Based on the detailed guidance and combatant commanders' general planning, nuclear weapons requirements are developed by the combatant commanders, the Military Services, and the Joint Staff. They are submitted to the Nuclear Weapons Council staff and combined with other inputs to inform the development of the Requirements & Planning Document (RPD). The RPD includes specific policies, military requirements, joint DoD-DOE planning factors, a long-range projection, and supporting programmatic details. The RPD is the basis for the draft presidential Nuclear Weapons Stockpile Plan (NWSP) that is submitted annually to the president with the Nuclear Weapons Stockpile Memorandum (NWSM), signed by the secretaries of defense and energy. When the president signs the associated Presidential Policy Directive, the NWSP becomes the presidential guidance that starts the process flow all over again.

This continuous cycle relies on the current combatant commanders' 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. 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. In recent years, changes to requirements have served to reduce weapons quantities. Because of the restriction on nuclear testing, there have not been any requirements associated with increasing effectiveness or achieving increased safety and security. If a required capability does not exist, the Services begin the acquisition process to provide the capability. If the required capability is a delivery platform, the Services use the Joint Capability 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 Capability Integration and Development System

JCIDS was established by the CJCS and the Joint Requirements Oversight Council (JROC) to identify, assess, and prioritize joint military capability needs. JCIDS is governed by DoDD 5000.01, *Defense Acquisition*; its scope includes major acquisitions or modifications, such as nuclear launch platforms (for example, strategic submarines) and delivery vehicles (for example, intercontinental ballistic missiles). The Military Services retain the responsibility for developing and acquiring the appropriate capability. JCIDS is an intra-DoD system operating among the Military Services and DoD Agencies; it does not operate in an interagency manner between the DoD and the DOE. The VCJCS leads the JROC in the JCIDS process. This "closes the loop" between the CJCS, the Combatant Commands, and the Military Services.

There are five phases in the JCIDs process: Phase 0, Concept Exploration and Definition; Phase I, Demonstration and Validation; Phase II, Engineering and Manufacture Development; Phase III, Production and Deployment; and Phase IV, Operation and Support.

The Joint Acquisition Process for Nuclear Weapons

The process for nuclear weapon acquisition has been in existence for over 55 years; 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, it relied on the Phase Process throughout the life-cycle of each weapon type. In the 1990s, the Phase Process was modified to accommodate the previously described system of weapons refurbishments. Today, the modified Phase Process is used to manage nuclear weapons programs. The NWC manages all aspects of nuclear weapons development in the Phase Process. (For more detailed information about the Phase Process, see Appendix D: *U.S. Nuclear Weapons Life-Cycle*.) In addition to the NWC, there are two other groups responsible for integrating the interagency acquisition of nuclear weapons: the NWCSSC and the POGs. The NWCSSC is 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 committees usually led by the Services 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 NNSA. They coordinate and approve all activities associated with maintaining nuclear weapons in accordance with DoD and DOE requirements; for major actions on weapons (for example, life extension programs), the POGs collect information on the requirements and submit them to the NWCSSC and then the NWC for approval.

2.4.2 Acquisition Process Drivers

The nuclear weapons program is not static; 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. As stated in the 2010 NPR Report, there are no current requirements for new warheads or new nuclear weapon capabilities.

Today, aging weapons components may require action in order to sustain the warhead's safety or reliability. These refurbishments could be in the form of a modification or an alteration. A modification, or 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 alteration, or 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 using units.

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.

2.5 Summary

Until 1992, U.S. stockpile management operated under a strategy of *modernize and replace*. With the moratorium on U.S. nuclear testing in 1992, the United States stopped producing new-design weapons, in part because the weapons could not be certified for safety or yield without a nuclear test. At that time, the stockpile management direction shifted to a strategy of *retain and maintain*. This change included adopting a life extension strategy using the basic life-cycle phase process to develop and field replacement components rather than new weapons. As the United States further reduces the nuclear stockpile on the path toward compliance with the New START, the nation continues to refine its strategy and policies to ensure that future life extension programs will provide a safe, secure, and reliable stockpile of nuclear weapons until effective and verifiable worldwide disarmament is achieved.

Chapter 3
U.S. Nuclear Forces

3.1 Overview

The fundamental role of U.S. nuclear weapons, which will continue as long as they exist, is to deter nuclear attack on the United States, its allies, and its partners. To do this, U.S. nuclear weapons must remain ready for use, and the United States must plan for this eventuality in the hopes that it will never come to pass. Therefore, the United States engages in activities to ensure the continued readiness of required quantities of nuclear weapons and delivery vehicles, and the United States also develops nuclear weapon targeting plans. This chapter will provide an overview of the various types and quantities of weapons in the U.S. nuclear stockpile, their functional categorization, the logistics and planning associated with their maintenance and delivery systems, and issues associated with their employment and targeting strategies.

3.2 Warhead Types

All nuclear weapons in the U.S. stockpile are designated either as a warhead or as a bomb.[1] In this handbook, the term "warhead" denotes individual weapons without

[1] The earliest U.S. nuclear weapons were distinguished by mark (MK) numbers, derived from the

distinguishing between “W” or “B” designators, and the terms “weapon” and “warhead” are used interchangeably. Additionally, the term warhead-type is used to denote a population of weapons with the same design. For a complete list of all weapons-types in the stockpile since 1945, see Figure 3.1.

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 to an already-complete design. For example, the B61 bomb has had 11 variations over time. Each variation was designated as a different modification, or *Mod*. Each Mod used the basic design of the B61, but each Mod had 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 use of this system of modifications provides significant cost savings because, in this model, proven and tested designs are modified rather than beginning each next generation warhead with a completely new weapon design. This approach also provides a more efficient way to conduct quality assurance testing and evaluation because warhead Mods that have a very large percentage of common components can be tested as a family of warheads.

All nuclear weapons in the U.S. stockpile are designated as strategic or non-strategic. Strategic weapons are those delivered by intercontinental ballistic missiles (ICBMs),[2] submarine-launched ballistic missiles (SLBMs),[3] or heavy bombers.[4] These are the three

old British system for designating aircraft. In 1949, the MK 5 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. 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 atomic demolition munitions (now retired and dismantled), are called bombs. Using these definitions, the total number of U.S. nuclear weapons is equal to the sum of warheads plus bombs.

[2] Intercontinental missiles have a range capability that exceeds 5,500 kilometers. Ballistic missiles are those that do not rely upon aerodynamic surfaces to produce lift and consequently follow a ballistic trajectory (which may be guided or unguided) when thrust is terminated.

[3] SLBMs are any ballistic missiles capable of being launched by submarines; range capability is not a factor for this category.

[4] Heavy bombers are specified by aircraft type. Generally, heavy bombers have greater range capability and greater payload lift capacity than non-strategic aircraft.

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)
* Currently in the U.S. force structure   ** Not Deployed

Figure 3.1 Historical List of Warhead-Types and Descriptions [part 1]

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)
* Currently in the U.S. force structure ** Not Deployed

Figure 3.1 Historical List of Warhead-Types and Descriptions [part 2] "legs" of the U.S. strategic nuclear force, commonly referred to as the "nuclear triad." The United States maintains nuclear weapons that rely on all three of these delivery systems.

All other nuclear weapons are non-strategic. Non-strategic nuclear weapons (which are sometimes called "tactical" nuclear weapons) may include: bombs delivered by non-strategic aircraft—usually dual-capable aircraft (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; atomic demolition munitions (ADM); and anti-submarine warfare nuclear depth bombs (NDB). Figure 3.2 shows U.S. nuclear forces by categories during the Cold War and in the present day.

System	Weapon Designation	Cold War	Current
STRATEGIC			
ICBMs	Warhead	Yes	Yes
SLBMs	Warhead	Yes	Yes
Heavy Bombers	Bomb Warhead	Yes Yes	Yes Yes
NON-STRATEGIC			
DCA	Bomb	Yes	Yes
GLCMs	Warhead	Yes	
GLBMs	Warhead	Yes	
Artillery	Warhead	Yes	
Air Defense	Warhead	Yes	
ADMs	Bomb	Yes	
NDBs	Bomb	Yes	

Figure 3.2 U.S. Nuclear Weapons, Cold War & Present Day

3.3 Stockpile Quantities

As stated in the 2010 Nuclear Posture Review Report, 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, as long as nuclear weapons exist.

Nuclear weapon stockpile quantities are authorized by Presidential Directive annually. The directive includes specific guidance to the Department of Defense (DoD) and the Department of Energy (DOE) (to be carried out through the National Nuclear Security Administration (NNSA)); it also includes a Nuclear Weapons Stockpile Plan (NWSP) that authorizes specific quantities of warheads, by type, by year, for a multi-year period.

From World War II through 1967, the U.S. stockpile quantities for both strategic and non-strategic warheads increased. By the end of 1967, both the former Soviet Union and the United States each had more than 30,000 warheads, and the majority of each stockpile consisted of short-range, non-strategic warheads. For the United States, the large number of stockpiled non-strategic warheads offset the vast advantage that the former Soviet Union had in conventional military forces. Beginning in 1968, the United States began a significant reduction in non-strategic warheads, while continuing to increase its quantities of strategic warheads. This began a shift in priority away from non-strategic nuclear weapons.

In 1991, the United States signed the first Strategic Arms Reduction Treaty (START I). At that time the total U.S. stockpile was approximately 19,000 nuclear weapons, of which more than half were non-strategic warheads (and thus unaffected by the treaty). Also in 1991, President George H.W. Bush initiated drastic reductions in non-strategic nuclear weapons. In the Presidential Nuclear Initiative (PNI) of 1991, the president announced that 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 the North Atlantic Treaty Organization (NATO) in Europe) and the Tomahawk SLCM, which was removed from deployment but retained as a hedge. Figure 3.3 shows the relative quantities of strategic and non-strategic warheads over time.

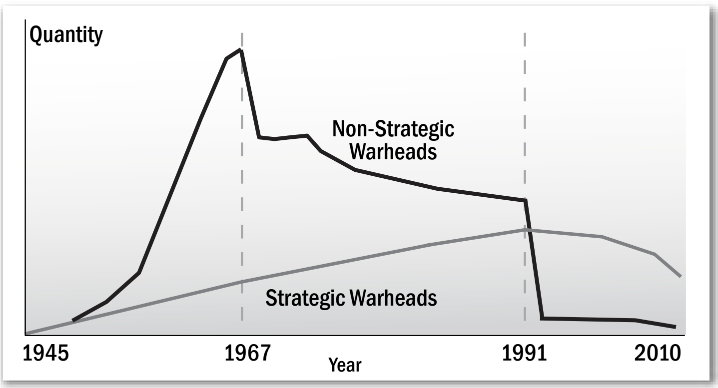

Figure 3.3 Quantities of U.S. Nuclear Weapons

The START I treaty put the United States on a path to a total stockpile of approximately 10,000 warheads, of which the majority were strategic weapons. As a result of the 2004 Strategic Capabilities Assessment, the United States reduced its total nuclear weapons stockpile to approximately 5,113 total warheads in 2009. Figure 3.4 shows the size of the U.S. nuclear stockpile from 1945 to 2009.

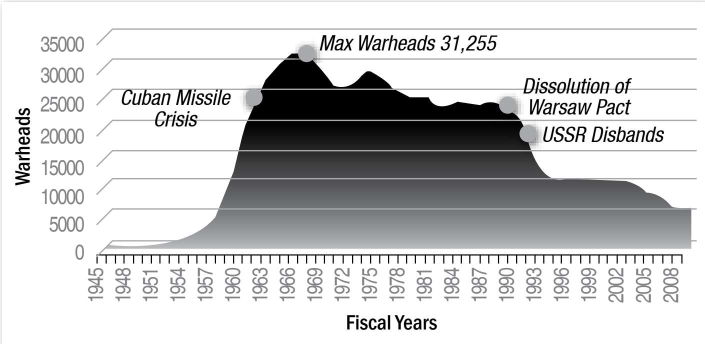

Figure 3.4 U.S. Nuclear Weapons Stockpile, 1945-2009
[Includes active and inactive warheads. Several thousand additional nuclear warheads are retired and awaiting dismantlement.]

The New START will lead to further reductions in the total number of U.S. nuclear weapons. As of September 30, 2009, the U.S. stockpile of nuclear weapons consisted of 5,113 warheads. This represents an 84 percent reduction from the stockpile's maximum (31,255) at the end of fiscal year 1967, and over a 75 percent reduction from its level (22,217) when the Berlin Wall fell in late 1989. Figure 3.5 provides total U.S. stockpile quantities from 1962 to 2009. Figure 3.6 shows the total number of warhead dismantlements from 1994 to 2009.

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

*Does not include weapons retired and awaiting dismantlement (several thousand as of Sept. 30, 2009)

Figure 3.5 Stockpile Numbers at the End of Fiscal Years 1962 - 2009

1994	1,369	1998	1,062	2002	344	2006	253
1995	1,393	1999	206	2003	222	2007	545
1996	1,064	2000	158	2004	206	2008	648
1997	498	2001	144	2005	280	2009	356

Figure 3.6 DOE Warhead Dismantlements (Fiscal Year 1994 - 2009)

3.4 Stockpile Composition

The current U.S. stockpile composition is determined by a number of factors but is most strongly influenced by the fact that the United States has produced no new nuclear weapons since 1991. The stockpile is composed of weapons developed and produced during the Cold War and maintained well beyond their original programmed lives for roles and missions that have evolved significantly since their original production. A large part of modern stockpile management (since the end of the Cold War) involves maintaining aging weapons in an environment where they cannot be replaced once they are dismantled or irreparable. Thus, stockpile composition refers not only to the differences among bombs and warheads and strategic and non-strategic weapons, but also to the various stockpile categories into which the weapons are divided for the purpose of being able to maintain the required numbers of operationally deployed weapons (those which could be deployed if they were 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 a range of 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 allies and partners of the reality of the U.S. nuclear umbrella. Because some contingencies are based on strategic warning—meaning that the United States would know in advance that it might need to employ its nuclear weapons to respond to emerging circumstances—not all nuclear weapons must be maintained in an operationally ready mode. To save money

[5] Combatant commanders and the Military Services determine the numbers and types of operational nuclear weapons required to satisfy national security policy objectives. These numbers, combined with National Nuclear Security Administration requirements and capacity to support surveillance, maintenance, and life extension, result in stockpile projections over time. These projections are codified in the annual Nuclear Weapons Stockpile Plan issued by the president. (See Appendix A: *Nuclear Weapons Council and Annual Reports* for information on the NWSP.)

and to account for limited facilities and capabilities, some weapons are maintained in less-ready modes requiring maintenance action or component replacement/production to become operationally ready. Other warheads are maintained in such a way that they can serve to fill in behind weapons that need repair or are being surveilled.

Because all U.S. nuclear weapons are not ready for immediate use all of the time, balancing the various operational requirements against logistical and fiscal realities is often a difficult task. Because, at this time (and for many years into the future), the United States has no capability to mass produce fissile components for nuclear weapons, U.S. stockpile composition must be managed to provide a hedge 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.

3.4.1 Configuration Management

Because the United States cannot devote unlimited resources to the maintenance of the stockpile, choices need to be made regarding the configuration of its stockpile through a process known as configuration management.

Stockpile maintenance is an intricate process that ultimately involves almost every part of the NNSA Nuclear Security Enterprise and organizations with nuclear missions within the DoD. This joint DoD-NNSA process coordinates technical complexities and operational needs associated with the various weapons systems. The Project Officers Groups are at one end of this joint process while the NWC is at the other. (For an explanation of the role of the NWC and the POG in the stockpile management process, see Chapter 2: *Stockpile Management, Processes, and Organizations*.)

Based on employment plans, hedge requirements, and logistical requirements, the U.S. stockpile plan specifies the number of warheads required to be operational (which requires funding to keep limited life components (LLCs) functioning) and the number of warheads that can serve an essential purpose in a non-operational status (saving the cost of maintaining limited life components while they are non-operational). The operational warheads are called the *active stockpile* (AS) and the non-operational warheads are called the *inactive stockpile* (IS).

The U.S. 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 reversal of the geopolitical situation that would require an increase in the number of weapons available for use. It is vital for the DoD and the NNSA to have procedures in place designed to mitigate these and other risks with a strategy that "hedges" against threats to the stability of the nuclear deterrent at lower stockpile levels.

There are two basic approaches to nuclear stockpile risk mitigation: the existence of a significant warhead production capability, the maintenance of warheads designated as hedge weapons, or some combination of the two. During the Cold War, the United States maintained a robust production capability to augment or decrease production, as required, depending on operational and geopolitical requirements. Today, the United States does not have an active nuclear weapon production capability and relies on the maintenance of a warhead hedge to reduce risk to acceptable levels.

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 size of the hedge and dismantle additional weapons is final and cannot be reversed. Once the weapons are gone, the total stockpile number is permanently decreased until the United States can produce replacements—using a production process whose construction and deployment time to a first weapon could take two decades or longer. Because of this, decisions regarding the U.S. nuclear weapons stockpile hedge are more complicated than they might seem and are being 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 limited life components (e.g., tritium components, neutron generators, and power-source batteries), usually at intervals of a few years. AS warheads are also refurbished with all required life extension program (LEP) upgrades, evaluated for reliability estimates (usually every six months), and validated for safety (usually every year). AS warheads may be stored at a depot, stored at an operational base, or uploaded on a delivery vehicle (e.g., a re-entry body, a re-entry vehicle, an air-launched cruise missile, or a delivery aircraft).

Active stockpile warheads include: *active ready* warheads that are operational and ready for wartime employment; *logistics* warheads that provide the operational flexibility for military weapons technicians to switch, with minimum loss of operational time, a logistics warhead with an active ready warhead needing maintenance (e.g., for limited life component exchange (LLCE)) or selected for quality assurance testing; *active near-term hedge* warheads that serve as part of the technical or geopolitical hedge and can serve as active ready warheads within six months; and *logistics* warheads to support active near-term hedge warheads.

Inactive Stockpile

Inactive stockpile warheads are maintained in a non-operational status. IS warheads have their tritium components removed as soon as logistically practical, and the tritium is returned to the national repository.[6] Other limited life components are not replaced until the warheads are reactivated and moved from the inactive to the active stockpile. Some IS warheads are refurbished with all required life extension program upgrades; others are not upgraded until the refurbishment is required for reactivation. Some IS warheads are evaluated for reliability estimates; other IS warheads may not require a reliability estimate. All IS warheads are validated for safety (usually every year). They are normally stored at a depot, not at an operational base. IS warheads are never uploaded on a delivery vehicle (e.g., a re-entry body, a re-entry vehicle, an air-launched cruise missile, or a delivery aircraft).

Inactive stockpile warheads include: *inactive near-term hedge* warheads that serve as part of the technical or geopolitical hedge and can serve as active ready warheads within six to 24 months; logistics warheads to support inactive near-term hedge warheads; *Quality Assurance and Reliability Testing (QART) Replacement* warheads (also known as *Surveillance Replacement* warheads); and *extended hedge* warheads that serve as either as part of the technical or geopolitical hedge and can serve as active ready warheads within 24 to 60 months.

Readiness States

The annual Requirements and Planning Document (RPD) provides the supporting details upon which the stockpile plan is based. The RPD uses a system of readiness states (RS) to determine what quantities of warheads require various programmatic activities.

RS levels determine quantities in five subcategories: *RS-1* are active weapons located at an operational base or uploaded on operational delivery vehicles; *RS-2* are active weapons stored at a depot; *RS-3* are inactive weapons that require refurbishment, reliability estimates, and safety validation; *RS-4* are inactive weapons that require reliability estimates and safety validation, but not refurbishment; and *RS-5* are inactive weapons

[6] Tritium is a radioactive gas that is 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 that none is wasted in the process of storing, moving, and maintaining warheads. The national repository for tritium is at the Savannah River Plant, located near Aiken, SC.

that require safety validation, but not refurbishment or reliability estimates. These RS levels are used as a management tool to ensure that only the required number of weapons receive component replacement and other programmatic actions; this helps to minimize the cost of maintaining, refurbishing, testing, and evaluating the nuclear stockpile.

The RS system also identifies quantities of warheads in four functional subcategories: *A warheads* are active ready and near-term hedge weapons; *B warheads* are logistics weapons; *C warheads* are QART Replacement weapons;[7] and *D warheads* are extended hedge weapons. By using these functional sub-categories, government leaders and program managers can easily determine what quantities of weapons are required for each function. In the recent past, this has helped decision makers reduce total stockpile quantities and the cost of the U.S. nuclear deterrent more quickly, while avoiding a significant increase to the various risks associated with a rapid draw-down.

3.4.2 Logistical Planning

Logistical planning is necessary for configuration management to ensure components and weapons movements and locations match, as appropriate. Logistical planning includes plans for storing, staging, maintaining, moving, testing, and refurbishing weapons. Nuclear weapons logisticians must comply with requirements and restrictions from several sources, including joint DoD-DOE agreements and memoranda of understanding, Joint Publications (JPs) published by the Joint Chiefs of Staff, the Joint Nuclear Weapons Publications System (JNWPS),[8] and Military Services' Regulations. The key theme for logistical planning is to ensure that weapons are handled or stored in a way that they are always safe, secure, maintained to be reliable, and to preclude unauthorized acts or events.

Storage

Storage refers to the placement of warheads in a holding facility for an indefinite period of time. Nuclear weapons are usually stored in secure, earth-covered bunkers, commonly called *igloos* (see figure 3.7) because of their near hemispherical appearance when observed from the outside. Logistical planning for nuclear weapons storage includes considerations for: 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

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[7] QART Replacement warheads are retained in the inactive stockpile to replace warheads consumed by the QART program or to provide replacement for a significant quantity of warheads planned to be unavailable for an extended period of time for QART evaluation.

[8] 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 to provide authoritative nuclear weapons instructions and data.

of certain types of nuclear warheads, inside traffic flow for access to warheads by serial number (for maintenance or movement of a QART sample), procedures for allowing igloo access by official visitors, and security both at the igloo exclusion area and greater distances for the overall storage facility. Currently, storage of nuclear warheads occurs only at DoD facilities operated by the Navy and the Air Force. Some current U.S. nuclear weapons have been in storage at DoD facilities for decades. Storage is also a consideration for retired nuclear weapons awaiting dismantlement.

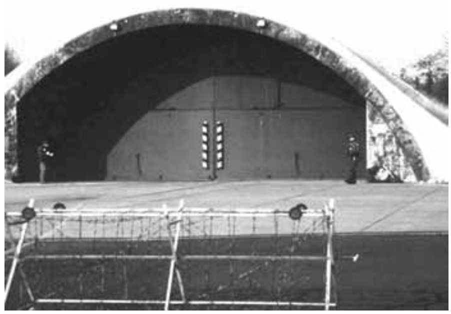

Figure 3.7 Nuclear Weapons "Igloo"

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. Nuclear weapons are usually staged in secure, earth-covered *igloos* or in a secure staging area awaiting disassembly or dismantlement at the NNSA Pantex Plant near Amarillo, TX. Logistical planning for nuclear weapons staging includes all of the considerations mentioned above, as well as the planned flow of warheads in the disassembly/dismantlement queue. Staging of nuclear warheads occurs only at the NNSA Pantex Plant, and it occurs for a limited period of time (normally not more than several weeks). Many current U.S. nuclear weapons have been staged in the disassembly queue at least once as QART samples (where they were disassembled, had components tested and evaluated, and then reassembled for return to the stockpile); 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. They also require special ordnance tools, technical manuals, and a secure and clean maintenance facility. Most maintenance operations, including limited life component exchanges, 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 NNSA establishes a limited life component exchange schedule. This LLCE schedule is managed by individual warhead and by serial number, and it is coordinated with the appropriate military service and NNSA offices.

Movement

Warheads are moved for several reasons. For example, they may be selected as QART samples, or they may be moved within an operational base area. Warheads may also be moved to the Pantex Plant for disassembly, or they may be returned from Pantex after re-assembly. 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 dismantlement. On occasion, a warhead will be returned from the Military Service to Pantex because of a special maintenance problem. Normally, all warhead movements from one installation to another within the continental United States are accomplished using NNSA secure safeguards ground transport vehicles. The Air Force uses its own certified ground vehicles and security for moves within an operational base area. Movements of weapons to and from Europe are accomplished by the Air Force using certified cargo aircraft. LLCs may be transported by special NNSA contract courier aircraft or by NNSA secure safeguards ground transport. 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 QART sample is downloaded from an ICBM missile. A logistics warhead is uploaded to replace the active ready warhead with minimum loss of operational readiness. The NNSA produces LLCs, which are sent to the depot; a QART replacement warhead is reactivated and transported by a secure safeguards vehicle to the operational base to replace the logistics warhead. The safeguards vehicle transports the QART sample warhead to Pantex for QART disassembly. After the QART testing is complete, the warhead may be reassembled and returned to the depot as an inactive warhead.

Logisticians plan and coordinate the dates and the required transport movements for each upload and download operation.

Forward Deployment

The United States remains committed to support NATO forces with nuclear warheads 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 Activities

Once life extension program components are produced, the remaining actions are almost all logistical functions. These actions include the process through which the NNSA publishes changes to technical manuals, if required, transports the LEP components to the appropriate locations, disassembles the warheads, extracts the old components, inserts the new LEP components, reassembles the warheads, and transports them back to the appropriate Military Service.

Retired Warheads

Warheads are retired from the stockpile by the Nuclear Weapons Council (NWC) in accordance with presidential guidance in the Nuclear Weapon Stockpile Plan. Retired weapons are shown as zero quantity in the NWSP covering the fiscal year in which they are retired. Retired weapons are not listed in subsequent NWSPs. Retired warheads fall into one of two categories:

- Retired warheads released for disassembly are scheduled for disassembly consistent with the throughput available in NNSA facilities so as not to impact support for DoD requirements. (Currently, there is a significant backlog of weapons awaiting disassembly. Most of these warheads remain stored at DoD facilities because of limited staging capability in NNSA facilities.)
- Warheads pending approval for disassembly (weapons in “Managed Retirement”) must be maintained by the NNSA in such a way that 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 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 the safety validation and may require additional sampling from the population of retired warheads.

3.5 Nuclear Weapons Force Structure

The U.S. nuclear force structure includes both nuclear warheads, which have been discussed above, and the units that can deliver the nuclear warheads to a target, if and when approved by the president. These delivery units consist of the launch platforms, delivery vehicles, support equipment, and the personnel required to accomplish the employment mission. Among other things, the delivery units have a staff that supports the commander for various functions, such as human resources, intelligence, delivery operations, security, training, and supply. The units also have technical and operational procedures, a security system, and a personnel support system that provides for the care of the unit's personnel. The remainder of this section will focus on nuclear delivery systems.

3.5.1 Nuclear Weapon Delivery Systems

Nuclear weapons are carried to their targets through the use of nuclear weapon delivery systems. A nuclear weapon delivery system is the military vehicle (ballistic or cruise missile, airplane, or submarine) by which a nuclear weapon would be delivered to its intended target in the event of authorized use. Most nuclear warheads have been designed for specific delivery systems. The United States currently maintains a nuclear triad, or a system of delivery vehicles comprised of a sea, land, and air deterrent based on submarine-launched ballistic missiles, intercontinental ballistic missiles, and heavy bombers. Figure 3.8 depicts the U.S. nuclear triad.

Figure 3.8 U.S. Nuclear Triad

The 2010 NPR concluded that, for planned reductions under the New START, the United States should retain a smaller triad of SLBMs, ICBMs, and heavy bombers. Retaining all three legs of the triad will best maintain strategic stability at a reasonable cost, while hedging against potential technical problems or vulnerabilities.

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 retaining all three legs in the near-term. Strategic nuclear submarines (SSBNs) and the SLBMs they carry represent the most survivable leg of the nuclear triad. Single-warhead ICBMs contribute to stability, and like SLBMs, have low vulnerability to air defenses. Unlike ICBMs and SLBMs, bombers can be visibly deployed forward as a signal in crisis to strengthen deterrence against potential adversaries and assurance of allies and partners;

it is also possible to recall a manned bomber after launch or takeoff toward a target. Figure 3.9 is a list of the current U.S. nuclear warheads and their associated delivery systems.

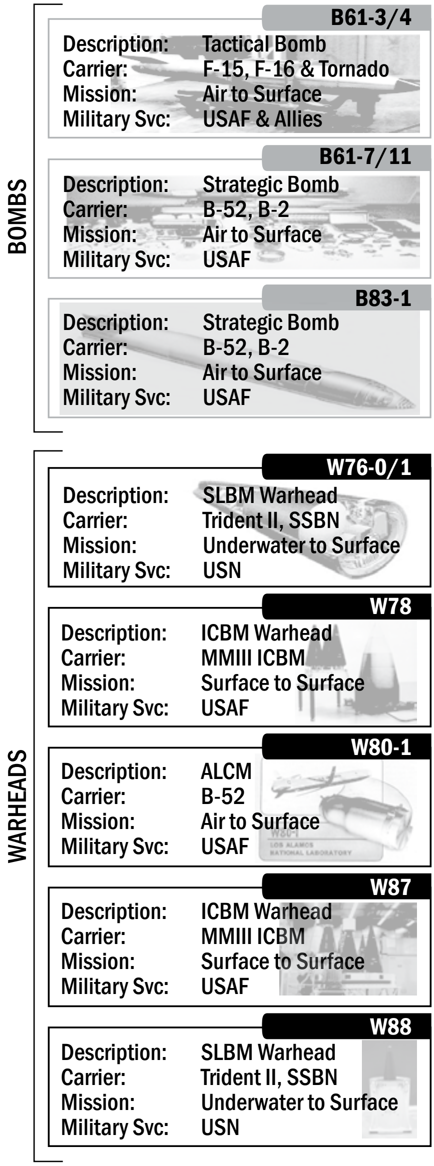

Figure 3.9 Current U.S. Nuclear Warhead-Types and Associated Delivery Systems

Strategic Submarines

Nuclear-powered SSBNs are designed to deliver ballistic missile attacks against assigned targets. These submarines carry submarine-launched ballistic missiles, which are the most survivable leg of the nuclear triad because of the ability of their SSBN delivery platforms to "hide" in the ocean depths, coupled with the long range of the missiles. Continuously on patrol, SSBN Trident missiles provide a worldwide launch capability, with each patrol covering a target area of more than one million square miles.

Each U.S. SSBN (Figure 3.10) is capable of carrying up to 24 Trident missiles. SSBNs are deployed from the west coast of the United States in Bangor, Washington, and from the east coast in Kings Bay, Georgia. These SSBNs carry the Trident II missile.

The 2010 NPR concluded that ensuring a survivable U.S. response force requires continuous at-sea deployments of SSBNs in both the Atlantic and Pacific oceans, as well as the ability to surge additional submarines in crisis. To support this requirement, the United States has 14 nuclear-capable Ohio-class SSBNs, of which 12 are operational at any one time, with the remaining two in long-term overhaul. By 2020, these Ohio-class submarines will have been 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 United States must develop a follow-on to the Ohio-class submarine. Because of the long lead times associated with the development and deployment of a

Figure 3.10 SSBN

new submarine, the secretary of defense has directed the Navy to begin technology development of an SSBN replacement immediately.

ICBMs

U.S. nuclear forces include intercontinental ballistic missiles, which are launched from stationary silos. ICBMs are on continuous alert, are cost-effective, can provide immediate reaction if necessary, and can strike their intended targets within 30 minutes of launch.

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. Figure 3.11 shows a Minuteman III missile in a silo.

Figure 3.11 MMIII in a Silo

The United States has 450 deployed, silo-based MMIII ICBMs, each with one to three warheads. The 2010 NPR Report announced the U.S. decision to "deMIRV"[9] all deployed ICBMs, so that each MMIII ICBM will have only one nuclear warhead. This step will enhance the stability of the nuclear balance by reducing the incentives for Russian preemptive nuclear attack or for U.S. launch under attack. The United States will continue the Minuteman III life extension program with the aim of keeping the fleet in service until 2030, as mandated by Congress. The Department of Defense will begin initial study of alternatives by Fiscal Year 2012, although a decision for a follow-on ICBM is not needed for several years. The study will consider a range of possible future options, with the objective of defining a cost-effective approach that supports continued reductions in U.S. nuclear weapons while promoting stable deterrence.

Bombers

The U.S. bomber force serves as a visible, flexible, and recallable national strategic asset. The active U.S. inventory of B-52s (Figure 3.12), which are located at Barksdale Air Force

[9] A "MIRVed" ballistic missile carries Multiple Independently Targetable Reentry Vehicles (MIRVs). "DeMIRVing" will reduce each missile to a single warhead.

Base in Louisiana and Minot AFB in North Dakota, has been the backbone of the strategic bomber force for more than 50 years. The B-52 "Stratofortress" 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 it can carry precision-guided conventional ordnance in addition to nuclear weapons. The B-52 is the only aircraft that can carry both gravity bombs and cruise missiles.

Figure 3.12 B-52 "Stratofortress"

The B-2 "Stealth Bomber" (Figure 3.13) entered the bomber 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 3.13 B-2 "Stealth Bomber"

The United States has 76 B-52 bombers and 18 B-2 bombers certified to deliver nuclear weapons. The 2010 NPR determined that the Air Force will retain nuclear-capable bombers, but it will convert some B-52s to a conventional-only role. The rationale behind retaining nuclear-capable (and dual-capable) bombers is twofold: first, this capability provides a rapid and effective hedge against technical challenges that might affect another leg of the triad and offsets the risks of geopolitical uncertainties; second, 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.

Dual-Capable Aircraft

In addition to its strategic nuclear forces, the United States has CONUS-based and forward-deployed DCA consisting of the F-15 (Figure 3.14) and the F-16 (Figure 3.15). DCA are able to deliver conventional munitions or non-strategic nuclear bombs from the B61 family.

The United States also maintains forward-based DCA assigned to the U.S. European Command. Some of these DCA are available to support the North Atlantic Treaty Organization (NATO) in combined-theatre nuclear operations.

Figure 3.14 F-15

Figure 3.15 F-16

As discussed in the 2010 NPR Report, the Air Force is in the process of replacing its F-16s with the F-35 Joint Strike Fighter. The Air Force will retain a dual-capable fighter in the F-35, and it will also conduct a full scope B61 LEP to ensure that weapon's functionality with the F-35. These decisions ensure that the United States will retain the capability to forward deploy non-strategic nuclear weapons in support of its commitments to its NATO allies.

3.6 Employment of Nuclear Weapons

The primary purpose of the U.S. nuclear force posture 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 weapons. 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 from conventional warfare and involves many considerations. The fundamental determinant of action is the political objective sought in the use of nuclear or other types of forces. Together, these considerations have an impact not only on the decision to use nuclear weapons but also on how they are employed. Other prominent planning and employment factors include: the strategic situation, the type and extent of operations to be conducted, military effectiveness, damage-limitation measures, environmental and ecological impacts, and calculations concerning how such considerations may interact.

3.6.1 Employment Guidelines and Planning Considerations

U.S. warfighters plan for the employment of nuclear weapons in a manner consistent with national policy and strategic guidance.[10] The employment of nuclear weapons must offer a significant advantage over the use of non-nuclear munitions. Moreover, the complete destruction of enemy forces may not be required to achieve a desired objective; rather,

[10] There is no conventional or customary international law that prohibits nations from employing nuclear weapons in armed conflict. Therefore, the use of nuclear weapons against enemy combatants as well as against other military targets is lawful, if authorized by the president.

containment and a demonstrated will to employ additional nuclear weapons toward a specific goal would be the preferred methods.

Planning for the use of nuclear weapons is based upon: knowledge of enemy force strength and disposition; the number, yields, and types of weapons available; and the status and disposition of friendly forces at the time that the weapons are 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 weapon 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) systems are important considerations in nuclear force planning and employment.

3.6.2 Nuclear Weapons Targeting

Targeting is the process of selecting targets and matching the appropriate weapon to those targets by taking account of operational requirements and capabilities. Targeting occurs and is performed at all levels of command within a joint force. 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 purpose through delaying, disrupting, disabling, or destroying critical enemy forces or resources.

Targeting considerations include:

- The inability of friendly forces to destroy targets using conventional 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 opponent's ability to reconstitute or regenerate;
- Avoidance of collateral damage; and
- Environmental conditions in the target vicinity including surface, upper air, and space conditions.

As reinforced in the 2010 Nuclear Posture Review Report, all U.S. ICBMs and SLBMs are "open-ocean targeted" so that, in the highly unlikely event of an accidental launch, the missile would land in the open ocean.

3.7 Summary

While the United States has developed dozens of warhead-types and produced tens of thousands of weapons since the first atomic bomb explosion in 1945, the current stockpile has been drastically reduced—through unilateral and bilateral efforts—to its current size (5,113 warheads as of September 30, 2009). The composition of the existing U.S. nuclear stockpile is in part determined by the fact that no new U.S. nuclear weapons have been produced since 1991. Today's stockpile is composed of nuclear warheads that are carried to their targets by one of a system of delivery vehicles that together comprise a sea, land, and air deterrent. The 2010 NPR concluded that this "nuclear triad" will be maintained into the foreseeable future, even as the United States continues to draw down its nuclear weapon stockpile in accordance with its treaty obligations and its stated intent to pursue a world free of nuclear weapons.

Chapter 4
Nuclear Command, Control, and Communications System

4.1 Overview

The U.S. nuclear command, control, and communications system refers to the 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 to be made based on relevant information and subsequently allow for those decisions to be communicated to forces for execution.[1] The nuclear C3 (NC3) system 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 purpose of the nuclear C3 system is to provide the president with the means to authorize the use of nuclear weapons in a crisis and to prevent unauthorized or accidental use. The former is accomplished through the assets of the nuclear C3 system, managed by the Military Services, nuclear force

[1] The Nuclear Command and Control System is made possible through the cooperation of multiple departments and agencies within the United States Government; this chapter focuses on the Department of Defense-related portion of the system, hereafter referred to as the *nuclear C3 system*.

commanders, and the defense agencies. (For more information on the prevention of unauthorized or accidental use, see Chapter 5: *Nuclear Safety and Security*.)

4.2 Nuclear Command and Control

Nuclear command and control (C2)—or the exercise of authority and direction by the president through established command lines over nuclear weapons operations, as the Chief Executive over all nuclear weapon activities that support those operations, and as the Head of State over required multinational actions that support those operations—is provided through a survivable "thin line" of communications and warning systems that ensure dedicated connectivity from the president to all nuclear-capable forces. The fundamental requirements of nuclear C2 are paramount; nuclear C2 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 full nuclear C3 system.

The president's ability to exercise these authorities is ensured by the Nuclear Command and Control System (NCCS)—the facilities, equipment, communications, procedures, and personnel that are essential for supporting the president's nuclear C2. The NCCS is an interagency system that includes stakeholders from the White House, the Department of Defense (DoD), the Department of State (DOS), the Department of Homeland Security (DHS), the Department of Justice (DOJ)/Federal Bureau of Investigation (FBI), the Department of Energy (DOE), and the Director of National Intelligence (DNI).

The DoD has been directed to ensure that the C2 architecture for the nuclear deterrent can serve as the core component of a broader *national* command, control, communications, computers, and intelligence system supporting the president. Because the NCCS is an interagency system, this chapter will use the term *nuclear C3 system* to refer to the DoD portion of the NCCS that would be used in responding to a nuclear crisis.[2]

4.3 Nuclear C3 Requirements, Functions, and Elements

National Security Presidential Directive (NSPD)-28, *United States Nuclear Weapons Command and Control, Safety, and Security*, is the authoritative source for NC3 requirements.

[2] The nuclear C3 system can also prove critical for U.S. response to other significant national events, such as 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.

The requirements have been translated into the functions that the nuclear C3 system must support: nuclear force planning; situation monitoring, including an integrated tactical warning and attack assessment of bomber threats and missile launches; senior leader decision making; dissemination of presidential force-direction orders; and management of geographically dispersed forces. Many factors—both current and future projections—can influence presidential decision making. Thus, the command elements of the nuclear C3 system must maintain constant awareness of world events, both through classified means—usually through access to national intelligence systems and other sensors—and from open sources such as cable news stations, weather forecasts, and other government sources.

The elements of the supporting NCCS provide the means to perform the functions of nuclear C3 for the president and his senior advisors in a nuclear crisis.

4.3.1 Nuclear C3 Requirements

There are a host of nuclear C3 requirements stated in national and DoD policy; among these are the requirements that nuclear C3 must be reliable, assured, enduring, redundant, unambiguous, survivable, secure, timely, flexible, and accurate. These requirements have been translated into specific, measurable, and testable criteria by which to evaluate the performance of the nuclear C3 system through exercise, testing, and analysis.

Two requirements have recently received additional attention as a result of new policy. The first mandates that mission-critical nuclear C3 system facilities and equipment must be built to resist ("hardened" against) the effects of a nuclear explosion, especially electromagnetic pulse (EMP), which can interrupt or destroy sensitive electronics. (See Appendix F: *The Effects of Nuclear Weapons*, for more information about nuclear effects.)

> *There exist five nuclear C3 functions that encompass all of the nuclear C3 activities performed by DoD personnel as they carry out their assigned military missions: force management, planning, situation monitoring, decision making, and force direction.*

The second requirement directs the progression to modern systems capable of operating on internet-like networks that provide survivable, reliable support for senior U.S. Government officials, the U.S. military, and allies, as appropriate. While the implications and applicability of this policy—referred to as *net-enabled* or *net-centric*—are being considered, it is still necessary to protect critical information and information systems against cyber attack or network intrusion.

4.3.2 Nuclear C3 Functions

There exist five nuclear C3 functions that encompass all of the nuclear C3 activities performed by DoD personnel as they carry out their assigned military missions: force management, planning, situation monitoring, decision making, and force direction.

Force Management

Force management includes the assignment, training, deployment, maintenance, and logistic 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 to respond quickly to any contingency, a necessary condition given the rapid 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 "open" sources.

Decision Making

Decision making refers to the assessment, review, and consultation that occurs when the employment or movement of nuclear weapons is considered for the execution of other nuclear control orders. This function relies on time-critical secure phone (and sometimes 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. It 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 nuclear C3 system. (For more information on nuclear physical security, see Chapter 5: *Nuclear Safety and Security*.)

4.3.3 NCCS Elements

The NCCS is composed of five elements: facilities, equipment, communications, procedures, and personnel. These elements compose the infrastructure that supports the president—through his military commanders—in exercising his authority over U.S. nuclear weapons operations, enabling the performance of the five nuclear C3 functions.

Personnel

NCCS personnel include the operators and maintainers of the facilities, equipment, communications, weapons, and delivery systems.

Procedures

NCCS procedures direct the actions of the people who operate nuclear systems.

Facilities

NCCS facilities are fixed (for example, the National Military Command Center (NMCC)), ground mobile (for example, the tractor trailer-mounted Mobile Consolidated Command Center (MCCC)), and airborne (for example, the E-4B National Airborne Operations Center (NAOC)), a highly modified Boeing 747 aircraft, and the E-6B Take Charge and Move Out (TACAMO)/Airborne Command Post, a highly modified Boeing 707 aircraft.

Figure 4.1
National Military Command Center

The primary nuclear C3 facility is the National Military Command Center (Figure 4.1) located in a shielded room within the Pentagon. The NMCC provides daily support to the president, the secretary of defense, and the Joint Chiefs of Staff, allowing for the monitoring of nuclear forces and ongoing conventional military operations.

In a crisis situation, the Alternate National Military Command Center (ANMCC) (Figure 4.2) can be activated to serve as a fully functional


Figure 4.2 Alternate National Military Command Center

alternate location. The ANMCC is located outside of Washington, D.C.; it is shielded from electronic damage from a nuclear blast and physically protected inside a mountain. The ANMCC is capable of being locked down behind massive blast-hardened doors to operate in a fully self-contained manner for a required period of time. When not fully functional, the ANMCC is minimally staffed. A second backup location to the NMCC is located underneath the United States Strategic Command (USSTRATCOM) Headquarters at Offutt Air Force Base in Nebraska. The USSTRATCOM Global Operations Center (GOC) enables the USSTRATCOM Commander to conduct nuclear C3 while also enabling the day-to-day management of forces and the monitoring of world events.


Figure 4.3
Mobile Consolidated Command Center

The MCCC (Figure 4.3) is a set of trucks that may deploy during a crisis to serve as a survivable road-mobile backup to the NMCC. Its survivability is achieved through mobility, the ability to host large numbers of battle staff and operators, and a diversity of communications capabilities that make it a key element of the overall nuclear C3 system.

Figure 4.4
E-4B National Airborne Operation Center (NAOC)


Figure 4.5 E-6B TACAMO

If fixed command centers are destroyed or incapacitated, several survivable alternatives exist to which nuclear C3 operations can transfer, including the E-4B NAOC and the E-6B (Figures 4.4 and 4.5). A NAOC aircraft is continuously ready to launch within minutes, from even 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, it acts as an airborne backup of the GOC. Because of this role, the E-6B performs two additional key missions: first, as the Airborne Launch Control System, the aircraft has the ability to launch Minuteman III ICBMs as back-up 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. It can deploy a 2½-mile-long trailing wire antenna and communicate directives to the nuclear forces over this survivable radio system, or over other radio or satellite systems.

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.

ITW/AA comprises 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,[3] correlation,[4] warning,[5] and assessment.[6] 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 telephone conference to the president, the secretary of defense, and the chairman of the Joint Chiefs of Staff. The assessment details whether an attack is occurring against North America or U.S. space 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 (commercial and military) sensors to transmit and receive voice, video, or data. The ability to move trusted

[3] *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.

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

[5] *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.

[6] *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.

data and advice from sensors to correlation centers, from presidential advisors to the president, from the president to the National Military Command System (NMCS), and from the NMCS to the nuclear weapons delivery platforms depends on nuclear C3 transport systems (Figure 4.6). These comprise a myriad of terrestrial, airborne, and satellite-based systems ranging in sophistication from the simple telephone, to radio frequency systems, to government and non-government satellites. Some of these systems are expected to be able to operate through nuclear effects, while are expected to be subject to nuclear effect disruption for periods ranging from minutes to hours.[7]

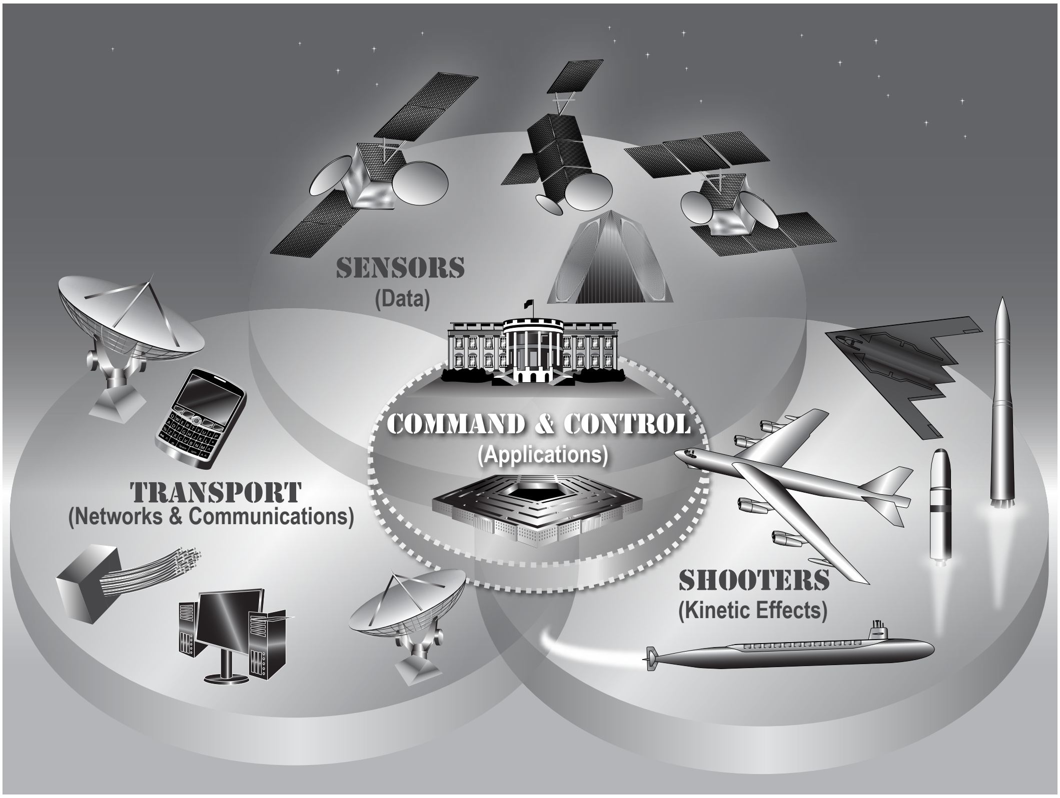

Figure 4.6 Nuclear C3 Transport Systems

[7] As with other critical elements of the nuclear C3 system, even communications systems whose frequency spectrum is expected to be available in a nuclear-affected environment are susceptible to physical effects, including burnout or temporary disruption, due to the effects of a nuclear detonation on their electronic components if they are not hardened against such effects.

4.4 Current U.S. Nuclear C3 Architecture

The present U.S. nuclear C3 architecture can be described in two layers. The first layer is the current day-to-day/crisis architecture, which can also be described as a "thick-line" system. 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 C2 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 chairman of the Joint Chiefs of Staff, and the designated commanders through all threat environments to perform all necessary C2 functions. The "thin-line" C3 architecture must be sustained and supported during any modernization effort to ensure it can meet presidential requirements.

Chapter 5
Nuclear Safety and Security

5.1 Overview

A primary responsibility of the Department of Defense (DoD) and Department of Energy (DOE) stockpile mission is to ensure that 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.

5.2 Dual Agency Surety Responsibilities

The Department of Defense and the Department of Energy, through the National Nuclear Security Administration (NNSA), 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.”

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.

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. The DOE, through the NNSA and the national security laboratories, is responsible for the design, production, assembly, surety technology, disassembly, and dismantlement of U.S. nuclear weapons. The DOE is also responsible for the transportation of weapons to and from the Military First Destination (MFD). There are, however, overlaps in responsibility between the Department of Defense and the Department of Energy, requiring considerable coordination between the two departments regarding surety issues. For example, the DoD and the DOE share responsibility for the interface between the weapon and the delivery system.

5.3 National Security Presidential Directive 28

National Security Presidential Directive 28 (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. NSPD-28 also called for the establishment of the Nuclear Command and Control System (NCCS) Committee of Principals (CoP).

5.3.1 The NCCS CoP

The NCCS CoP was established in 2004, and its membership includes a senior official (i.e., a principal) from each of the following NCCS components:

- White House Military Office
- Department of Defense
- Department of State (DOS)
- Department of Energy, National Nuclear Security Administration
- Department of Homeland Security (DHS)
- Department of Justice (DOJ), Federal Bureau of Investigation (FBI)
- Office of the Director of National Intelligence (DNI)
- National Security Staff (formerly National Security Council)[1]
- Nuclear Support Staff (NSS)[2]
- Nuclear Regulatory Commission (NRC)
- Office of Science and Technology Policy (OSTP)

In 2008, the CoP drafted and approved its first official charter that clarified members' roles and responsibilities under the broader guidance in NSPD-28. In 2009, by direction of the CoP chairman, the charter was revised to add two new voting members to the CoP, the Nuclear Regulatory Commission and the Office of Science and Technology Policy.

In addition to the members listed above, the vice chairman of the Joint Chiefs of Staff and the associate director for National Security Programs at the Office of Management and Budget (OMB) attend NCCS CoP meetings as invited guests.

The NCCS CoP first met in December 2004. CoP meetings are normally held three times per year or at the direction of the presiding chairman, the deputy secretary of defense.

5.3.2 NCCS CoP Responsibilities

NSPD-28 established the NCCS CoP in order to facilitate interagency cooperation and to ensure effective implementation of the NSPD. The NCCS CoP has direct oversight of implementation activities, including:

- Addressing NCCS-related issues applicable to two or more departments or agencies;

1 The National Security Council and the Homeland Security Council were merged in 2009 to create the National Security Staff.

2 As stated in DoD Directive 3150.06, *U.S. Nuclear Command and Control System Support Staff*, the Commander, United States Strategic Command (USSTRATCOM), is designated as the Director of the Nuclear Support Staff.

- Promoting effective liaison among federal government NCCS components;
- Coordinating interdepartmental NCCS supporting programs and policies to ensure unified and integrated management of the NCCS priority objects stated in NSPD-28;
- Recommending priorities for funding;
- Monitoring corrective actions within implementing organizations; and
- Establishing mechanisms to share best practices and lessons learned.

The NCCS CoP provides oversight through the assistance of several committees and subcommittees, including the Deputies Committee, the Action Officers Group, the Nuclear Weapons Accident/Incident Response Subcommittee (NWAIRS), and the Nuclear Weapons Physical Security Subcommittee (NWPSS).

5.4 Nuclear Weapon System Safety

Nuclear weapons systems require special safety considerations because of the weapons' unique destructive power and the potential consequences of an accident or unauthorized act. Therefore, nuclear weapons systems must be protected against risks and threats inherent in both peacetime and wartime environments. Nuclear weapons system safety refers to the collection of positive measures designed to minimize the possibility of a nuclear detonation because of accidents, 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.

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 (i.e., pilot) intervention 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; 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.

5.4.1 DoD and DOE Safety Programs

The objective of the DoD Nuclear Weapon System Safety Program and the DOE Nuclear Explosive and Weapons Surety Program is to prevent accidents and inadvertent or unauthorized use of U.S. nuclear weapons. DoD Safety Standards are promulgated under DoD Directive 3150.2, *DoD Nuclear Weapons System Safety Program*. The DOE revised its standards to emphasize its responsibilities for nuclear explosive operations in 2005 with DOE Order 452.1C, *Nuclear Explosive and Weapons Surety Program*. Although the operating environments differ significantly, DoD and DOE standards share many similarities. Figure 5.1 compares DoD nuclear weapons system safety standards with DOE nuclear explosive surety standards.

The 4 DoD Nuclear Weapon System Safety 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 5 DOE Nuclear Explosive Surety Standards

There must be controls to...

1. Minimize the possibility of accidents, inadvertent acts, or authorized activities that could lead to fire, high-explosive deflagration, or unintended high-explosive detonation.
2. Minimize the possibility of fire, high-explosive deflagration, or high-explosive detonation, given accidents or inadvertent acts.
3. Minimize the possibility of deliberate unauthorized acts that could lead to high-explosive deflagration or high-explosive detonation.
4. Ensure adequate security of nuclear explosives.
5. Minimize the possibility of or delay unauthorized nuclear detonation.

Figure 5.1 Comparison of DoD Nuclear Weapon System Safety Standards with DOE Nuclear Explosive Surety Standards

5.4.2 Nuclear Weapon Design Safety

Modern nuclear weapons incorporate a number of safety design features. These features provide an extremely high assurance that an accident, or other abnormal environment, will not produce a nuclear detonation. They 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. All legacy warheads, however, 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 expected 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 -180 to +155 degrees Fahrenheit, a force of 10G set-back upon missile launch, or shock from an impact of a container being dropped from a height of up to two inches.

Abnormal environments are the expected logistical and operational environments, as defined in a weapon's MCs and STS documents, in which the weapon is not expected to retain full operational reliability. Abnormal environments include conditions not expected in normal logistical or operational situations but which 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 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 modern weapons, the firing system forms a key part of detonation safety implementation. The goal of nuclear safety design is to prevent inadvertent detonation 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 that nuclear safety is achieved in an abnormal environment despite the appearance of premature signals at the input of the special region. Figure 5.2 illustrates this modern nuclear safety architecture.

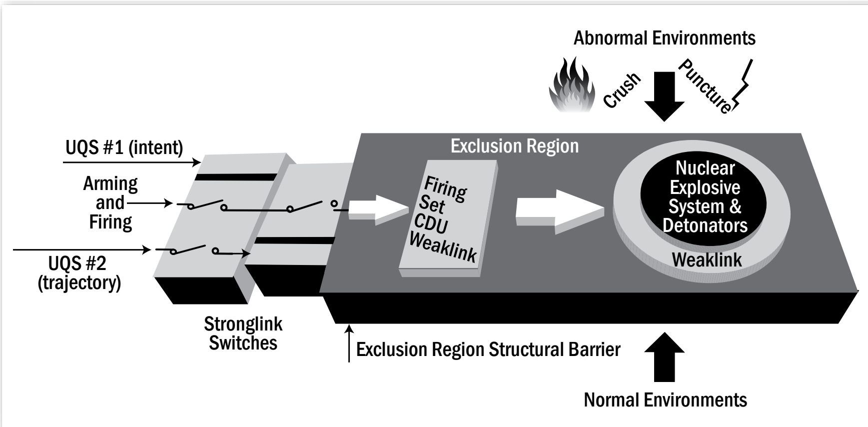

Figure 5.2 Modern Nuclear Safety Architecture

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 fireset 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 unique signal for the intent stronglink cannot be stored in the weapon and must be entered by a human being. The pattern for the trajectory stronglink is frequently stored in a device known as a trajectory-sensing signal generator (TSSG).

There are four principal safety themes for nuclear weapons: isolation, incompatibility, inoperability, and independence. The stronglink plays an important role in all four themes.

Isolation

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

The barrier is not perfect, and 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. 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. The stronglink provides the energy gateway.

Incompatibility

It is critical to ensure that only a deliberate act opens the shutter; 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 specific pattern of a specific number of long and short electrical pulses, which must also be in the correct sequence. This is the only signal that will activate the stronglink; any other pattern is incompatible. An incompatible pattern will cause the switch to lock up and remain in a safe condition. Figure 5.3 illustrates the concept of incompatibility.

Each stronglink contains one pattern and can only be operated by the application of its unique pattern. Stronglink patterns are analyzed for their uniqueness to ensure they are incompatible with naturally occurring signals; stronglinks are engineered so that the

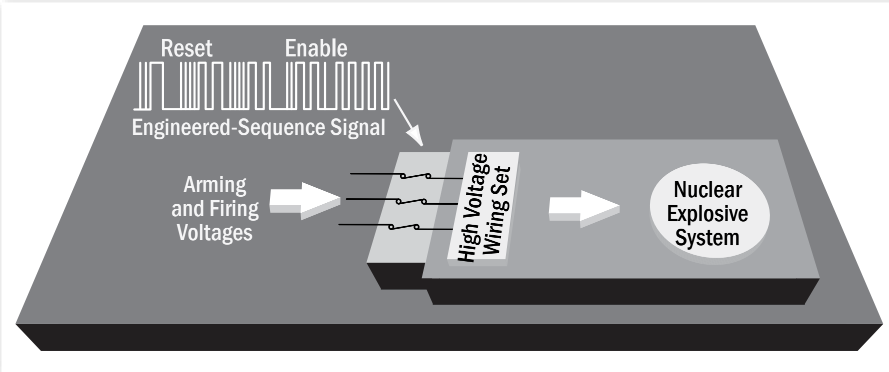

Figure 5.3 Incompatibility

odds of their accidental generation from a naturally occurring source are far less than one chance in a million.

Inoperability

At some level of exposure to an abnormal environment, the energy from the surroundings becomes so intense the barrier loses integrity, and the barrier 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. Ideally, the weaklinks are co-located with the stronglink so that both components experience the same environmental assault. Figure 5.4 is a diagram of the concept of inoperability.

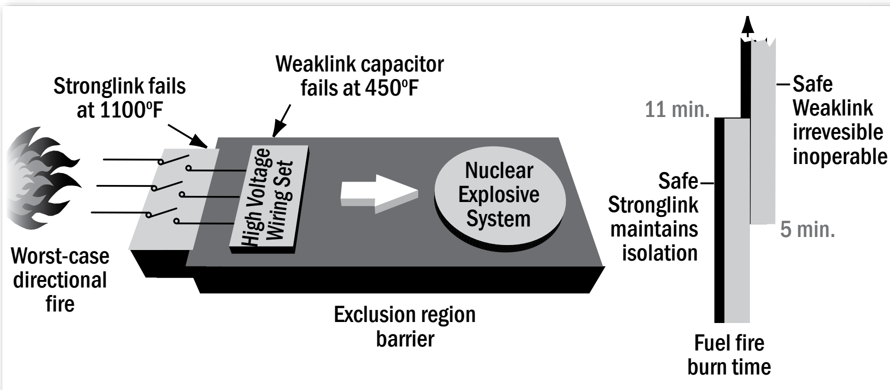

Figure 5.4 Inoperability

Independence

Typically, two different stronglinks are used per weapon. Different stronglinks with different patterns are used to gain independence and to provide the required assurance of safety. With independent stronglinks, a design flaw may cause the first stronglink to fail, but the second stronglink will still protect the weapon.

Insensitive High Explosive

Another feature of nuclear weapons design safety is the use of insensitive high explosive (IHE) as opposed to conventional high explosive. IHE is much less sensitive to shock or heat; it is highly resistant to accidental detonation and represents a great advance in safety by reducing the likelihood of plutonium scatter.

Fire-Resistant Pit

A third 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.

5.5 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 prevent loss or damage. These measures include department nuclear security policy; security forces; equipment; technology; tactics, techniques, and procedures (TTPs); and personnel security standards. Ensuring security is vital throughout the entire life-cycle of a weapon.

Nuclear weapons security is essential for both the Department of Defense and the Department of Energy. Each department is responsible for providing appropriate security for all nuclear weapons in its custody. Custody is defined as the responsibility for controlling the transfer, movement, and access to a nuclear weapon or its components.

5.5.1 DoD Nuclear Weapons Security Standard

DoD Directive O-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 custody; 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 access, commanders must take any and all actions necessary to regain control of nuclear weapons immediately."

> *. . . the five "Ds" of nuclear security: deter, detect, delay, deny, and defeat.*

The central and overriding objective of nuclear weapons security is *denial* of unauthorized access. This is accomplished by employing an integrated, defense-in-depth concept that leverages five distinct security capabilities. These security system capabilities are commonly referred to as the five "Ds" of nuclear security: deter, detect, delay, deny, and defeat. Together, the security capabilities support the NWSS. 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, TTPs, and an aggressive counterintelligence program.

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

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

Security forces must incorporate capabilities to *deny* adversaries unauthorized access to nuclear weapons. Denial can be achieved through technological means (lethal or non-lethal) or by creating adversarial duress sufficient to prevent unauthorized access. If denial fails, however, security forces and systems must be capable of *defeating* a hostile adversary and immediately regaining custody of the nuclear weapon.

The DoD has a program called Mighty Guardian (MG) that is designed to ensure that 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 and identify its failure points. MG results are used to identify shortfalls and improvements in 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 that security capabilities are adequate to meet the NWSS.

5.5.2 DOE Safeguards and Security

The Department of Energy has programs similar to those of the Department of Defense to ensure the physical security of nuclear weapons and special nuclear materials in transport and at NNSA locations and laboratories. Like the DoD, the DOE—through the NNSA—is evaluating its future security capabilities in concert with its plans for the future of the Nuclear Security Enterprise to ensure that adequate security is provided to meet identified threats. (For more information on the Nuclear Security Enterprise, see Chapter 7: *U.S. Nuclear Infrastructure*.)

5.5.3 DoD and DOE Personnel Security

Both the DoD and the DOE have programs in place to ensure that personnel assigned to nuclear weapons-related duties are trustworthy. Both the DoD Personnel Reliability Program (PRP) and the DOE Human Reliability Program (HRP) ensure that personnel are reliable and possess the necessary judgment to work with nuclear weapons. Unescorted access to nuclear weapons is limited to those who are PRP- or HRP-certified.

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 individual's loyalty, integrity, trustworthiness, and behavior. 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, or who control access to, nuclear weapons. Personnel positions associated with nuclear weapons are designated as either critical or controlled depending on the degree of physical access to nuclear weapons and the technical knowledge required by the person in that position. The DOE HRP, similar to the DoD PRP, is designed to ensure that 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 the following:

- a personal security investigation and the granting of a security clearance;

- a medical evaluation to determine the physical and mental fitness of the individual;
- a review of the individual's personnel file and any other locally available information concerning behavior that may be relevant;
- a proficiency qualification process designed to certify that the individual has the training and experience necessary to perform the assigned duties; and
- a personal interview to ascertain the individual's attitude toward the reliability program.

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

Once a person begins to perform duties in a DoD PRP or DOE HRP position, that individual is periodically evaluated to ensure continued conformity to reliability standards. Any information raising questions about an individual's judgment or reliability is subject to review. For example, whenever a prescription drug is prescribed to a PRP-certified individual, depending on the effects of the particular medication, that person might be temporarily suspended from nuclear weapons-related duty. Personnel who cannot meet the standards are eliminated from the program and relieved of their nuclear weapons-related responsibilities.

The first and 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.

5.5.4 Procedural Security

The first and 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. Each person is required to be capable of detecting incorrect or unauthorized actions pertaining to the task being performed. Additionally, restricted entry to certain sectors and exclusion areas based on strict need-to-know criteria reduces the possibility of unauthorized access.

5.5.5 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 forward deployed in other countries, the United States has established Programs of Cooperation (POCs) to delineate the duties and responsibilities involved in the weapons' deployment.

DoD Security Program Authorities

DoD policies and procedures for nuclear weapons security are found in DoD Directives and Manuals. They are designed to guard against threats to the security of U.S. nuclear weapons.

DoD Directive O-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.

DoD Directive 5210.42, *Nuclear Weapons Personnel Reliability Program*, provides the specific guidance needed to implement the DoD PRP.

DoD Instruction 5210.63, *DoD Procedures for Security of Nuclear Reactors and Special Nuclear Materials (SNM)*, directs policy, responsibilities, procedures, and minimum standards for safeguarding DoD nuclear reactors and special nuclear material.

DoD Manual S-5210.92, *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.

DoD Directive 3224.3, *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

Several DOE Regulations and Orders address the security of nuclear weapons.

DOE Order 452.1C, *Nuclear Explosive and Weapon Surety Program*, outlines the Nuclear Explosive and Weapon Surety (NEWS) Program and the five DOE surety standards.

DOE Order 470.1, *Safeguards and Security Program*, outlines the DOE Safeguards and Security Program, which provides the basis for security for all NNSA activities related to nuclear weapons.

10 CFR Part 712, *Human Reliability Program*, establishes the policies and procedures for the Human Reliability Program in the DOE, including the NNSA. This document consolidates

and supersedes two former programs, the *Personnel Assurance Program* and the *Personnel Security Assurance Program*.

DOE Order 452.2C, *Nuclear Explosive Safety*, addresses security regarding the safety of NNSA nuclear explosive operations.

5.6 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. Figure 5.5 shows a nuclear consent switch, one of several use control features. Not all use control features are installed on every weapon system.

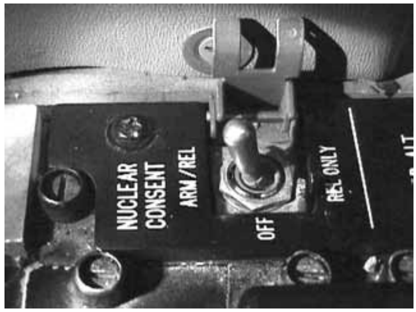

Figure 5..5
Nuclear Consent Switch

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 launch a missile. Similarly, 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 discussed above.

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. It is not installed on all weapons systems.

Environmental Sensing Device

The environmental sensing device 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. Accelerometers are commonly employed for this purpose.

Figure 5.6
Entering a Code into a Bomb

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 that can activate components within the weapon or weapon system. Most modern U.S. PAL systems include a multiple-code coded switch (MCCS) component. Figure 5.6 shows an individual entering a PAL authorization code into a bomb.

5.6.1 The DoD Use Control Program

The DoD has broad responsibilities in the area of nuclear weapons use control. DoD Directive S-3150.7, *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.

5.6.2 The NNSA Use Control Program

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

- use control measures for nuclear explosives and nuclear weapons, including design features that are 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 NNSA program includes 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 NNSA conducts research and development on a broad range of use control methods and devices for nuclear weapons. It assists the DoD in developing, implementing, and maintaining plans, procedures, and capabilities to store and move nuclear weapons. The 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 6
Countering Nuclear Threats

6.1 Overview

At the end of the Cold War there was great hope that the fall of the Soviet Union would herald a new era of peace and security and end the fears of global thermonuclear war. To some extent, this vision has materialized insofar as the threat of global nuclear war has been greatly diminished, and the U.S. relationship with Russia can no longer be characterized as adversarial. Unfortunately, with the reduced risk of strategic nuclear exchange have come the twin scourges of nuclear terrorism and nuclear proliferation. The uncertainty of a world with an increasing number of nuclear players has replaced the relative stability of a bipolar balance. The rational actor model of bipolarity has been supplanted by the knowledge that there are state and non-state actors whose risk calculations dictate that a nuclear attack against the United States, its allies, partners, or interests would be worth any cost to themselves.

> *"We must ensure that terrorists never acquire a nuclear weapon. This is the most immediate and extreme threat to global security."*
>
> *President Barack Obama*
> *April 5, 2009*

The threat, as President Obama stated in his April 2009 speech in Prague, is "immediate and extreme." Terrorist groups have declared their intent to purchase, steal, or otherwise obtain nuclear materials to create a nuclear threat device (NTD), which can be anything from a crude, homemade nuclear device, to an improvised nuclear device (IND) or radiological dispersal or exposure device (RDD or RED), to a weapon from one of the established nuclear states that has fallen out of state control.[1]

6.2 CNT Efforts

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 bringing the perpetrators to justice.

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 achieved through unconventional means, regardless of origin. Failing successful prevention of a radiological or nuclear incident, CNT also includes activities to manage the consequences of a radiological or nuclear incident and to support the attribution of the source. Prevention and protection activities encompass those actions and programs that take place prior to detonation, while response activities are those actions and programs that prepare for post-detonation response.

CNT efforts are diverse, with a broad scope of activities and tasks that require the involvement of many agencies within the federal government. 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 gaining new visibility as the threat of nuclear terrorism continues to emerge. New capabilities and structures throughout the United States Government are required to address this evolving paradigm.

The goal of the CNT mission is to counter all nuclear threats, from the most crudely developed devices to state-built weapons that have fallen out of state control (i.e., weapons or nuclear components that have been lost or stolen). The CNT mission requires a whole-

[1] An IND is built from components of a stolen state-built nuclear weapon or from scratch by a non-state organization using nuclear material to produce a nuclear explosion. An IND may create an extremely destructive nuclear explosion with very high radiation levels. An IND differs from an RDD, which simply disperses radioactive material. A radiological exposure device is designed to expose people to ionizing radiation over a period of time.

of-government approach; the Department of Defense (DoD), the Department of Homeland Security (DHS), the Department of Energy (DOE), the Department of State (DOS), the Federal Bureau of Investigation (FBI), the Intelligence Community (IC), and other departments and agencies have roles in addressing the nuclear and radiological threat. Additionally, the CNT mission is international in scope, and the United States works with multiple international partners to reduce the nuclear threat.

The goal of the CNT mission is to counter all nuclear threats across the proliferation spectrum, from the most crudely developed devices to state-built nuclear weapons that have fallen out of state control.

6.3 Nuclear Event Pathways

There are a number of generic steps that must be achieved for a potential attacker to be successful in carrying out an attack. These "nuclear event pathway" steps are illustrated in Figure 6.1. Terrorists do not share the same goals or need the same capabilities as governments. For a nuclear threat device, *any* yield production would be a success, so low yield and unpredictable devices might be satisfactory. Weight and size constraints may not be important to a terrorist, so crude designs that are not militarized could be good enough. Unsafe designs are acceptable, as are hazardous materials and dose rates. Finally, a wide variety of delivery methods could be used.

Figure 6.1 Nuclear Event Pathway

A potential attacker begins with motivation and planning—the intent to attack and the plan to do so. A second step is the acquisition of nuclear materials (or nuclear components or a device); this is the most difficult of the steps on the nuclear event pathway, *making access to fissile material the key to a terrorist's success.*

Today, it is estimated that there is enough weapons-usable nuclear material in the world to build more than 120,000 nuclear bombs. Much of this material remains unprotected, in spite of the fact that there have been repeated attempts by terrorists to acquire this type of material for use in a nuclear device. Securing weapons-usable nuclear material is the best way to prevent nuclear terrorism; this prevents terrorists from acquiring the one part of the bomb they cannot make themselves.

In April 2010, to highlight the urgency of these issues and identify an effective path forward, the United States hosted a Nuclear Security Summit in Washington, D.C. 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 come to a common understanding of the threat posed by nuclear terrorism, to agree to effective measures to secure nuclear material, and to prevent nuclear smuggling and terrorism. The summit resulted in a number of concrete steps to secure nuclear material worldwide, and plans have been initiated to hold a second summit in the Republic of Korea in 2012.

Acquiring nuclear materials or a nuclear device is not the last step on the nuclear event pathway, although it is arguably the most difficult for a terrorist (or potential proliferator) to accomplish. Following the acquisition of materials, a potential attacker must design and fabricate a nuclear threat device (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 (or dispersal or exposure). There are difficulties associated with every step along this pathway, and there are specific indicators, or "tells," at each step that can facilitate the detection and interdiction of a nuclear threat device or, failing that, the rendering of the device safe or unusable if it gets to the target, thereby responding effectively to the emergency. Finding and correctly interpreting these "tells" are the focus of the CNT mission in its work prior to a detonation. In a post-detonation environment, the focus of the CNT mission shifts to consequence management, nuclear forensics, and ultimately, attribution.

At each step along the pathway, a potential attacker must be successful; failure at any point results in the overall failure of the objective and, conversely, success in prevention. Therefore, efforts to counter the nuclear threat must only succeed in thwarting a potential attacker 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 still effective steps to be taken to manage the consequences of such an event and prosecute the perpetrators. The ability to mitigate the damage and accurately attribute the event to those responsible can be a powerful deterrent to an attack.

This spectrum of CNT activities is illustrated in Figure 6.2; the figure highlights activities that begin well before a potential nuclear event. Materials security, including the efforts embodied by the 2010 Nuclear Security Summit, is the first step in preventing nuclear terrorism and nuclear proliferation. To prevent terrorist acquisition of nuclear materials, President Obama called for the attainment—by 2014—of a "lockdown" of all "loose" global

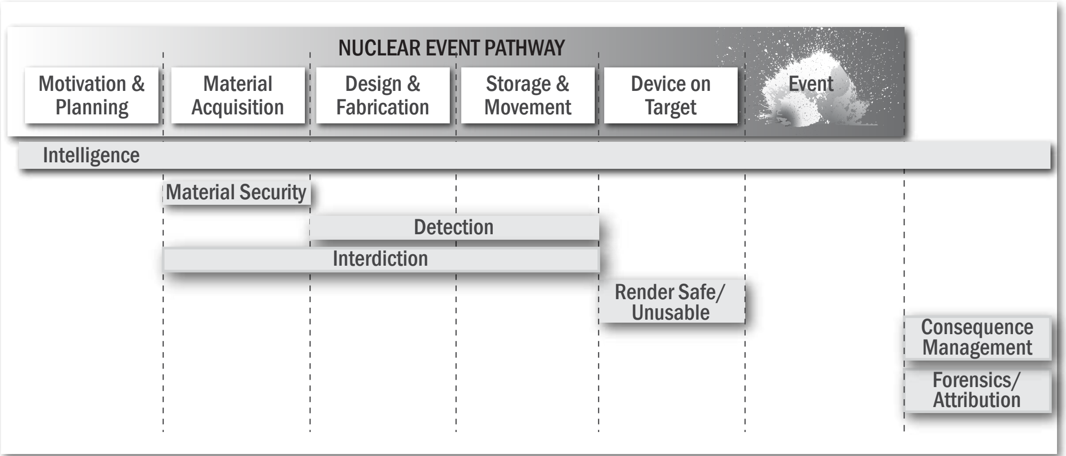

Figure 6.2 The Spectrum of CNT Activities

nuclear material. In addition to these efforts is the continued need to scrutinize and modify the nuclear fuel cycle to ensure that the production of weapons-usable materials is extremely limited by instituting new processes and procedures that minimize the risks inherent in the use of nuclear power for peaceful purposes.

6.4 Understanding the Threat

Figure 6.3 illustrates the nuclear threat device spectrum, highlighting the uncertainty involved with identifying specific nuclear threat devices: what the device is made of, how it is configured, and how it might work (whether it will produce a nuclear yield). As a result, there is no fixed set of NTD concepts or designs; knowledge and understanding of NTD possibilities continue to evolve. NTDs can be developed from a variety of materials and can be configured crudely and simply or with higher levels of complexity and sophistication. Generally, the cruder the device, the more nuclear material it requires, even to achieve a

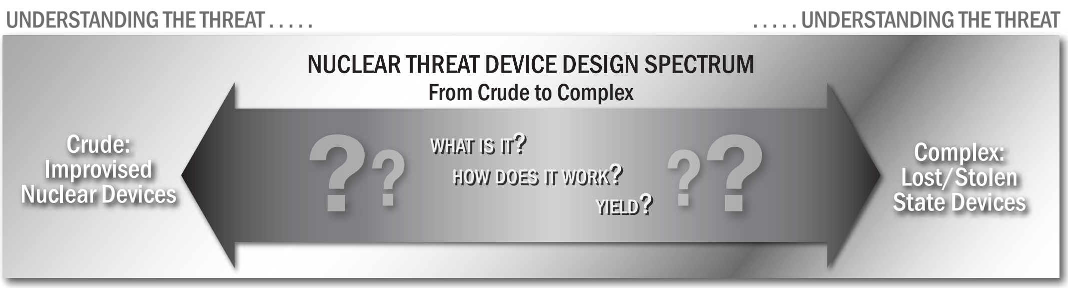

Figure 6.3 The Nuclear Threat Device Spectrum

very low yield. Also, a crude device would tend to be large and bulky. More sophisticated designs tend to be smaller and lighter and achieve greater yield in relation to the mass of the special nuclear material.

The uncertainties associated with NTDs directly impact the ability to detect, interdict, and render a device safe and/or unusable, as well as post-detonation nuclear forensics and attribution efforts. Understanding the threat affects the entire continuum of CNT activities. This knowledge could mean the difference between success and failure in preventing a nuclear detonation. It is imperative that the United States continue its work to understand and characterize the full range of potential nuclear threat devices, including the characterization of nuclear and explosive materials and configurations. Figure 6.4 illustrates the importance of having a sound scientific and technical understanding of a full range of NTD designs to underpin the success of all activities on the CNT spectrum.

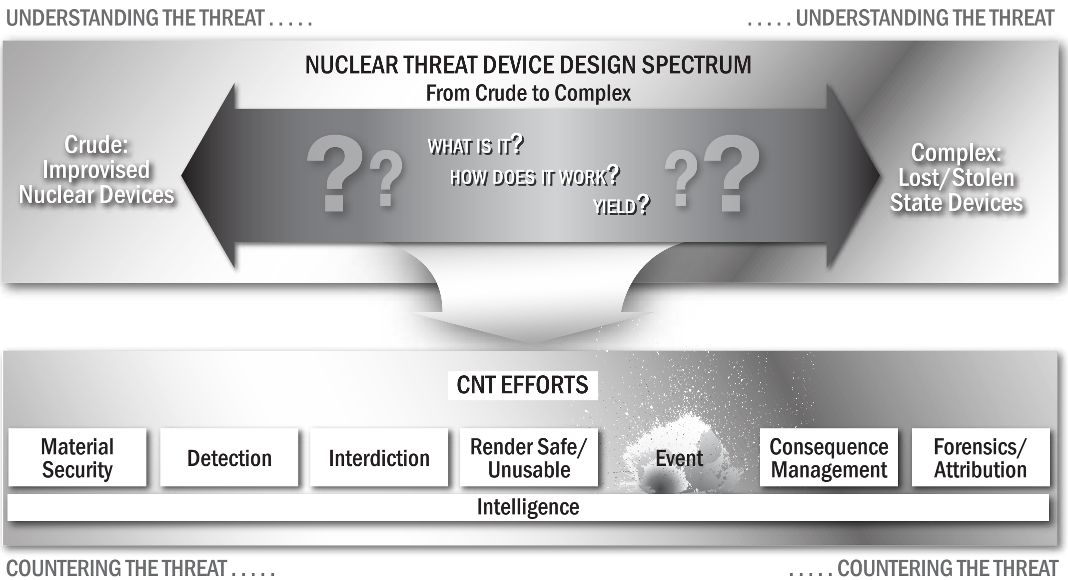

Figure 6.4 Understanding the Threat

To further the scientific and technical understanding of NTDs, the National Nuclear Security Administration (NNSA) works with U.S. and international partners to perform nuclear and explosive materials characterization, device modeling, and simulation analyses; 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 that facilitate nuclear device vulnerability exploitation and thus help to perform render safe/unusable functions in a timely and effective manner.

6.5 Actions to Counter the Nuclear Threat

Various departments and agencies within the U.S. government and in the international arena continue their efforts to understand and characterize the threat to inform the work that is being done to address those aspects of the nuclear event pathway spectrum discussed above. Efforts in these areas have been divided into the following categories: material security, detection, interdiction, render safe, consequence management, nuclear forensics, and attribution.

6.5.1 Material Security

It is estimated that there are 1,600 metric tons of highly enriched uranium and 500 metric tons of plutonium around the globe, and these stockpiles are growing. These materials are located at hundreds of sites worldwide. A single breach at one of these locations could have an impact that would profoundly change the way the world sees and addresses nuclear terrorism today. In the early 1990s, it became clear that a harmonized, global effort was needed to safeguard nuclear materials. There have been multiple collaborations among countries to ensure the threat of nuclear terrorism will not be realized and that, in time, the threat will be eliminated.

One such example of collaboration between states is the Material Protection, Control, and Accounting (MPC&A) program between the United States and Russia. The program provides improved security and material accounting for former Russian sites that house radiological materials. The United States has provided funding for the program and hopes that it will serve as a template for future programs that may be initiated with other countries. The ultimate goal of the program is to improve global nuclear security and ensure that radiological sources are not accessible to terrorists or proliferators.

Under the auspices of the Cooperative Threat Reduction (CTR) Act, the United States and Russia worked to build the Mayak Storage Facility in Russia. The facility was built to enhance security for nuclear material recovered from dismantled nuclear warheads in Russia. With space to permanently store 50,000 containers of weapons-grade plutonium from 12,500 dismantled nuclear warheads, the Mayak facility demonstrates a significant achievement in the reduction of the Russian nuclear stockpile and the increase in security for nuclear materials. The United States helped with the construction and funding of the facility and has made similar efforts with other countries.

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 combat the global threat of nuclear terrorism. Currently, there are 82 countries involved in the initiative. Together, members work to implement standards in securing nuclear material and methods to secure, detect, and respond to nuclear terrorism incidents.

Domestically, the DoD and DOE are responsible for special nuclear materials and nuclear weapons in their custody. Additionally, the 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 sites, as well as commercial nuclear power facilities operating under the Nuclear Regulatory Commission). This program also requires FBI field offices to develop site-specific incident response plans and to exercise those plans with facility security personnel.

6.5.2 Detection

The radiation detection mission is broad and 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 has a direct correlation to the ease with which the material can be detected. The quantities of interest for nuclear materials can be very small, and some have limited radioactive activity, limiting their detection by passive means. Second, shielding plays a role in the ability to detect radiological materials. All radioactive sources can be shielded to prevent detection. Special nuclear material can, at times, be self-shielding. This means that some types and amounts of radiation will not leak from the innermost portions of the material. Third, the distance between the material and the detector is the final physical attribute limiting the ability to passively detect radiological materials. Nuclear radiation, like other forms of electromagnetic radiation, decreases in intensity with the square of distance.

While radiation detection is difficult, the detection mission is being addressed in an interagency forum to help offset the complexity of the mission. Many departments and agencies are involved in finding solutions to improve detection. For example, the DoD supports multiple missions within the detection arena. As an example, the Office of Naval Research Maritime Weapons of Mass Destruction (WMD) Detection Program explores technologies for tracking, detecting, determining intent, intercepting, deciding on operational options, identifying, engaging, and neutralizing WMD in the maritime domain. The DOE integrated program to prevent and detect nuclear smuggling also plays a significant role in countering possible terrorist activities involving nuclear weapons or devices. The DOE works closely with the DHS, the DoD, the FBI, and others in the interagency community to provide technology support for the detection and interdiction of illicit nuclear material. The DOE also fields teams that are ready to deploy to aid in search activities.

In 2005, the DHS established the Domestic Nuclear Detection Office (DNDO) to manage and improve U.S. capabilities to detect and report unauthorized attempts to import, possess, store, develop, or transport radiological and nuclear material. The DNDO also has the responsibility to coordinate federal efforts to detect and prevent nuclear and radiological terrorism against the United States. In this role, it is responsible for the global nuclear detection architecture. As such, it 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 office is also responsible for monitoring some of the largest U.S. points of entry to ensure illicit radiological materials are not smuggled into the country.

6.5.3 Interdiction

Interdiction includes the seizure of materials or technologies that pose a threat to 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, continue nuclear detection programs, and support technological enablers for these efforts.

For situations within the continental United States, the FBI is the federal lead for the U.S. response. The FBI response is fully coordinated with the DHS and the DOE, and the DoD provides support to each of the civil authorities as requested. This process ensures that the response is integrated and coordinated. The DOE acts as a cooperating federal agency, bringing assets to aid in the overall federal response. The DOE can assist with the search of an asset, and it maintains the ability to aid in tactical operations when requested by the lead federal agency. 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.

6.5.4 Render Safe

The ability to render a weapon safe is understandably complex. Each IND, RDD, and RED is unique; because of this, each requires a unique 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 and take appropriate render safe actions until the weapon is ready for transport. 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, the NNSA, 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 DOE or the DoD. The DoD, the FBI, and the DOE execute training exercises individually and jointly to streamline the render safe process and to build relationships and share technologies across the interagency.

Diagnostics

Diagnostics of a nuclear or radiological weapon will help determine render safe procedures and the weapon's final disposition. Should a detonation occur, post-detonation diagnostics, including prompt diagnostics of signatures and effects immediately after detonation, would aid in attribution efforts.

6.5.5 Consequence Management

To minimize the impact of a nuclear terrorist event, the United States engages in planning activities for post-event consequence management. An event in this case can range from an IND or RDD detonation or the deployment of an RED to a successful render safe of an IND or RDD. 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.

> *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.*

While the FBI is the lead agency for the crisis management response (interdiction), the Federal Emergency Management Agency (FEMA), an agency that resides within the DHS, concurrently works with state, tribal, and local authorities in order to address the responsibilities for consequence management. As the lead agency for consequence management, FEMA manages and coordinates any federal consequence management response in support of state and local governments in accordance with the National Response Framework and the National Incident Management System (NIMS). Additionally, the Homeland Security Act of 2002 requires that specialized DOE emergency response assets fall under DHS operational control when they are deployed in response to a potential nuclear incident in the continental United States.

The DOE serves as a support agency for consequence management operations. The DOE provides scientific and technical personnel and equipment during all aspects of a nuclear/radiological terrorist incident, including consequence management. The DOE capabilities include threat assessment, technical advice, forecasted modeling predictions, radiological medical expertise, and operational support. Deployable DOE scientific technical consequence management assistance and support includes capabilities such as 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 foreign governments.

6.5.6 Nuclear Forensics

Nuclear forensics provides information on interdicted materials and devices before detonation and on debris post-detonation to facilitate the attribution of the event. Attribution is an interagency effort requiring coordination of law enforcement, intelligence, and technical nuclear 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.

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

In the event of the interception of nuclear or radiological material or a device, or after a nuclear or radiological detonation targeting United States interests, the public and leaders will demand information about the incident. 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 nuclear detonation. Nuclear forensics is an integral component of the broader task of attribution, which merges TNF results with traditional law enforcement and intelligence information to identify those responsible for the planned or actual attack.

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

The NTNF program is an interagency mission drawing on capabilities of the Department of Justice (DOJ), the DOE, the DoD, the DHS, the 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 requires nations to act collaboratively, the U.S. Government NTNF community is engaged in a number of activities with foreign partners.

Attribution

Attribution is defined as the capability and process to identify the nature, source, perpetrator, and pathway of an attempted or actual nuclear or radiological attack. This includes rapid and comprehensive coordination of intelligence reporting, law enforcement information, technical 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.

6.6 The Future of CNT

President Obama has offered a vision of a world without nuclear weapons and stated that the most "immediate and extreme" threat to global security today comes from nuclear terrorism and nuclear proliferation. To mitigate these risks and move toward eventual nuclear abolition, nuclear threat reduction efforts and international work to counter nuclear threats must be appropriately informed by a thorough scientific and technological understanding of the full range of nuclear threat devices. Understanding the nuclear threat is the key to nuclear threat reduction.

The goal of preventing or, if prevention fails, 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 scientific and technical knowledge and research and development related to understanding nuclear threat device designs and how these affect all aspects of countering nuclear threats, including: material protection and security, detection, intelligence, interdiction, diagnostics, emergency response/disablement, forensics, and attribution. To accomplish this integration and achieve an effective whole-of-government response to CNT the United States is:

- redoubling efforts to understand the realm of the possible with respect to nuclear threat device design and ensure contingency planning is informed by real-world intelligence and advanced science and technology;
- continuing to advance scientific and technical understanding of nuclear explosive characteristics and configurations;
- enhancing collaboration and cooperation between science and technology efforts, the intelligence community and operational functions;
- integrating emerging science and technical knowledge with intelligence analysis and policy development and promulgation;
- continuing to work closely with international partners to share best practices, offer peer review, and reinforce work being done by individual nations to achieve synergies and increase effectiveness in preventing an attack; and
- continuing to leverage work being done to sustain a safe, secure, and effective deterrent to ensure the availability of capabilities and facilities to support the nuclear counterterrorism mission to understand the "non-stockpile stockpile."

CNT is a very broad spectrum of activities, performed by a wide range of agencies and organizations. CNT is, by definition, an international challenge. 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 7
U.S. Nuclear Infrastructure

7.1 Overview

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

> *"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 Report*

7.2 The Nuclear Security Enterprise

In partnership with the DoD, the NNSA provides the research, development, production, and dismantlement capabilities necessary to support the U.S. nuclear weapons stockpile. The NNSA also manages the physical infrastructure required to maintain those capabilities. The NNSA Nuclear Security Enterprise (NSE) spans eight sites, including three national laboratories. These sites are:

- Manufacturing sites: Kansas City Plant, Kansas City, Missouri; Pantex Plant, Amarillo, Texas; Savannah River Site, Aiken, South Carolina; and Y-12 National Security Complex, Oak Ridge, Tennessee
- Test site: Nevada National Security Site, Nevada[1]
- National laboratories: Lawrence Livermore National Laboratory, Livermore, California; Los Alamos National Laboratory, Los Alamos, New Mexico; and Sandia National Laboratories, Livermore, California and Albuquerque, New Mexico

Each site within the Nuclear Security Enterprise provides a unique contribution to ensure the safety, security, and effectiveness of the U.S. nuclear deterrent, as well as to support U.S. nuclear counterterrorism and counterproliferation missions.

All of the NNSA Nuclear Security Enterprise sites are government owned, contractor operated (GOCO). This status indicates that the facility, while owned by the United States Government, is managed and operated through a contract between the NNSA and a contractor selected by NNSA through a competitive bid process.

The facilities of the NNSA Nuclear Security Enterprise are primarily focused on supporting the U.S. nuclear weapons stockpile mission. Additionally, however, the NNSA Nuclear Counterterrorism and Nonproliferation programs utilize the key expertise and many of the facilities originally developed for the U.S. nuclear weapon mission. The associated facilities and infrastructure are managed and funded solely by the nuclear weapon program. Proposed infrastructure downsizing, modernization, and recapitalization efforts are optimized around the future needs of a reduced capacity weapons complex. Future infrastructure decisions may greatly affect the Nuclear Counterterrorism and Nonproliferation programs' capability while not necessarily reflecting their needs. NNSA leadership is working to resolve these issues and determine the best path forward to account for competing requirements in a cost- and resource-constrained environment.

KANSAS CITY PLANT

7.2.1 Kansas City Plant

The Kansas City Plant (KCP), established in 1949, is the primary entity responsible for the procurement and manufacturing

[1] On August 23, 2010, the NNSA announced a new name for what was previously called the Nevada Test Site (NTS). The new name reflects the diversity of nuclear, energy, and homeland security activities being conducted at the site.

of non-nuclear components for nuclear weapons. These include electrical, electronic, electromechanical, plastic, and nonfissionable metal components. The Kansas City Plant is also responsible for evaluating and testing non-nuclear weapon components.

In its non-nuclear component manufacturing role in support of the NNSA, the KCP receives product requirements from headquarters and designs from the national laboratories, procures the necessary supplies, and produces components and systems for other Nuclear Security Enterprise sites and the United States military.

The Kansas City Plant is managed and operated by Honeywell Federal Manufacturing & Technologies. It is currently located in the Bannister Road Facility in Kansas City, Missouri. As part of NNSA efforts to modernize and sustain critical physical infrastructure, a new non-nuclear components production facility for the KCP is under construction; this effort, part of the Kansas City Responsive Infrastructure Manufacturing and Sourcing (KCRIMS) initiative, is expected to be operational in the 2014 timeframe. The KCRIMS initiative is expected to reduce the Kansas City Plant's operating footprint by over 50 percent.

7.2.2 Pantex Plant

BWXT Pantex

The Pantex Plant (PX) is charged with supporting three main missions: stockpile stewardship, nonproliferation, and safeguards and security. In support of the stockpile stewardship mission, Pantex is responsible for the evaluation, retrofit, and repair of weapons 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 its role in support of the nonproliferation mission, the plant 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 Babcock & Wilcox Technical Services Pantex, LLC or B&W Pantex. The plant originally opened for nuclear weapons, high explosive, and non-nuclear component assembly operations in 1951.

7.2.3 Savannah River Site

SRS

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).

(For more information on the NWSP, see Chapter 2: *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 formed by the Fluor Corporation with Northrop Grumman and Honeywell and subcontractors Lockheed Martin and Nuclear Fuel Services.

7.2.4 Y-12 National Security Complex

The Y-12 National Security Complex is located in Oak Ridge, Tennessee. In support of the NNSA, the Y-12 mission focuses on the production or rework 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.

The Y-12 National Security Complex is managed and operated by Babcock & Wilcox Technical Services Y-12, LLC or B&W Y-12. As part of the Y-12 Infrastructure Reduction program, in March 2010, the Highly Enriched Uranium Materials Facility (HEUMF) began operations; 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 an approximately 350, 000 square foot Uranium Processing Facility (UPF) that is intended to replace and consolidate approximately 800,000 square feet of highly enriched uranium production capabilities. Construction is expected to be completed by year 2020.

7.2.5 Nevada National Security Site

Historically, the Nevada National Security Site (NNSS) was the main site for the United States' underground nuclear test (UGT) program. Since the 1992 moratorium on U.S. underground nuclear testing and the installation of the Stockpile Stewardship Program in 1994, a suite of enhanced capabilities and facilities have been developed across the Nuclear Security Enterprise to provide data and knowledge relevant to identified stockpile concerns. Capabilities specific to NNSS include:

- Atlas, a pulsed-power machine that discharges electrical energy into a cylindrical metal shell to produce an intense pressure pulse that implodes a target containing non-nuclear materials of interest;

- Big Explosives Experimental Facility (BEEF), a hydrodynamic testing facility that provides data through conventional high explosive experiments;
- Device Assembly Facility (DAF), the criticality experiments facility;
- Joint Actinide Shock Physics Experimental Research (JASPER) Facility, a two-stage gas gun that generates high-shock pressures, temperatures, and strain rates simulating those of a nuclear weapon; and
- U1A Complex, an underground location in which subcritical experiments are conducted.

NNSS is managed and operated by National Security Technologies, LLC, a partnership that includes Northrop Grumman, AECOM, CH2M Hill, and Nuclear Fuel Services.

7.2.6 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 high-energy-density physics capabilities and unique performance scientific computing assets. LLNL is the associated physics laboratory for the W80-2/3, B83-0/1, and W87 warheads. LLNL operates facilities that support both the NNSA stockpile and non-stockpile missions, including the High Explosives Application Facility (HEAF), Site 300 Experimental Test Site, and the Nonproliferation and International Security Center (NISC), among others.

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

Los Alamos
NATIONAL LABORATORY
EST. 1943

7.2.7 Los Alamos National Laboratory

Los Alamos National Laboratory (LANL), like 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. Similar to LLNL, 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, neutron scattering, enhanced surveillance, radiography, plutonium science and engineering, and beryllium technology. LANL is the associated physics laboratory for the B61-3/4/10, B61-7/11, W76, W78, W80-0, W80-1, and W88 warheads. LANL operates facilities that support both the NNSA stockpile and non-stockpile missions, including the Dual Axis Radiographic Hydrodynamic Test (DARHT) facility, the Plutonium Facility Site TA-55, and the Los Alamos Neutron Science Center (LANSCE), among others.

Los Alamos National Laboratory is operated by Los Alamos National Security, LLC, which is composed of Bechtel National, the University of California, the Babcock and Wilcox Company, and the Washington Division of URS Corporation.

Sandia National Laboratories

7.2.8 Sandia National Laboratories

Sandia National Laboratories (SNL) serves as the design authority for nuclear warhead systems engineering, integration, and quality assurance. SNL also provides research, development, and production of specialized non-nuclear components and ensures their integration with nuclear explosive packages and delivery systems. Like LLNL and LANL, Sandia plays an important role in providing annual safety, security, and reliability assessments in the annual stockpile assessment process. SNL operates facilities that support both the NNSA stockpile and non-stockpile missions, including Thunder Range and the Explosive Components Facility, among others.

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 (LLNL and LANL).

7.3 Nuclear Security Enterprise Transformation

At the direction of the NNSA and in coordination with the Department of Defense, the Nuclear Security Enterprise sites described above are responsible for carrying out the work associated with providing the United States with a safe, secure, and effective stockpile. Since the end of the Cold War and the subsequent transition from the “build and test” paradigm, the Nuclear Security Enterprise has been in the process of transforming from a large complex with an impressive production capability to a smaller, safer, more secure, and less expensive complex that leverages the scientific and technical abilities of a condensed, post-Cold War workforce. There are several facilities that were once part of the NSE that have been transitioned away from nuclear weapons-related activities. Among the largest of these facilities are the Idaho National Engineering Laboratory, the Rocky Flats Plant, the Mound Site, the Pinellas Plant, and the Hanford Site. (For a visual depiction of the downsized Nuclear Security Enterprise, see Figure 7.1.)

7.3.1 Idaho National Engineering Laboratory

The Idaho National Engineering Laboratory (INEL) was established in 1949. The INEL served as one of the primary centers for DOE research and development activities on reactor performance, materials testing, environmental monitoring, waste processing, and breeder reactor development; it also served as a naval reactor training site. INEL reactors represent the world's most extensive and varied collection of reactors, ranging from research and testing to power and ship propulsion. Until 1992, spent reactor fuels were reprocessed at the laboratory's Idaho Chemical Processing Plant. Today, the INEL has transitioned to the Idaho National Laboratory (INL), a leading United States laboratory for nuclear energy research and development.

7.3.2 Rocky Flats Plant

From 1952 until the early 1990s, the Rocky Flats Plant produced nuclear and non-nuclear components for new warheads, disassembled nuclear and non-nuclear components for retired warheads, and recovered nuclear materials. As a DOE facility, Rocky Flats machined and milled plutonium components for new warheads and recovered plutonium from dismantled warheads. The site was located on 6,500 acres in Golden, Colorado, about 20 miles northwest of Denver.

Nuclear production work at Rocky Flats ceased in 1992 and non-nuclear production was terminated in 1994. In October 2005, the Department of Energy completed an accelerated, ten year, seven billion dollar cleanup of chemical and radiological contamination, remnants of almost 50 years of production. The cleanup required the decommissioning, decontamination, demolition, and removal of over 800 structures, including six plutonium processing and fabrication building complexes, removal of more than 500,000 cubic meters of low-level radioactive waste, and remediation of more than 360 potentially contaminated environmental sites.

Following completion of the cleanup, Rocky Flats was designated as two operable units within the boundaries of the property: the 1,308-acre Central Operable Unit and the 4,883-acre Peripheral Operable Unit. The Central Operable Unit consolidates all areas of Rocky

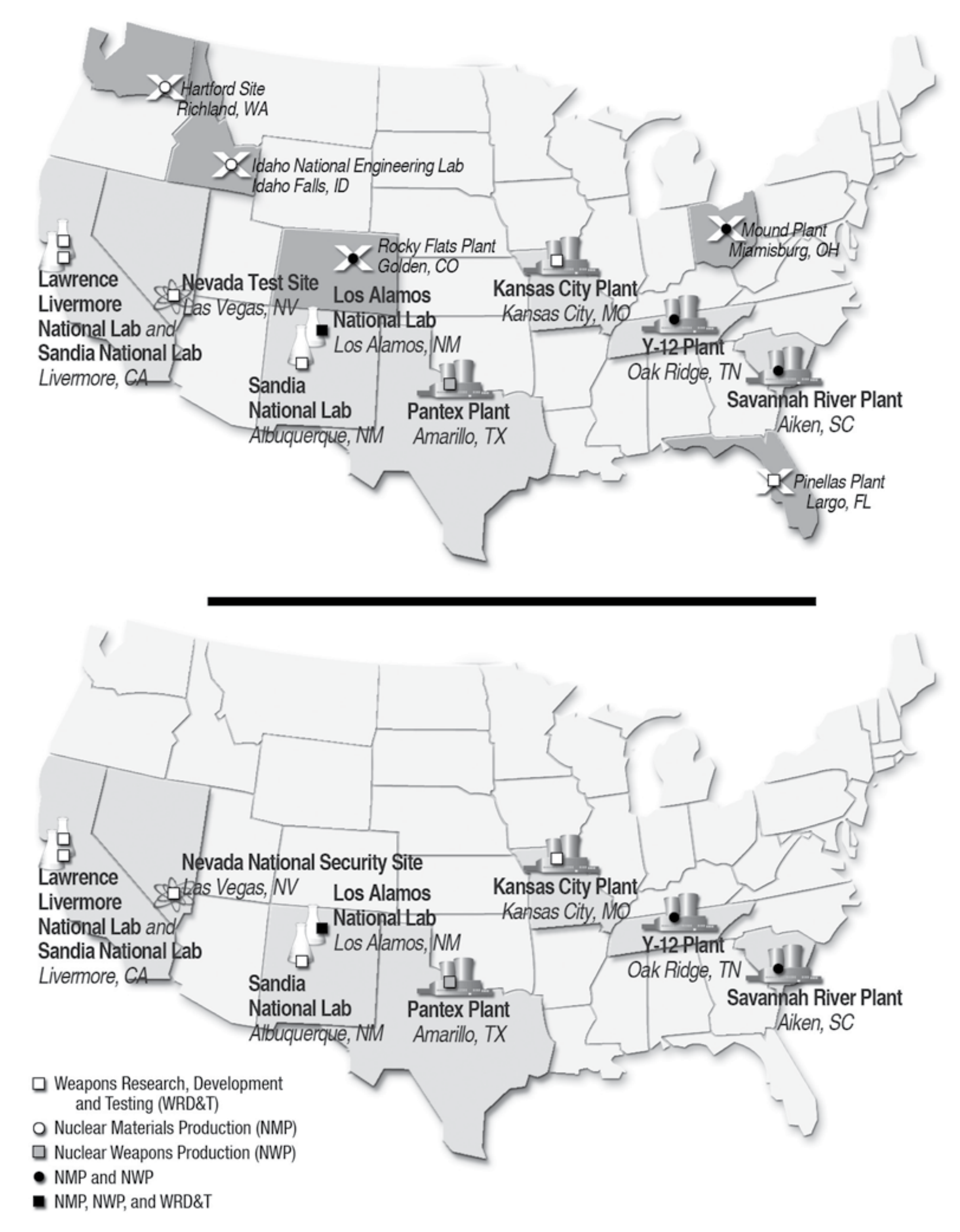

Figure 7.1 Downsized Nuclear Security Enterprise

Flats that require additional remedial and response actions. The primary contaminants, contaminated media, and waste present in the Central Operable Unit include: disposed wastes, trash and construction debris, contaminated subsurface soils, contaminated surface soils, and areas of ground water contaminant plumes. In 2007, the Department of Energy transferred the majority of the property comprising the Peripheral Operable Unit to the United States Fish and Wildlife Service in order to establish the Rocky Flats National Wildlife Refuge. The DOE Office of Legacy Management remains responsible for the long-term surveillance and maintenance of the Rocky Flats Site (now consisting of the Central Operable Unit) in perpetuity.

7.3.3 Mound Site

The Mound Site was established in 1948 in Miamisburg, Ohio. Early work at the site involved production of polonium-beryllium initiators used in early nuclear weapons and research related to radionuclides and detonators. In the 1950s, the Mound Site manufactured a variety of nuclear weapons parts, including cable assemblies, explosive detonators, and electronic firing sets. The Mound Site evolved into an integrated research, development, and production facility performing various tasks, which included production of explosive and inert components, diagnostic surveillance testing of nuclear and explosive components, and recovering tritium from retiring tritium components.

In 1995, the administration of the site was transferred to the DOE Environmental Management program. Since that time, the DOE has worked with the Environmental Protection Agency (EPA) and the Ohio EPA to assess and review the status of each building and potential contamination release site to determine the appropriate remediation. As of August 2009, all nuclear material was shipped off the Mound Site, all facilities were demolished or transitioned, and all environmental remediation activities were complete. The 306-acre site was divided into discrete land parcels, and, since February 1999, more than 60 percent of the site footprint has been transferred to the Miamisburg Mound Community Improvement Corporation (MMCIC) that, in cooperation with the local community, works to transition the Mound Site for reuse as a technology and industrial park.

7.3.4 Pinellas Plant

The Pinellas Plant was established in 1957 on 100 acres in Largo, Florida, between St. Petersburg and Clearwater. Until 1994, the Pinellas Plant manufactured neutron generators, thermal batteries, lithium ambient batteries, special capacitors and switches, and other electrical and electronic components for nuclear weapons. It also manufactured radioisotope thermoelectric generators (RTGs), using plutonium-238 capsules provided by the Mound Plant.

The Pinellas Plant ceased all operations in 1997, and the DOE and the Pinellas County government jointly redeveloped the site for commercial use. Pinellas County currently owns the facility, now called the Young-Rainy Science, Technology, and Research Center, which houses more than 20 businesses. As a result of historical waste disposal practices, portions of the site's subsurface and the shallow surficial aquifer were contaminated with organic solvents and metals. The DOE has conducted ongoing cleanup and surveillance activities to remedy these issues.

7.3.5 Hanford Site

The Hanford Site sits on 586 square miles near Richmond in southeastern Washington State. The area is home to nine former nuclear reactors and their associated processing facilities that were built beginning in 1943. The reactors were used to produce plutonium needed for U.S. nuclear weapons. Plutonium from Hanford was used in the *Fat Man* bomb, which was dropped on Nagasaki, Japan in August 1945.

Figure 7.2
Workers preparing debris at the Hanford Site

Hanford reactors produced approximately 53 metric tons of weapons-grade plutonium from 1944 until 1987. Today, Hanford workers are involved in an environmental cleanup project of immense proportions necessitated by the processes required to transform raw uranium into plutonium for nuclear defense. All of the facilities and structures associated with Hanford's defense mission are undergoing deactivation, decommissioning, decontamination, and demolition.

7.4 Future Nuclear Security Enterprise

In developing the plans for the future of the NSE, the NNSA has proposed a future complex that would:

1. Consolidate special nuclear materials from six to five sites and reduce the square footage of SNM within those sites.

2. Reduce the square footage of buildings and structures supporting weapons missions by approximately 9 million square feet.
3. Employ 20-30 percent fewer workers in activities that directly support weapons missions.
4. Allow for the dismantlement of weapons at a significantly faster pace in keeping with the United States' nonproliferation goals.

While the NNSA is in process of implementing this transition, it is still responsible for maintaining the current U.S. nuclear stockpile in a manner consistent with presidential guidance and national directives. The NNSA accomplishes this task through the Stockpile Stewardship Program.

7.5 Stockpile Stewardship Program

The purpose of the Stockpile Stewardship Program is to sustain the safety and effectiveness of the nation's nuclear arsenal in the absence of nuclear testing.

The NNSA Stockpile Stewardship Program was established by Presidential Directive and authorized by Congress in October 1993. The purpose of the program is to sustain the safety and effectiveness of the nation's nuclear arsenal in the absence of nuclear testing. Stockpile stewardship is an all-encompassing program that includes:

- operations associated with surveying, assessing, maintaining, refurbishing, manufacturing, and dismantling the nuclear weapons stockpile;
- activities associated with the research, design, development, simulation, modeling, and non-nuclear testing of nuclear weapon components; and
- the assessment of the safety, security, and reliability and the certification of the stockpile.

Current statute requires: "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." This document, known as the Stockpile Stewardship Plan (SSP), has been submitted to Congress every year since 1998. It is commonly referred to as "the Greenbook."

In the past, nuclear testing and the continuous development and production of new nuclear weapons were essential to preserve high confidence in the stockpile. However, the United States has not manufactured a new weapon-type for almost twenty years. Under the SSP, the U.S. strategy is to maintain the existing nuclear weapons stockpile using improved experimental capabilities complemented by advanced simulation and surveillance tools, which serve as a substitute for underground nuclear testing.

7.5.1 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 NNSA, Stockpile Stewardship Plan implementation has been organized into Weapons Activities involving eight programs and five campaigns. The programs are:

- Directed Stockpile Work (DSW) program
- Readiness in Technical Base and Facilities (RTBF) program
- Secure Transportation Asset (STA) program
- Nuclear Counterterrorism Incident Response (NCTIR) program
- Facilities and Infrastructure Recapitalization program (FIRP)
- Site Stewardship program
- Defense Nuclear Security (DNS) program
- Cyber Security program

The campaigns are:

- Science campaign
- Engineering campaign
- Inertial Confinement Fusion (ICF) Ignition and High Yield campaign
- Advanced Simulation and Computing (ASC) campaign
- Readiness campaign

The thirteen separate—yet related—elements constitute the Weapons Activities effort, essential for continuing the assessment and certification of the nuclear weapons stockpile. A detailed description of the programs and campaigns is below.

Programs

Directed Stockpile Work

The Directed Stockpile Work program mission is to provide nuclear warheads and bombs to the Department of Defense in accordance with the Nuclear Weapons Stockpile Plan memorandum. To fulfill this mission, DSW is responsible for ensuring that the safety, security, and reliability of the nation's nuclear weapons are maintained and enhanced. DSW is also responsible for the dismantlement and disposition of retired weapons and weapon components and the sustainment of the plutonium enterprise.

Four subprograms comprise DSW:

1. Life Extension Programs (LEPs), which enable the nation's nuclear weapons to respond to current-day threats.
2. Stockpile Systems, to include: weapon-specific research and development, assessment, and certification activities; limited life component exchange activities; surveillance activities; maintenance, feasibility, and safety studies; and military liaison work for the B61, W76, W78, W80, B83, W87, and W88 weapon systems.
3. Weapons Dismantlement and Disposition (WDD), to include the dismantlement and disposition of retired weapons, weapon components, and supporting functions.
4. Stockpile Services, which provides: research, development, and production support base capabilities for multiple warheads and bombs; certification and safety efforts; quality engineering and plant management, technology, and production services; support for stockpile evaluation and surveillance; and investigation options for meeting DoD requirements.

Readiness in Technical Base and Facilities

The goals of the Readiness in Technical Base and Facilities program are to operate and maintain NNSA program facilities in a safe, secure, efficient, reliable, and compliant condition in areas including facility operating costs (e.g., utilities, equipment, facility personnel, training, and salaries); facility and maintenance equipment costs (e.g., staff, tools, and replacement parts); and environmental, safety, and health costs. The RTBF program is also responsible for planning, prioritizing, and constructing state-of-the-art facilities, infrastructure, and scientific tools that are not directly funded by DSW or campaigns.

Secure Transportation Asset

The STA program is a Direct Federal Program (government-owned and operated). Its mission is to provide a capability for the safe and secure transport of nuclear warheads, components, and special nuclear material that meets projected NNSA, DOE, DoD, and other customer requirements. These shipments are highly guarded for the utmost protection of the public and U.S. national security. The federal agents who do this work are trained to defend, recapture, and recover nuclear materials in case of an attack. The STA program is also involved with international shipments to and from Canada, the United Kingdom, and France.

Nuclear Counterterrorism Incident Response

The mission of the NCTIR program is to ensure that capabilities are in place to respond to DOE/NNSA facility emergencies or to any nuclear or radiological incident with the United States or abroad. The NCTIR program also provides operational planning and training to counter both domestic and international nuclear terrorism. The NCTIR program administers and directs the DOE/NNSA emergency response programs that provide the capability to respond to and mitigate the effects of a nuclear or radiological incident or emergency. To meet its mission, the NCTIR program is divided into seven subprograms:

1. Emergency Management,
2. Emergency Response,
3. NNSA Emergency Management Implementation,
4. Emergency Operations Support,
5. National Technical Nuclear Forensics,
6. International Emergency Management and Cooperation, and
7. Nuclear Counterterrorism.

Facilities and Infrastructure Recapitalization

The FIRP mission is to restore, rebuild, and revitalize the physical infrastructure of the Nuclear Security Enterprise. FIRP applies direct appropriations to address an integrated, prioritized series of repair and infrastructure projects focusing on completion of deferred maintenance with the intent to significantly increase operational efficiency and effectiveness of the NSE.

Site Stewardship

The Site Stewardship program is responsible for maintaining facility and overall site capabilities and efficacies by ensuring: regulatory and energy efficiency requirements are being met, SNM is being appropriately and cost-effectively managed, and NNSA excess facilities are properly disposed of (i.e., sold, transferred, or demolished) in order to better focus resources in support of the overall NNSA mission.

Defense Nuclear Security

The DNS program is responsible for the implementation of security programs for the NNSA. In this capacity, DNS is responsible for security direction and program management with respect to prioritization of resources, program evaluation, and funding allocation. DNS continuously evaluates the status of protection programs at all NNSA facilities against national policy and departmental security requirements to determine the appropriate level of resource allocation at each site across the NSE. Resource allocation is based on a rigorous requirements validation and evaluation process that incorporates site-level vulnerability analysis and risk assessments.

Cyber Security

The Cyber Security program provides the requisite guidance needed to ensure that sufficient information technology and information management security safeguards are implemented throughout the NSE. The program implements a flexible, comprehensive, and risk-based cyber security program that adequately protects NNSA information and information assets; is predicated on Executive Orders, national standards, laws, and regulations and DOE and NNSA orders, manuals, directives, and guidance; and results in a policy-driven cyber architecture, a programmatic framework and methodology that is based on current policies and procedures, and a management approach that integrates all of the components of a comprehensive cyber security program.

Campaigns

Science

The Science campaign supports the development of the knowledge, tools, and methods used to assess the performance of the nuclear warhead's nuclear explosive package. These tools and methods support critical stockpile decisions—for example, those decisions relating to the impact of significant finding investigations (SFIs) on nuclear safety and performance or those affecting the annual assessment and certification processes. Science campaign results also provide technical and scientific resources required to carry out Directed Stockpile Work support for each warhead-type and to ensure the nation's ability to respond quickly and flexibly to changing requirements to the United States' nuclear posture.

Engineering

The primary goal of the Engineering campaign is to develop capabilities to assess and improve the safety, reliability, and performance of the engineering components within the nuclear and non-nuclear explosive package of the nuclear weapon without the use of underground nuclear testing. An additional goal of the Engineering campaign is to increase the ability to predict the response of all nuclear weapons components and subsystems to external stimuli (such as large thermal, mechanical, and combined forces and extremely high radiation fields) and to predict the effects of aging. The results of these studies provide information, data, tools, predictive capability, and expertise to designers, analysts, and surveillance and systems managers that assist in the development of technology options and essential capabilities for the stockpile.

Inertial Confinement Fusion Ignition and High Yield

The Inertial Confinement Fusion Ignition and High Yield campaign mission is to provide experimental capabilities and scientific understanding in the area of high energy density physics (HEDP). The campaign has three strategic objectives:

1. Achieve thermonuclear ignition in the laboratory and develop it as a routine scientific tool to support stockpile stewardship.
2. Develop advanced capabilities—including facilities, diagnostics, and experimental methods—that can access the high energy density regimes of extreme temperature, pressure, and density required to assess the nuclear stockpile.
3. Maintain U.S. preeminence in high energy density science and support broader national science goals.

HEDP experiments on ICF facilities are required to validate the advanced theoretical models that are used to assess and certify the stockpile without nuclear testing.

Advanced Simulation and Computing

The Advanced Simulation and Computing campaign's mission is to provide high-end simulation capabilities needed to meet weapons assessment and certification requirements and to predict—with confidence—the behavior of nuclear weapons through comprehensive, science-based simulations.

Readiness

The Readiness campaign identifies, develops, and deploys new or enhanced processes, technologies, and capabilities to meet current nuclear weapon design, production, and dismantlement needs and provide quick response to national security requirements.

7.6 Nuclear Counterterrorism

The NNSA Nuclear Counterterrorism (NCT) program, integrates, sustains, and executes key activities and provides specialized expertise in partnership with the NNSA weapons design-, stockpile science-, weapons surety-, and nuclear material-related programs to advise and enable all technical aspects of U.S. government nonproliferation, counterproliferation, and nuclear counterterrorism missions. The program focuses on nuclear materials and nuclear threat devices, which include improvised nuclear devices, foreign weapon designs of a proliferant concern, and any device that may have fallen outside the custody of a foreign nuclear weapon state.

The NCT program works to understand the full range of nuclear threat device (NTD) designs; from an unknown “homemade nuke” or improvised nuclear device (IND) to a weapon from one of the established nuclear weapons states that has fallen out of state control. The NCT focus is on nuclear terrorism, sub-state actors, and proliferators and includes modified stockpile and non-stockpile nuclear devices (i.e., attractive to terrorists or sub-state actors).

The strategic objectives of the Office of Nuclear Counterterrorism are to: achieve the president’s vision of preventing nuclear terrorism, serve as the premier U.S. government program regarding NTDs, guide research and development to understand the full spectrum of NTDs to support the full range of countering nuclear threat activities, provide accurate information to ensure effective response to nuclear terrorism and to inform associated policies, protect sensitive information from disclosure, and advocate for the long-term stewardship of the nation’s capability to prevent nuclear terrorism.

Chapter 8
International Nuclear Cooperation

8.1 Overview

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

The international security environment has changed dramatically since the end of the Cold War. As stated in the 2010 Nuclear Posture Review Report, the threat of global nuclear war has become remote, but the risk of nuclear attack against the United States and its allies and partners has increased. Nuclear terrorism and nuclear proliferation are global problems requiring cooperation among the United States and its international partners and allies. The United States works closely with certain allies to ensure the common use of best practices and to enjoy the benefits of independent peer review. The United States also engages cooperatively with its 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.

As a result of this need for international engagement, the United States participates in various Programs of Cooperation—legal frameworks for international information exchange—with a number of international partners, including the United Kingdom, France, and NATO. The most robust of these programs are with NATO and the United Kingdom, and this chapter will focus on these programs as representative examples of how such Programs of Cooperation function.

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]

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.

Given the existence of a formal mutual defense agreement, the Atomic Energy Act 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." In 1959 and 1961, however, President Eisenhower and President Kennedy, respectively, delegated this authority to the secretaries of defense and energy through Executive Orders 10841 and 10956. As a result of these orders, Presidential Determinations became Statutory Determinations (SDs). Executive Order 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 secretary of defense and the secretary of energy. Each SD must explain the purpose of the international communication (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.

[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.

8.2 U.S. Nuclear Cooperation with NATO

On April 4, 1949, the North Atlantic Treaty was signed by the founding members of NATO (Belgium, Canada, Denmark, France, Iceland, Italy, Luxembourg, the Netherlands, Norway, Portugal, the United Kingdom, and the United States) in Washington, D.C. 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; it 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. It 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, and the NPG also covers other issues of common concern such as nuclear arms control and nuclear proliferation.

The role of the NPG is to review the Alliance'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 of the Alliance 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 *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. As a contributor to the strategic nuclear forces of the NATO alliance, United States nuclear cooperation with NATO will remain important into the future.

8.3 U.S.-UK International Program of Cooperation

The United States and United Kingdom have worked closely on nuclear weapons issues since the 1940s. The work of Frisch and Peierls in England during the early days of World War II 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 1: *Nuclear Matters History and Policy.*)

> *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.*

Apart from a period of restriction under the McMahon Act (1946-1958), 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 that 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, the UK maintains a liaison officer at the United States Strategic Command. The closeness of the relationship and the level of nuclear cooperation between the two sovereign nations should never be mistaken for an inability to act alone. The president of the United States is the only person who can authorize the use of U.S. nuclear weapons, and the prime minister of the United Kingdom is the sole individual able to authorize the launch of a UK Trident missile.

As the United States and United Kingdom face the challenges of maintaining safe, secure, and effective independent deterrents, the importance of the relationship endures. Under the U.S.-UK International Program of Cooperation, there are regular exchanges of information and experience at all levels. Through this relationship, both countries are able to benefit from shared wisdom and experience as they work together to counter nuclear threats and independently advance the status of their nuclear weapons programs.

As the nature of the special relationship between the United States and the United Kingdom has evolved over the decades 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 Statutory Determinations on a case-by-case basis, taking into account the desired outcomes of the proposed collaboration and the potential risks to national security of sharing such sensitive nuclear weapon information.

The intent of the SDs has been to share only certain atomic information (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. There still exist some areas of information not authorized by any SD; however, these areas have the potential to become eligible over time as changing scientific, military, and political necessities dictate.

Under the terms of the Atomic Energy Act, the Department of Energy (DOE) and the Department of Defense (DoD) 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 Statutory Determinations. 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 Working Groups (JOWOGs), Exchanges of Information by Visit and Report (EIVRs), and Channels.

8.3.1 Management Arrangements

The Management Arrangements detail the means of supervisory oversight over the cooperation effort. The two management levels are known as the Principals and the Second Level. The Principals (consisting of the assistant secretary of defense for Nuclear, Chemical, and Biological Defense Programs (ASD(NCB)), the NNSA administrator, and the UK Ministry of Defence chief scientific advisor) 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. The meeting of the Second Level participants is held every six-to-nine months and is led by government officials one step below the 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.

8.3.2 Administrative Arrangements

Administrative Arrangements with the various nations and regional defense organizations lay out the various mechanisms for information exchange, whether in person, in written form, or in electronic exchanges. The Administrative Arrangements supporting the MDA between the United States and the United Kingdom, as an example of such arrangements, is a document signed by the deputy administrator for Defense Programs within the NNSA, the assistant secretary of defense for Nuclear, Chemical, and Biological Defense Programs for the DoD, the Director, Strategic Technologies within the UK Ministry of Defence, and the UK Head, Nuclear and Strategic Deterrent Office, British Embassy. The arrangements detail 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.

8.3.3 Joint Atomic Information Exchange Group

The Joint Atomic Information Exchange Group (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 (ASD(NCB)) and the DOE (the NNSA Administrator). The JAIEG is also responsible for providing support to the DoD, the DOE, 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. In the United Kingdom, the Atomic Control Office (London) or the Atomic Co-ordinating Office (Washington) acts for the UK Ministry of Defence in these matters as they pertain to the Mutual Defense Agreement.

8.3.4 Joint Working Groups

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 various areas of 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, to suggest further avenues for investigation, and to propose divisions of work between participating laboratories or agencies. Under the auspices of a JOWOG, visits between laboratories or agencies are made to review a particular project or to accomplish a specific objective.[2] Current U.S.-UK JOWOGs include nuclear counterterrorism technology, nuclear warhead physics, nuclear warhead accident response technology, and methodologies for nuclear weapon safety assurance, among others.

8.3.5 Exchange of Information by Visit and Report

In addition to the JOWOGs, the United States has developed an EIVR concept to be used as an administrative instrument to promote the controlled oral/visual exchange of atomic information. EIVRs differ from JOWOGs in that, with one exception, they are not granted continuous authorization for the exchange of atomic information, as JOWOGs are within their areas of exchange. Authorization to exchange U.S. atomic information under the

[2] All visits are subject to the procedures and controls required by the United States and United Kingdom for visits involving the exchange of atomic information.

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.

8.3.6 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 by the authorizing authority. 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/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, among others.

U.S.-UK Nuclear Threat Reduction

In recent years, the United States and the United Kingdom have built on the relationship established for the exchange of nuclear deterrent atomic information to develop a series of scientific programs to address and reduce the threat posed by nuclear proliferation. This has been reflected in new governance procedures, as shown in Figure 8.1. As part of this work, the United States and the United Kingdom are conducting joint work to further develop the nations' capabilities in nuclear forensics to identify sources of radioactive material, to improve capabilities to detect nuclear material, and to 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.

8.4 International Nuclear Cooperation Issues and Challenges

Nuclear weapons-related information and knowledge are closely controlled by those countries that maintain it. Because of the sensitivities associated with these weapons and the nature of nuclear cooperation among nations, there are several issues and challenges associated with international nuclear cooperation that must be effectively approached and managed.

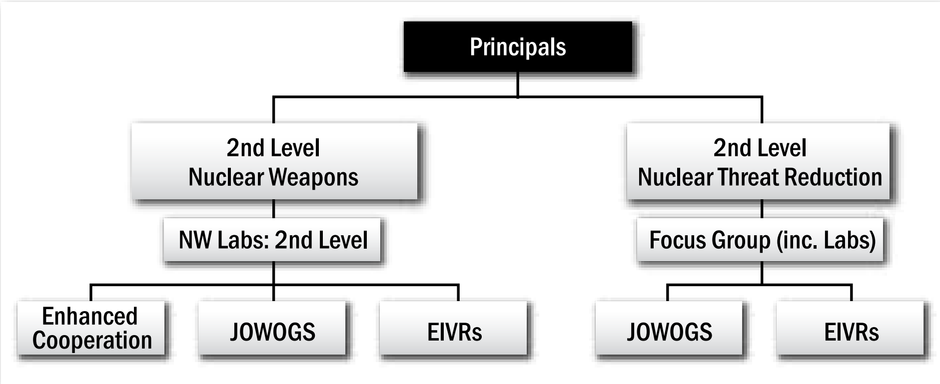

Figure 8.1 NTR Governance

One such issue involves an option currently being considered called "Direct Release," wherein scientists and engineers at the U.S. national security laboratories would be granted permission to transmit information to foreign partners directly without first going through the JAIEG. At issue is whether the United States should delegate heretofore inherently government functions to non-governmental organizations and individuals for the sake of efficiency, convenience, and, given the growing challenges arising from nuclear terrorism, efficacy in fighting common nuclear threats. Specifically, at issue is the right balance between a productive flow of information and open communication between international partners and appropriate and prudent limitations on the level of openness. Statistically speaking, the more people who share secrets, the more vulnerable the secrets become. Similarly, the more organizations and nations that join the classified discussion, the more vulnerable the information may become.

All sovereign nations must evaluate the risks and rewards of expanding the circle of classified information sharing. Each nation must consider the trustworthiness of partner nations; specifically, whether the other country is willing and able to safeguard classified information in an acceptable manner. Partner nations may also have relationships with third-party countries with which the United States has issue or vice versa.

On the other hand, nuclear threats are becoming increasingly global in their impact. An act of nuclear terrorism would not only directly affect the nation attacked, but it would also affect all states within the international community that value order and stability. Thus, international cooperation to combat nuclear terrorism and nuclear proliferation is more important than ever, and the calculations among the competing considerations that affect national and international security must also evolve with the threat and the ability to respond effectively.

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 Department of Defense (DoD) and Department of Energy (DOE) organization 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 stockpile management process to ensure high confidence in the safety, security, reliability, and performance of U.S. nuclear weapons. The NWC meets regularly to raise and resolve issues between the DoD and the DOE regarding concerns and strategies for stockpile management.

The NWC is also responsible for a number of annual reports that focus senior-level attention on important nuclear weapons issues. The NWC is required to report regularly 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 (UGT) to preserve the credibility of the U.S. nuclear deterrent. The NWC is obligated to evaluate the surety of the stockpile and to report its findings to the president each year. The NWC, through its oversight and reporting functions, also ensures that any significant threats to the continued credibility of the U.S. nuclear capability will be identified quickly and resolved effectively.

A.2 History

Following World War II, Congress wanted to ensure civilian control over the uses of nuclear energy. Consequently, the *1946 Atomic Energy Act* created the Atomic Energy Commission (AEC), which has evolved into what is now the National Nuclear Security Administration (NNSA).[1] The act also stipulated that the DoD would participate jointly in the oversight of the U.S. nuclear weapons program to ensure the fulfillment of military requirements for atomic weapons.

A.2.1 The Military Liaison Committee

The *1946 Atomic Energy Act* also established the Military Liaison Committee (MLC), the predecessor of the NWC. The MLC was created to coordinate joint DoD-DOE nuclear defense activities.

The MLC was an executive or flag-level (one-/two-star) DoD 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 the MLC chairman, and members included two flag-level representatives from each of the Military Services. 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 Action Officers (AO) Group, which was composed of AOs representing each of the seven members and each of the three

[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.

official observers, supported the MLC. Other organizations with a direct interest in nuclear weapons matters, such as the national weapons 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 (SASC) 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 responsibility; they argued that 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 for Fiscal Year (FY) 1985* (Public Law 98-525) directed the president to establish a Blue Ribbon Task Group to examine the issue.

A.2.2 The Blue Ribbon Task Group on Nuclear Weapons Program Management

On January 18, 1985, the president 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 to 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 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 1985, 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 to oversee joint nuclear activities. The task group suggested that 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. These 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 that a dedicated staff drawn from both departments and reporting to a full-time staff director would be 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 Department of Defense dedicated primarily to nuclear weapons matters. This office was the ATSD(AE) until 1996 and has since transitioned to the office of the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs (ASD(NCB)). The successor position to the ATSD(AE) is the Deputy Assistant Secretary of Defense for Nuclear Matters (DASD(NCB/NM)).

[2] The POGs are joint DoD-DOE 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.

A.3 The NWC Today

Acting on the recommendations of the president's *Blue Ribbon Task Group*, Congress established the NWC in the *National Defense Authorization Act for FY 1987* (Public Law 99-661). A letter signed by the Secretary of Defense formalized the establishment of the NWC.

The original 1986 statute establishing the NWC and delineating its responsibilities reflected the concerns of the day. 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 U.S. plans for continued nuclear weapons production were indefinite, and the U.S. production capability was relatively robust. Congress was concerned about the expense of the U.S. nuclear weapons program and wanted to realize possible cost savings without jeopardizing the safety, security, or reliability of the stockpile.

The statute establishing the NWC has been amended several times. 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 evolved to accommodate changing circumstances. Each additional responsibility assigned to the NWC has reflected emerging concerns as the Cold War ended and the Post-Cold War era began.[3]

A.4 Organization and Members

By law, the NWC now comprises five members: the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)); the Under Secretary of Defense for Policy (USD(P)); the Vice Chairman of the Joint Chiefs of Staff (VCJCS); the Commander of the U.S. Strategic Command (CDRUSSTRATCOM); and the Under Secretary of Energy for Nuclear Security/National Nuclear Security Administration (NNSA) Administrator. The USD(AT&L) serves as the chairman of the NWC. The ASD(NCB) is designated as the NWC staff director. Figure A.1 illustrates NWC membership as stated in Title 10, Section 179 of the United States Code (10 USC 179).

The law also directed the DoD and the DOE 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. As the executive secretary, the

[3] In addition, the law has been amended to include a broader membership.

ASD(NCB) manages the agendas and facilitates the activities of the NWC. As the NWC staff director, the ASD(NCB) also has oversight responsibilities for the NWC Staff and the other subordinate organizations of the NWC.

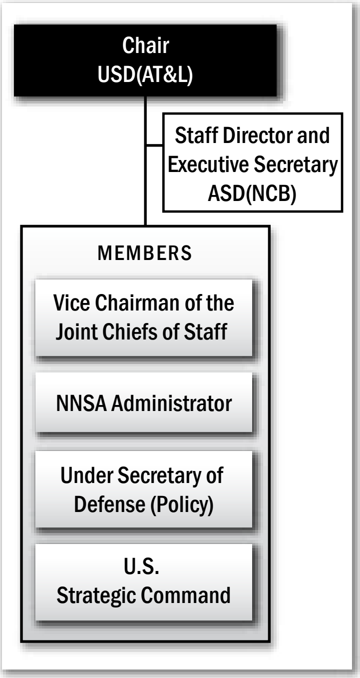

Figure A.1 NWC Membership per 10 USC 179

NWC membership includes several guest and observer organizations in addition to its official members. Though not voting members, these organizations make valuable technical contributions to NWC deliberations. NWC guests 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 for Intelligence (USD(I));
- National Security Staff (NSS)[4];
- Director, Defense Threat Reduction Agency (DTRA); and
- Under Secretary of Defense, Comptroller (USD(C)).

NWC observer organizations include:

- U.S. Army Nuclear and Combating Weapons of Mass Destruction Agency (USANCA);
- U.S. Navy (Strategic Systems Programs (SSP));
- U.S. Air Force (Strategic Deterrence and Nuclear Integration Office (AF/A10));
- Office of the Deputy Under Secretary of Defense for Acquisition and Technology (ODUSD(A&T)); and
- National Security Agency (NSA).

[4] The National Security Council and Homeland Security Council merged under the Obama Administration to form the National Security Staff.

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. The NWC currently fulfills four annual reporting requirements: the Nuclear Weapons Stockpile Memorandum/Requirements and Planning Document (NWSM/RPD), the NWC Report on Stockpile Assessments (ROSA), the NWC Joint Surety Report (JSR), and the NWC Chairman's Annual Report to Congress (CARC).

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's 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 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 NNSA;
- receiving information and recommendations from advisory committees on nuclear weapons issues and recommending appropriate actions to the DoD and the NNSA;
- providing broad guidance to the DoD and the 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 that 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 that 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. Issues that require NWC action, including decisions or recommendations, are recorded through an Action Item tracking process.

For some actions, such as a decision to approve the progress of a warhead-type from one life-cycle phase to the next, a voice vote at the meeting may be recorded in the NWC's meeting minutes. This voice vote, as recorded in the minutes, would serve as the official NWC approval.

In theory, each member of the NWC could veto any action or decision. In practice, however, the NWC works to achieve consensus among its members before it issues official decisions or recommendations. Issues rarely reach the NWC level until they have been thoroughly vetted by NWC subordinate organizations, as appropriate. Documents, including NWC reports, memoranda, and letters, are revised and coordinated until all NWC members concur. The majority of revision and coordination occurs at the subordinate levels.

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 NNSA, and the national weapons 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.

Briefings are generally tailored for the individual audience in terms of length and level of detail. Because the NWC has delegated some responsibilities to its subordinate organizations, the subordinate group may determine that a briefing need not progress to the NWC.

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. 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 Title 10, Section 179 of the U.S. Code. This affords the NWC the necessary flexibility to create, merge, or abolish organizations as needed.

Two committees were established shortly after the creation of the NWC: 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." 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 NWC Action Officers Group and an NWC Staff 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 to define them more precisely where 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. 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 national nuclear enterprise. New committees will be created, as needed, by the NWC to respond to issues of the day. Figure A.2 illustrates the subordinate bodies of the NWC, and Figure A.3 provides a timeline of their establishment.

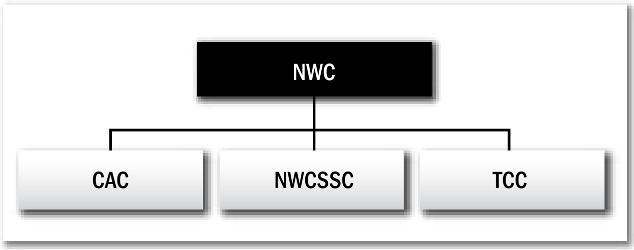

Figure A.2
The NWC and Its Current Subordinate Bodies

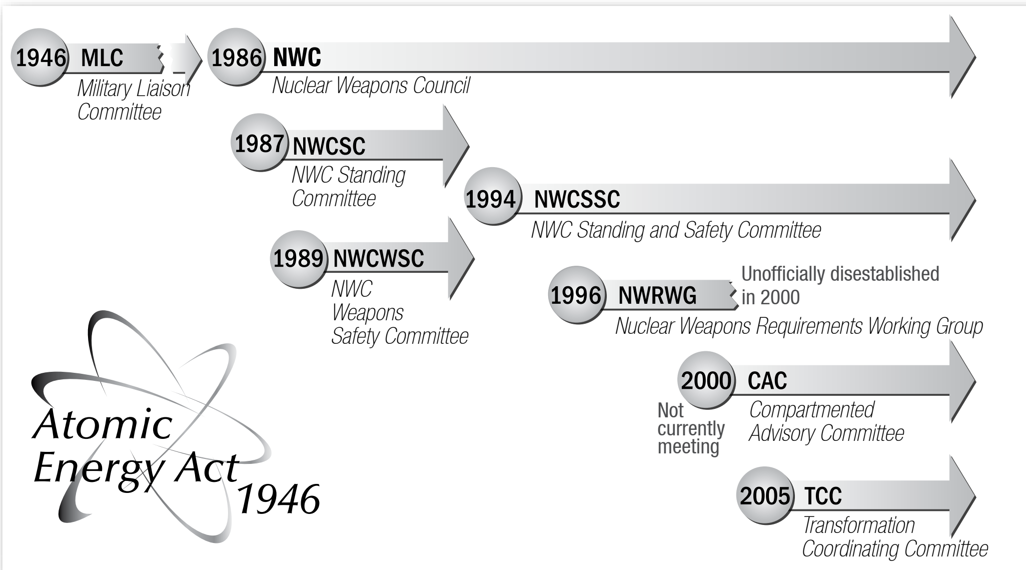

Figure A.3 Timeline of the Establishment of the NWC and Its Subordinate Bodies

A.7.1 The Nuclear Weapons Council Standing and Safety Committee

The NWCSSC is a subordinate body to the NWC. The primary mission of the NWCSSC is to advise and assist the NWC and to provide preliminary approval for many NWC activities. The NWCSSC is a joint DoD-DOE senior executive or flag-level (one-/two-star) committee that conducts transactions between the DoD and the DOE on behalf of the NWC. The NWC has also delegated certain approval authorities to the NWCSSC.

NWCSSC Organization and Members

The NWC staff director is the ASD(NCB). The ASD(NCB) also serves as the chair of the NWCSSC and represents the USD(AT&L) as well as the Office of the Secretary of Defense (OSD). An NNSA senior official is the NWCSSC vice-chair and represents the NNSA Administrator. For an illustration of NWCSSC membership, see Figure A.4.

The NWCSSC is composed of one flag-level representative or the civilian equivalent from each of the following organizations: the NNSA, the Office of the Under Secretary of Defense for Policy, the Office of the Assistant Secretary of Defense (NCB/Nuclear Matters) (OASD(NCB/NM)), the Joint Staff, the United States Strategic Command, the Navy, the Air Force, USANCA, and the Defense Threat Reduction Agency.

NWCSSC MEMBERS	
Chair	NNSA
ASD(NCB)	OUSD(P)
	OASD(NCB/NM)
Vice-Chair	JS
NNSA	USSTRATCOM
	Navy
	Air Force
	USANCA
	DTRA

NWCSSC TECHNICAL ADVISORS
LANL
LLNL
SNL
NSA

Figure A.4 NWCSSC Membership

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 not available or when the alternate's skills are appropriate to the topic of discussion. The NWCSSC executive secretary, who is also the NWC assistant staff director, is the NNSA liaison to the NWC Staff.

The NWCSSC is also supported by official observers and invited guests. When they are responsible for NWC actions in progress, these agencies and organizations send staff to participate as observers or invited guests. Additionally, the NWCSSC benefits from the support of technical advisors. Technical advisors represent the following organizations:

Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (SNL), and the National Security Agency.

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 to Congress.

The NWCSSC also actively participates in Project Officers Group 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 Service-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. Over the past several years, the NWCSSC has reviewed a number of topics, including: Nevada Test Site (NTS) readiness, warhead dismantlement activities, findings of the Joint Advisory Committee (JAC) on nuclear weapons surety, component and warhead storage, nuclear component production, and nuclear weapons safety standards.

In summary, NWCSSC responsibilities include:

- preparing and coordinating the annual Nuclear Weapons Stockpile Memorandum and Requirements and Planning Document, which are then provided to the NWC for review and approval before being forwarded to the secretaries of defense and energy for signature;
- approving nuclear weapons stockpile quantity adjustments within the authority delegated by the president and the NWC;
- reviewing the stockpile when required, and providing recommended stockpile improvements to the NWC for its endorsement;
- preparing and coordinating the annual NWC Report on Stockpile Assessments for the NWC;

- preparing and coordinating the Joint Surety Report for the DoD-DOE annual report to the president on nuclear weapons surety;
- preparing and coordinating the NWC chairman's Annual Report to Congress;
- reviewing Joint Requirements Oversight Council (JROC) recommendations related to nuclear weapons planning for possible impact on nuclear warhead programs;
- approving Design Review and Acceptance Group (DRAAG) Report findings;
- authorizing the establishment of POGs for NWC-directed studies or reviews, reviewing Military Service-approved POG charters, providing tasking and guidance to these POGs, reviewing POG study plans and reports, and resolving outstanding issues;
- reviewing and approving the original and/or amended military characteristics proposed by the Military Services through their respective POGs. (Safety-related MCs must be approved by the secretaries of defense and energy.);
- reviewing the stockpile-to-target sequence requirements for each nuclear warhead-type and considering proposed changes to the STS that may have a significant impact on cost or weapons performance;
- advising the NWC on weapons safety design criteria, safety standards and processes, safety rules, and the safety aspects of Military Characteristics and STSs as well as weapons transportation, storage, and handling;
- reviewing information from the DoD and the DOE on nuclear weapons-related issues under the NWC purview;
- reviewing the status and results of nuclear weapons safety studies performed either by the Military Services or jointly by the DoD and the DOE;
- requesting weapon program status information from the DoD and the DOE;
- conducting 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; and
- coordinating or taking action on other matters, as appropriate.

NWCSSC Procedures and Processes

The NWCSSC normally meets once each month. On occasion, the NWCSSC will meet in special session to address a specific issue that must be resolved before the next regularly scheduled meeting. The majority of the work performed by the NWCSSC involves issues related to DoD military requirements in relation to 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 weapons laboratories, as well as individual components within the DoD and the DOE. The NWCSSC chairman leads NWCSSC meetings and facilitates discussion among the members.

The NWC Staff is responsible for coordinating meeting times and places as well as developing meeting agendas 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 Action Officers and approved by the members at the next meeting.

A.7.2 The NWC Action Officers Group

The NWCSSC is supported by an Action Officer Group that meets to review nuclear weapons stockpile management issues, to ensure consistent progress, and to facilitate information dissemination. The AOs prepare nuclear weapons issues for their NWCSSC principals. In a frank and informal meeting environment, the AOs discuss issues, receive pre-briefings in preparation for NWCSSC or NWC meetings, and coordinate actions for consideration by their principals at the NWCSSC level.

AO Group Organization and Members

The AO Group is composed of AOs representing NWCSSC member organizations, observer organizations, technical advisors, and agencies involved in nuclear weapons program matters, where appropriate. The NWC Staff supports the AO Group. When they are responsible for NWC actions in progress, other agencies and organizations such as the POGs and the national weapons laboratories send AOs to participate as observers or invited guests. Figure A.5 illustrates NWC AO Group membership.

AO MEMBERS

Chair	
NWC	NNSA
Asst. Staff Director	OUSD(P)
	OASD(NCB/NM)
	JS
	USSTRATCOM
	Navy
	Air Force
	USANCA
	DTRA

Figure A.5 NWC AO Group Membership

AO Group Responsibilities and Activities

The responsibilities of the AO Group have been established through practice as well as direction from the NWCSSC principals. The AOs are responsible for keeping their NWCSSC principals fully informed regarding all NWC-related activities and preparing their principals for NWCSSC or related meetings. Normally, the NWC Staff is responsible for creating and distributing an informal meeting summary as well as tracking any actions that arise from the AO meetings.

AO Group Procedures & Processes

The NWCSSC executive secretary, who is also the NWC assistant staff director, chairs the AO meetings. The NWC Staff is responsible for coordinating meeting times and locations as well as for developing meeting agendas. The AOs normally meet once each week to discuss issues and coordinate actions.

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. Official observers and technical advisors may also provide comments to the assistant staff director for consideration and potential inclusion. 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 The Nuclear Weapons Council Staff

The NWC Staff provides analytical and administrative support to the NWC and its subordinate organizations. As codified in the 1997 NWC Memorandum of Agreement signed by the secretaries of defense and energy, both the DoD and the 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 OASD(NCB/NM) at the Pentagon. The NWC Staff is composed of an NNSA staff member and a DTRA staff member, both of whom have been assigned to the OASD(NCB/NM). The NWC Staff is also supported by government contractors, as required. The NWC Staff reports through the DASD(NCB/NM) to the NWC staff director.

NWC Staff Responsibilities and Activities

The NWC Staff has a variety of responsibilities, all of which ensure that the NWC and its subordinate bodies operate as efficiently and effectively as possible. The primary responsibilities of the NWC Staff can be divided into two areas: meetings, for planning and follow-up activities; and the NWC annual reports, for development, drafting, coordination, and execution.

The NWC Staff plans and schedules all meetings of the NWC, the NWCSSC, and the NWC AO Group. The responsibilities of the NWC Staff include: preparing meeting agendas; drafting and distributing tasking letters to request information or briefings from organizations within the nuclear weapons community; and preparing the Chair of the AO Group to lead the meeting and facilitate discussion and decision-making, if required. The NWC Staff works with the 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 responsible for a variety of follow-up activities including: preparation of meeting minutes, the development of vote packages for NWC or NWCSSC paper votes, the scheduling of supplementary briefings, and the development of responses to members' questions or requests. The NWC Staff maintains the official records of the NWC, the NWCSSC, and the AO Group proceedings and other official documents.

The NWC Staff facilitates the timely development of the four annual reports for which the NWC is responsible. The NWC Staff manages the coordination of these reports with the many different representatives from the DoD and the DOE. NWC Staff activities include: publishing report milestone completion schedules, developing first and subsequent drafts of each annual report, conducting coordination meetings, consolidating and reconciling input from various participants, and guiding the reports through the progressive approval channels.

A.8 Annual Reports

The Nuclear Weapons Council is responsible for a number of annual reports. These include the Nuclear Weapons Stockpile Memorandum and Requirements and Planning Document, the Report on Stockpile Assessments, the Chairman's Annual Report to Congress, and the Joint Surety Report. Each of the NWC annual reports focuses senior-level attention on important nuclear weapons issues. Each report responds to a separate executive or congressional requirement; each has an individual purpose; and each communicates unique information. Figure A.6 illustrates the NWC Annual Reports schedule and nominal due date.

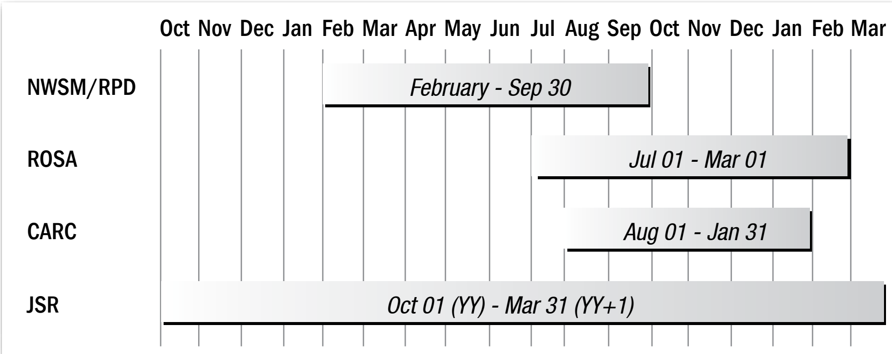

Figure A.6 NWC Annual Reports Schedule

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

The NWSM is an annual memorandum to the president from the secretaries of defense and energy. The NWSM transmits a proposed Presidential Directive, which, if approved, becomes the Nuclear Weapons Stockpile Plan. The NWSP specifies the size and composition of the stockpile for a projected multi-year 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 actually guides U.S. nuclear stockpile activities as mandated by the Atomic Energy Act. For ease of reference, the NWSM and the proposed Directive containing the NWSP are collectively called the "NWSM package" or "the NWSM."

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

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.[5] 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 Requirements and

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

Planning Document, previously known as the Long Range Planning Assessment (LRPA), was developed to facilitate this shift in emphasis. The RPD is now linked with the NWSM to form a single NWC vote package for coordination and approval through the NWC chair. The chair forwards the NWSM to the secretaries of defense and energy for signature and distributes the RPD to the NWC and NWCSSC members.

NWSM/RPD

Requirement:	*10 USC 179*
Reporting period:	*Fiscal Year*
Annual due date:	*September 30*
Drafted by:	*NWC Staff*
Coordinated through:	*NWCSSC and NWC*
Signed by:	*The Secretary of Defense and the Secretary of Energy*
Submitted/Transmitted to:	*The President and Congress*

The RPD 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 NWSM, which was formerly coordinated to satisfy a statutory requirement, has evolved into an instrument for programmatic authorization. This is particularly true for the 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 (AS and IS). If resources and throughput capacities were unconstrained, all weapons would be maintained as active ready (AR) warheads. Because resources and throughput capacities are severely constrained, the NNSA has had to develop innovative configuration management techniques to ensure that weapons are available in ready-for-use configuration when they are required by the DoD. Because not all weapons are maintained in an AR configuration, there are lead-times associated with reactivating weapons that are not in the active stockpile or designated as augmentation warheads. However, the readiness state of any particular warhead should be transparent to the force provider (the DoD) insofar as the NNSA is able to meet requirements for maintenance and reactivation on schedules previously agreed to by both departments. Readiness states are determined by stockpile category, location, and maintenance requirements.

Figure A.7 depicts the readiness states and categorizes them as part of the AS or the IS. There are currently ten different readiness states, defined below:

Readiness state 1A (RS-1A): Active ready warheads located on launchers or at an operational base that may be used for possible wartime employment, and must be fully maintained in a ready-to-use status at all times; i.e., all RS-1A warheads must have all of their limited life components (LLCs) installed, undergo life extension, and are assessed for reliability and safety.

Readiness state 1B (RS-1B): Logistics warheads positioned at various locations and used for logistical purposes to support upload quantities and that are intended to be maintained in a ready-to-use status; i.e., RS-1B warheads must have their LLCs installed, undergo life extension, and are assessed for safety and reliability, but may be in various states of disassembly to serve logistical requirements.

Readiness state 2A (RS-2A): AS augmentation warheads located either at an operational base or at a depot that may serve as active ready weapons (within a timeframe that does not exceed six months), and must be fully maintained in a ready-to-use status at all times; i.e., they have their LLCs installed, undergo life extension, and are assessed for reliability and safety.

ACTIVE STOCKPILE

RS -1A: Operationally deployed weapons*

RS-1B: Operationally deployed spares

RS-2A: AS Augmentation weapons

RS-2B: AS Augmentation spares

INACTIVE STOCKPILE

RS-3A: IS Augmentation weapons

RS-3B: IS Augmentation spares

RS-3C: QART Replacement warheads [R]

RS-3D: Reliability Replacement warheads [R]

RS-4C: QART Replacement Warheads [NR]

RS-5D: Reliability Replacement Warheads [NR]

* Weapons in any readiness state can be either strategic or non-strategic.

1 = Operationally deployed weapons
2 = Operationally deployed logistical spares
3 = Weapons that are planned for Life Extension when that warhead-type undergoes LEP
4 = Weapons that are not planned for LEP even when the rest of that warhead-type undergoes LEP
5 = Weapons that are only assessed for safety and reliability if no weapons of that type exist in RS 1-4

A = Wartime employment warheads
B = Logistics spares
C = QART warheads
D = Reliability Replacement warheads

[R] refurbished
[NR] not refurbished

Figure A.7 Warhead Readiness States

These warheads are included as part of the nuclear weapons stockpile hedge against unexpected reversals in the geopolitical security environment.

Readiness state 2B (RS-2B): AS Logistics warheads positioned at various locations, used for logistical purposes, and maintain in a ready-for-use status; RS-1B warheads must have their LLCs installed, undergo life extension, and are assessed for safety and reliability, but may be in various states of disassembly to serve logistical requirements.

Readiness state 3A (RS-3A): IS augmentation warheads located either at an operational base or at a depot that may serve as active ready weapons (within a timeframe that does not exceed six months), that have tritium components removed prior to their projected limited-life or stockpile-life dates, undergo life extension, and are assessed for reliability and safety. These warheads are included as part of the nuclear weapons stockpile hedge against unexpected reversals in the geopolitical security environment.

Readiness state 3B (RS-3B): IS logistics warheads positioned at various locations and used for logistical purposes that have the tritium components removed prior to their projected limited-life or stockpile-life dates, undergo life extension, and are assessed for reliability and safety, but may be in various states of disassembly to serve logistical requirements.

Readiness state 3C (RS-3C): IS quality assurance and reliability testing (QART) replacement warheads are located at either an operational base or a depot and used for QART replacement (i.e., to replace warheads consumed primarily in destructive testing during surveillance), that have the tritium components removed prior to their projected limited-life or stockpile-life date, undergo life extension, and are assessed for reliability and safety.

Readiness state 3D (RS-3D): IS reliability replacement warheads located either at an operational base or at a depot and used for reliability replacement (i.e., to replace warheads that have a safety, reliability, or yield problem; these weapons are part of the U.S. nuclear weapons stockpile hedge against unexpected technical failures and technological breakthroughs that threaten U.S. nuclear forces' survivability), that have the tritium components removed prior to their projected limited-life or stockpile-life date, undergo life extension, and are assessed for reliability and safety.

Readiness state 4C (RS-4C): IS QART replacement warheads are located at either an operational base or a depot and used for QART replacement (i.e., to replace warheads consumed primarily in destructive testing during surveillance), that have the tritium components removed prior to their projected limited-life or stockpile-life date, do not undergo life extension, but are assessed for reliability and safety.

Readiness state 5D (RS-5D): IS reliability replacement warheads located either at an operational base or at a depot and used for reliability replacement (i.e., to replace warheads that have a safety, reliability, or yield problem; these weapons are part of the U.S. nuclear weapons stockpile hedge against unexpected technical failures and technological breakthroughs that threaten U.S. nuclear forces' survivability), that have the tritium components removed prior to their projected limited-life or stockpile-life date, but do not undergo life extension, and are assessed for safety, but not for reliability. If these warheads needed to be reactivated for the technical hedge, the time period required for a reliability estimate for RD-5D warheads is approximately two years.

NWSM/RPD Development

When the military requirements are received from the Joint Staff in March, the NWC Staff develops and coordinates the NWSM/RPD package for review and comments 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 package is transmitted to the secretaries of defense and energy for signature.

After it is signed by the two secretaries, the NWSM is forwarded to the president with the proposed NWSP. The approved RPD is distributed to the NWC and NWCSSC members and is provided to the National Security Staff, if requested. The NWSM package is due annually to the president no later than September 30.

A.8.2 NWC Report on Stockpile Assessments

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 Test Ban Treaty." As a central part of this decision, the president 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.[6] The annual assessment process, of

[6] This clause is written into almost all international treaties. It states that 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 that are party to the treaty.

which the NWC Report on Stockpile Assessments (formerly called the "Annual Certification Report") is but one element, was originally developed to correspond with Safeguard F.

ROSA

Requirement:	*Statute*
Reporting period:	*Fiscal Year*
Annual due date:	*March 1*
Drafted by:	*NNSA/NWC Staff*
Coordinated through:	*NWCSSC and NWC*
Signed by:	*NWC Members*
Submitted/Transmitted to:	*The Secretary of Defense and the Secretary of Energy*

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 UGT. 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 testing moratorium, or until the CTBT receives U.S. ratification and enters into force, the annual assessment process serves to ensure that the safety and reliability of the stockpile is regularly evaluated in the absence of UGT.

The annual assessment process itself was originally modeled on the structure of Safeguard F, and that 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 FY03 National Defense Authorization Act (FY03 NDAA) legally codified the requirement for an annual stockpile assessment process. Specifically, Section 3141 of the FY03 NDAA requires that 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. The president must forward the reports to Congress by March 15.

These reports are prepared individually by the directors of the three DOE national security laboratories—Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories—and by the Commander of USSTRATCOM, 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 addition, the Commander of USSTRATCOM assesses the military effectiveness of the weapons. In particular, the reports include a recommendation on whether there is a need to conduct an underground nuclear test to resolve any identified issues. 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 a nuclear test. If an issue with a weapon were to arise that required a nuclear test to resolve, 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 NWC Chairman's Annual Report to Congress

An FY95 amendment to 10 USC 179 requires the NWC chairman to submit a report to Congress each fiscal year evaluating the "effectiveness and efficiency of the NWC and the deliberative and decision-making processes used." The CARC is submitted through the secretary of energy. The law requires that the CARC also contain a description of all activities conducted by the NNSA during the reporting period, as well as all nuclear weapons-related activities planned by the NNSA for the following fiscal year that have been approved by the NWC for the study, development, production, or retirement of nuclear warheads. When the president's budget is submitted to Congress, the secretary of energy is required to submit the CARC to Congress in a classified form. The report is sent to the House and Senate Committees on Armed Services and Appropriations. The first CARC was submitted to Congress in February 1995.

CARC

Requirement:	*FY95 amendment to 10 USC 179*
Reporting period:	*Fiscal Year*
Annual due date:	*NLT first Monday in February*
Drafted by:	*NWC Staff*
Coordinated through:	*NWC and NWCSSC*
Signed by:	*Secretary of Energy*
Submitted/Transmitted to:	*House and Senate Committees on Armed Services and Appropriations*

The NWC Staff drafts and coordinates the CARC in consultation with the AOs representing the NWC members. The report is coordinated at the NWCSSC level and forwarded to the NWC for final review and approval. After NWC approval, the CARC is signed by the NWC chairman and forwarded to the secretary of energy. The DOE prepares the eight letters containing the CARC to the committee chairpersons and ranking members. The secretary signs the letters, and they are then transmitted to Congress.

A.8.4 Joint Surety Report

National Security Presidential Directive 28, *United States Nuclear Weapons Command and Control, Safety, and Security*, dated June 20, 2003, requires the DoD and the DOE to prepare and submit to the President an annual joint surety report (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 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.

JSR

Requirement:	*NSPD-28*
Reporting period:	*Fiscal Year*
Annual due date:	*March 31*
Drafted by:	*NNSA/NWC Staff*
Coordinated through:	*NWC and NWCSSC*
Signed by:	*Secretary of Defense and Secretary of Energy*
Submitted/Transmitted to:	*The President*

Currently, the NNSA prepares the preliminary draft of the JSR. The NWC Staff is then responsible for further drafting and coordinating the JSR with input from the DoD and the 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 signature. The National Security Staff requires joint transmittal of the JSR along with the Nuclear Command and Control System Annual Report, prepared by the Nuclear Command and Control System Support Staff. The reports are due to the President by March 31 each year.

As the role of nuclear weapons changes in the United States, so, too, does the NWC change to adapt to the new environment. While the U.S. stockpile exists, however, it remains imperative to maintain a body like the NWC in order to ensure a “whole of government” approach to the coordination of activities associated with this central element of U.S. national security policy.

Appendix B
International Nuclear Treaties and Agreements

B.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 B.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 (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 (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 (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 Treaty (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 (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 (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 (SALT II)
Signed: 1979 | The SALT II Treaty 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 (INF))
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 (START I))
Signed: 1991 | Entry into force: 1994

Presidential Nuclear Initiatives (PNI)
Announced: 1991 (The PNI were "reciprocal unilateral commitments" and are thus 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 (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
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 B.1 Timeline of Nuclear-Related Treaties

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

Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
Southeast Asia	Brunei Darussalam, Cambodia , Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam
South Pacific	Australia, Cook Islands, Fiji, Kiribati, Nauru, New Zealand, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu

Figure B.2 Map of Nuclear Weapon-Free Zones

B.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 were able to work out arrangements for effective cooperation. 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 the 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, 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 operation of the treaty if any parties so request.

B.2.2 The Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco)

The idea of a Latin American Nuclear Weapons-Free Zone was first introduced to the United Nations General Assembly in 1962. On November 27, 1963, this declaration 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.

B.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. 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. 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;

[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.

- 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.

B.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 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 give assistance 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.

B.2.5 African Nuclear Weapon-Free Zone 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; however, the United States and Russia have not yet ratified those protocols. On May 3, 2010, Secretary of State Clinton announced that the United States would submit the protocols for Senate ratification.

B.2.6 Central Asian Nuclear Weapon-Free Zone

The concept of a Central Asian Nuclear Weapon-Free Zone (CANWFZ) first arose in a 1992 Mongolian initiative in which the country declared itself a nuclear weapon-free zone and called for the establishment of a regional NWFZ. A formal proposal for a Central Asian Nuclear Weapon-Free Zone was made by Uzbekistan at the 48th session of the United Nations General Assembly in 1993, but a lack of regional consensus on the issue blocked progress on a CANWFZ until 1997. On February 27, 1997, the five presidents of the Central Asian states (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) issued the Almaty Declaration, which called for the creation of a CANFWZ.

The text of the CANWFZ treaty was agreed upon at a meeting held in Uzbekistan from September 25-27, 2002. On February 8, 2005, the five states adopted a final draft of the treaty text, and the treaty was opened for signature on September 8, 2006. The treaty establishing the CANWFZ entered into force on March 21, 2009. The United States has not ratified the Protocol to the treaty.

B.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 under ground, 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.

B.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.

B.5 Strategic Arms Limitation Talks

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.

B.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.

B.5.2 Interim Agreement - 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. Neither side would 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. Mobile ICBMs were not covered.

B.5.3 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: the weapon systems to be included; factors involved in providing for equality in numbers of strategic nuclear delivery vehicles, taking into account the important differences between the forces of the two sides, bans on new systems, qualitative limits, and a Soviet proposal to include U.S. forward-based systems. The positions of the sides differed widely on many of these issues. In subsequent negotiations, the sides 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 Treaty. The duration of the treaty was to have been 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 because of 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 it had made its intentions clear not to become a party to the treaty.

SALT II has never entered into force.

B.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 detailing the technical data to be exchanged and limited weapon testing to specific designated test sites to assist 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 has taken place, the geographic coordinates of the test location were to be furnished to the other party to help in placing the test in the proper geological setting and in assessing the 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, this exchange improved assessments by both parties of 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.

For many years, neither the United States nor the Soviet Union ratified the TTBT or the PNET. 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 agreement on additional verification provisions that would make it possible for the United States to ratify the two treaties. Agreement on additional verification provisions, contained in new protocols substituting for the original protocols, was reached in June 1990. The TTBT and PNE Treaty both entered into force on December 11, 1990.

B.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.

B.8 Intermediate-Range Nuclear Forces Treaty

The *Treaty between the United States of America and the Union of Soviet Socialist Republics on the Elimination of their Intermediate-Range and Shorter-Range Missiles*, commonly referred to as the Intermediate-Range Nuclear Forces (INF) Treaty, 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. On December 8, 1987, the treaty was signed by President Ronald Reagan and General Secretary Mikhail Gorbachev at a summit meeting in Washington, D.C. 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 continuation of full implementation 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 inspectable facilities on their territory, namely Russia, Ukraine, Belarus, Kazakhstan, Turkmenistan, and Uzbekistan. The multilateralizing of what was previously a bilateral U.S.-Soviet INF Treaty required establishing agreements between the United States and the governments of the relevant Soviet Successor States on numerous issues. Among the tasks undertaken were: arrangements for the settlement of costs connected with implementation activities in the new, multilateral treaty context; 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.

B.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 requires 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). 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 had a 15-year duration and allowed the parties an option to extend it for 5-year periods, but the United States and the Russian Federation decided against that option and allowed the treaty to expire on December 5, 2009. Negotiations for the follow-on to START I were ongoing, and the agreement, called New START, was signed in Prague on April 8, 2010.

B.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 announced the Soviet response. President Gorbachev pledged the destruction of all nuclear artillery ammunition and nuclear mines, the removal of nuclear warheads from anti-aircraft missiles and all theater nuclear weapons on surface ships and multi-purpose submarines, the dealerting of strategic bombers, and the abandonment of plans to develop mobile ICBMs and to build new mobile launchers for existing ICBMs. He also pledged to eliminate an additional 1,000 nuclear warheads beyond those 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.

B.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 MIRVed ICBMs (including all heavy ICBMs), limit the number of SLBM warheads to no more than 1,750 and reduce the overall 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 Treaty 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.

B.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. Nine 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 continues to observe a self-imposed moratorium on underground nuclear testing, which began in 1992.

B.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 will reduce their strategic nuclear warheads to a level between 1,700 and 2,200 by December 31, 2012, nearly two-thirds below current levels. Each side may determine for itself the composition and structure of its strategic forces consistent with this limit.

Both the United States and Russia intend to reduce their strategic offensive forces to the lowest possible levels, consistent with their national security requirements and alliance obligations, reflecting the new nature of their strategic relationship. 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. In addition, there will be some logistical spares stored 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.

B.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 the treaty, the United States and Russia will be limited to significantly fewer strategic arms within seven years from the date the treaty enters into force. Each party has the flexibility to determine for itself 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.
- 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. The parties may agree to extend the treaty for a period of no more than five years. The treaty entered into force on February 5, 2011.

B.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, and 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.

B.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. Inspections also can include remote inspection activities to include remote monitoring of movement of declared material in a facility and the evaluation of 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 6: *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.

B.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, 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, so as to increase transparency and supplement verification provisions.

Appendix C
Basic Nuclear Physics

C.1 Overview

This appendix offers a basic overview of nuclear physics, which is the study of the properties of the atomic nucleus—the very tiny object at the center of every atom. This short tutorial is meant to be neither an authoritative nor a comprehensive examination of the subject. Instead, the purpose of this appendix is to provide background information useful in understanding the basic technical aspects of the U.S. nuclear stockpile, which are significant considerations for many important programmatic decisions. This appendix also serves to provide an understanding of the complexity of the science behind nuclear weapons and how this complexity affects weapon design, component production, and post-fielding issues.

C.2 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 over 110 known chemical substances, each of which cannot be broken down further without changing its chemical properties. Some examples are hydrogen, nitrogen, silver, gold, uranium, and plutonium. The smallest unit of a given amount of an element is called an atom. Atoms are composed of electrons, protons, and neutrons. For the purpose of this book, there is no benefit in discussing a further breakout of sub-atomic particles.

Nuclear weapons depend on the potential energy that can be released from the nuclei of atoms. In the atoms of the very heavy elements that 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. Electron interactions determine the chemical characteristics of matter, and 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 (e.g., copper and silver are better conductors than sulfur); and the ability to undergo chemical reactions, such as oxidation (e.g., iron and oxygen combine to form iron oxide or rust). On the other hand, nuclear characteristics are based on an element's tendency to undergo changes at the nuclear level, regardless of the number of electrons it contains. Examples of nuclear characteristics include: the tendency of a nucleus to split apart or fission (e.g., atoms of certain types of uranium will undergo fission more readily than atoms of iron) and the ability of a nucleus to absorb a neutron (e.g., the nuclei of certain types of cadmium will absorb a neutron much more readily than beryllium nuclei). An important difference between chemical and nuclear reactions is that there can neither be a loss nor a gain of mass during a chemical reaction, but mass can be converted to energy in a reaction at the nuclear level. In fact, this change of mass into energy is what is responsible for the tremendous release of energy during a nuclear explosion.

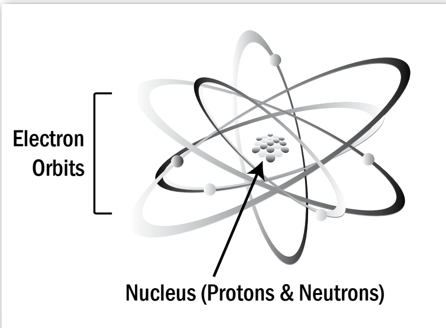

Figure C.1 Diagram of an Atomic Structure

The number of protons in an atom identifies the element to which it belongs. For example, every atom with eight protons belongs to the element called oxygen, and every oxygen atom has eight protons. There are 92 naturally occurring elements. In addition to these, modern technology has enabled scientists to increase the number of elements to more than 110 by artificially producing them. The periodic table is a tabular method of displaying the chemical elements, first devised in 1869 by the Russian chemist, Dmitri Mendeleev. Mendeleev intended the table to illustrate recurring ("periodic") trends in the properties of the elements; hence, this listing of elements became known as the periodic table. See Figure C.2 for an illustration of the periodic table.

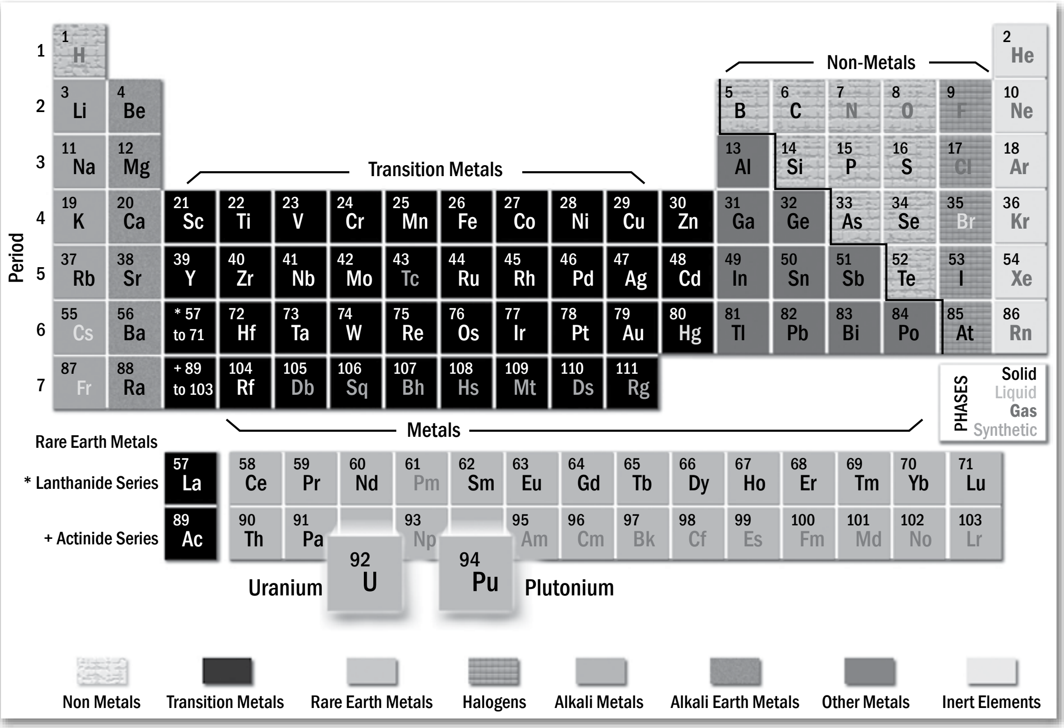

Figure C.2 Periodic Table

Atoms are electrically neutral when the number of negatively charged electrons orbiting the nucleus equals the number of positively charged protons within the nucleus. When the number of electrons is greater than or less than the number of protons in the nucleus, atoms are no longer electrically neutral; instead, they carry a net-negative or net-positive charge. They are then called ions. Ions are chemically reactive and tend to combine with other ions of opposite net charge. When atoms are combined in molecules, they may share electrons to achieve stability of the electron shell structure.

The term *atomic number* (Z) describes the number of protons in a nucleus, and because the number of protons determines the element, each different element has its own atomic number. Atoms of different elements have different numbers of protons in their nuclei.

The total number of protons and neutrons in an atomic nucleus is referred to as the *atomic mass* or *atomic weight* (A). A method of denoting atomic structure that is often used is $^{A}_{Z}X$, where X is the chemical symbol of the element. Another common format uses the name of the element followed by a dash and the atomic weight, e.g., uranium-233 (U-233). This information is typically not included in a periodic table, but it can be determined from a chart of the nuclides, which details specific nuclear properties of the elements and their isotopes. Isotopes are atoms that have identical atomic numbers (same number of protons) but a different atomic mass (different numbers of neutrons). This distinction is important because different isotopes of the same element can have significantly different nuclear characteristics. For example, when working with uranium, U-235 has significantly different nuclear characteristics than U-238, and it is necessary to specify which isotope is being considered. See Figure C.3 for an illustration of two of the 23 currently known isotopes of uranium.

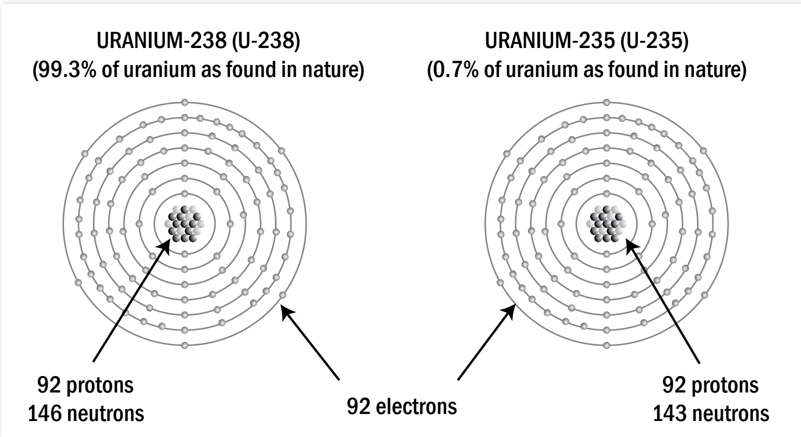

Figure C.3 Isotopes of Uranium

C.3 Radioactive Decay

Radioactive decay is the process of nucleus breakdown and the resultant particle and/or energy release as the nucleus attempts to reach a more stable configuration. The nuclei of many isotopes are unstable and have statistically predictable timelines for radioactive decay. These unstable isotopes are known as radioisotopes. Radioisotopes have several decay modes, including alpha, beta, and gamma decay and spontaneous fission. The rate of decay is often characterized in terms of "half-life," or the amount of time required for half of a given amount of the radioisotope to decay. Half-lives of different isotopes range from a tiny fraction of a second to billions of years. Rate of decay is also characterized as activity, or the number of decay events or disintegrations that occur in a given time.

C.4 Nuclear Reactions

The splitting apart of atoms, called fission, and the fusing together of atoms, called fusion, are key examples of nuclear reactions or reactions that can be induced in the nucleus. Fission occurs when an element with a very large nucleus, such as plutonium, is split into smaller pieces. This may occur spontaneously, or it may occur when a sub-atomic particle, such as a neutron, collides with the nucleus and imparts sufficient energy to cause the nucleus to split apart. The fission that powers both nuclear reactors and nuclear weapons is typically the neutron-induced fission of certain isotopes of uranium or plutonium. Fusion occurs when the nuclei of two atoms, each with a small nucleus, such as hydrogen, collide with enough energy to fuse two nuclei into a single larger nucleus. Fusion occurs most readily between nuclei with just a few protons, as in the isotopes of hydrogen.

C.4.1 Fission

During nuclear fission, a nucleus splits into two or more large fission fragments, which become the nuclei of newly created lighter atoms, and which are almost always radioactive (prone to radioactive decay). Fission releases a large amount of energy—millions of times more energy than the chemical reactions that cause conventional explosions. The fission process will almost always release some number of neutrons that can, in turn, cause other nuclei to fission; this is known as a *chain reaction*. See Figure C.4 for an illustration of a fission event.

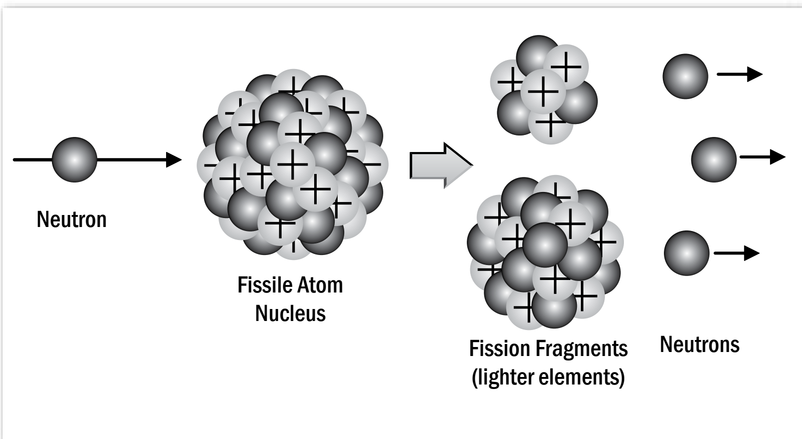

Figure C.4 Fission Event

Criticality describes whether the rate of fission increases (supercritical), remains constant (critical), or decreases (subcritical) in a particular situation. See Figure C.5 for an illustration of a sustained chain reaction of fission events. In a highly supercritical configuration, the fission rate increases very quickly, which results in the release of tremendous amounts of energy in a very short time, causing a nuclear detonation. For this reason, the fissile material in a nuclear weapon must remain subcritical until detonation is required.

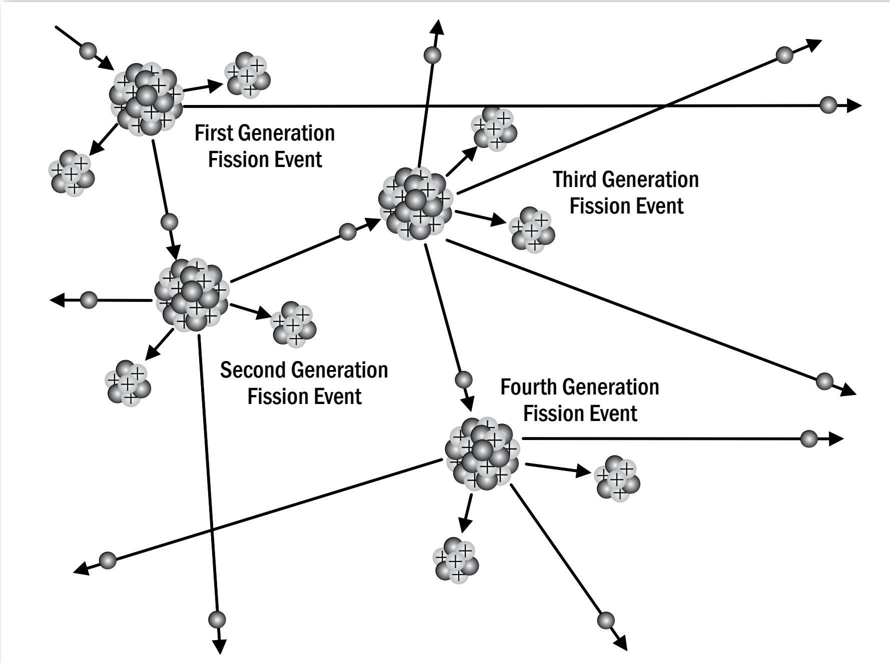

Figure C.5 Sustained (Critical) Chain Reaction

There are seven factors that affect criticality: the type of fissile material, the amount of fissile material, the enrichment of the material, the purity of the material, the shape of the material, the density of the material, and the environment. Different types of fissile isotopes have different probabilities of fission when their nuclei are hit with a neutron (called "cross-section") and produce a different average number of neutrons per fission event. These are the two primary factors in determining the material's fissile efficiency. 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. Enrichment is a term that indicates the percentage of the fissile material that is a more fissile efficient isotope than the other isotopes in that material. For this reason, using the words uranium or plutonium to describe some material as fissile material does not provide enough information to determine its isotopic distribution within that material. The purity of fissile material is important because either production of the fissile material or radioactive decay within the material can cause the material to contain atoms that act as neutron absorbers, which will decrease the material's fissile efficiency. Shape is important because some shapes (for example, a sphere) will increase the probability of neutrons meeting nuclei within the material, causing a subsequent fission event, and other shapes (for example, material in a long thin line) will decrease the probability that neutrons produced from one fission event can interact with another nucleus to cause another fission event. Density is important because the closer the fissile nuclei are, the more likely the neutrons are to interact with those nuclei before they can escape to the perimeter of the material. The environment in which the fissile material is contained is important because if a neutron-reflecting material immediately surrounds the fissile material, then neutrons that would otherwise escape at the perimeter of the material will be reflected back into the fissile material to cause other fission events. Additionally, if the fissile material is immediately surrounded by a huge amount of material, such as being buried deeply underground, then the surrounding material "tamps" the fissile material, keeping it together for a longer period of time (only a small fraction of a second) before it can explosively separate.

Only a handful of isotopes can support a chain reaction. The most important of these fissile isotopes are uranium-235 (U-235) and plutonium-239 (Pu-239); these are the only fissile isotopes that currently exist in large quantities. Obtaining significant quantities of fissile material has historically been the greatest challenge to a country seeking to build nuclear weapons.

Natural uranium consists of approximately 99.3 percent U-238, approximately 0.7 percent U-235, and very small amounts of other uranium isotopes. For use in weapons, the U-235 fraction must be enriched relative to the more abundant U-238 isotope. There are several different ways to enrich uranium, but all of them require significant technical expertise and energy. Figure C.6 depicts the typical uranium enrichment process. The process begins with a large amount of natural uranium converted to a form that can be processed for enrichment; currently, the gaseous compound uranium hexafluoride (UF6) is the most commonly used form. At each stage, the UF6 is subjected to a force that separates the UF6 with the heavier U-238 atoms from the UF6 with the lighter U-235 atoms by a small fraction of a percent. The portion of the UF6 with more of the fissile isotope U-235 is called enriched; the portion with more of the non-fissile U-238 is called depleted. By putting the enriched UF6 through successive stages, it becomes slightly more enriched at each stage. Initially, it is considered low enriched uranium (LEU). When it reaches 20 percent U-235, it is called highly enriched uranium (HEU). After thousands of enrichment stages, it can be enriched to approximately 90 percent U-235, which is considered to be weapons-grade HEU and can be configured into a weapon-sized package to produce a nuclear detonation.

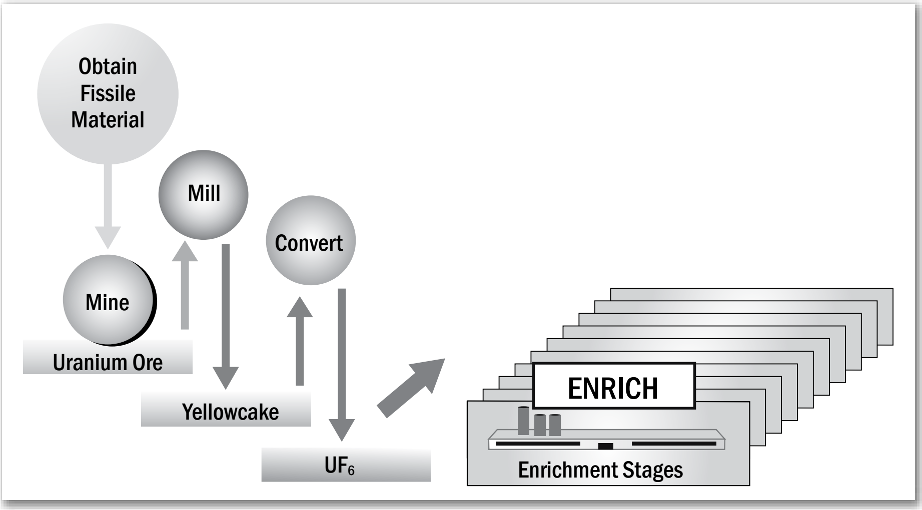

Figure C.6 Uranium Enrichment Process

By the end of the process, the very large amount of natural uranium has had most of the U-238 stripped away from the fissile U-235, leaving only a small fraction of the original quantity of uranium, but that small quantity has a much larger percentage of U-235. The U-235 has not been created or produced; it has only been separated away from most of the non-fissile U-238.

Plutonium is another fissile material used in nuclear weapons; it does not occur naturally in practical quantities. Plutonium is produced in nuclear reactors when U-238 nuclei absorb a neutron and become U-239. The resulting nuclei decay (via beta decay) to neptunium-239 and then to Pu-239, which is the plutonium isotope desired for nuclear weapons. As the reactor operates, the amount of plutonium increases and gradually becomes contaminated with undesirable isotopes due to additional neutron absorption.

Over time, the percentage of the undesirable isotopes, especially Pu-240 and Pu-241, increase. These heavier isotopes have shorter half-lives than Pu-239, making the material "hotter" for gamma radiation emissions. While the percentage of the undesirable isotopes is 7 percent or less, it is considered to be weapons-grade Pu. When that percentage becomes greater than 7 percent, it is considered to be reactor-grade Pu, and when the percentage exceeds 15 percent, it is considered "high-level waste" plutonium, with a high level of radioactivity that precludes it from being handled safely with the normal procedures for weapons-grade Pu.

This means that for the plutonium to be weapons-grade, the "spent" fuel containing Pu-239 must be removed more frequently. If the reactor is serving to both produce electricity and plutonium, this results in additional costs and less efficient power production. The plutonium must be chemically separated from the other elements in the "spent" nuclear fuel and extracted if it is to be used as fissile material for a nuclear weapon. This reprocessing step is an additional challenge for those who wish to divert weapons-grade plutonium from reactors that produce electricity.

C.4.2 Fusion

In general, fusion may be regarded as the opposite of fission. Nuclear fusion is the combining of two light nuclei to form a heavier nucleus. For the fusion process to take place, two nuclei must be forced together by sufficient energy so that the strong, attractive, short-range, nuclear forces overcome the electrostatic forces of repulsion. Because the positively charged protons in the colliding nuclei repel each other, it takes a large amount of energy to get the nuclei close enough to fuse. It is, therefore, easiest for nuclei with smaller numbers of protons, such as the isotopes of hydrogen, to achieve fusion. One of the most important fusion reactions occurs between two isotopes of hydrogen, deuterium (H-2) and tritium (H-3), resulting in helium-4 (HE-4) plus one high-energy free neutron (a neutron unattached to a nucleus), which can be used in a nuclear weapon to cause another fission event. Fusion also releases millions of times more energy than a chemical reaction does. See Figure C.7 for an illustration of a fusion event.

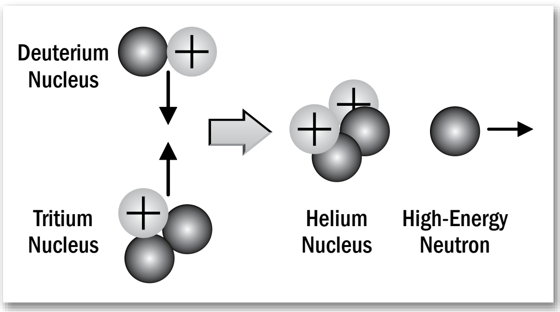

Figure C.7 Fusion Event

C.5 Basic 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).

A variety of names are used for weapons that release energy through nuclear reactions—atomic bombs, hydrogen bombs, nuclear weapons, fission bombs, fusion bombs, and thermonuclear weapons. Therefore, it is necessary to address terminology.

The earliest name for a nuclear weapon was *atomic bomb* or *A-bomb*. These terms have been criticized as misnomers because all chemical explosives generate energy from reactions between atoms. Specifically, when exploded, conventional explosives release chemical molecular binding energy that had been holding atoms together as a molecule. Technically, a fission weapon is a "nuclear weapon" because the primary energy release comes from the nuclei of fissile atoms; it is no more "atomic" than any other weapon. However, the name is firmly attached to the pure fission weapon and is well-accepted by historians, the public, and by some of the scientists who created the first nuclear weapons.

Fusion weapons are called *hydrogen bombs* or *H-bombs* because isotopes of hydrogen are the principal components of the large number of fusion events that add significantly to the nuclear reactions involved. Fusion weapons are also called *thermonuclear weapons* because high temperatures and pressure are required for the fusion reactions to occur.[1] Because the distinguishing feature of both fission and fusion weapons is that they release energy from the transformations of the atomic nucleus, the best general term for all types of these explosive devices is *nuclear weapon*.

C.5.1 Achieving Supercritical Mass

To produce a nuclear explosion, a weapon must contain an amount of fissile material (usually either HEU or plutonium) that exceeds the mass necessary to support a critical chain reaction; in other words, a supercritical mass of fissile material is required. A supercritical mass can be achieved in two fundamentally different ways. One way is to have two subcritical components positioned far enough apart so that any stray neutrons that cause a fission event in one subcritical component will not 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 joined together. A second approach is to have one subcritical fissile component surrounded with high explosives (HE). When the detonation is desired, the HE is exploded with its force driving inward to compress the fissile component, causing it to go from subcritical to supercritical. Each 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 that the fissile material reaches its designed supercriticality, so that the first generation of fission events in the multiplying chain reaction will be a larger number of events.

Currently, nuclear weapons use one of four basic design approaches: gun assembly, implosion assembly, boosted, or staged. (This list is in order of simplest to most sophisticated—and thus most difficult to successfully produce.)

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

C.5.2 Gun Assembly Weapons

Gun assembly (GA) weapons use the first approach described above to producing a supercritical mass and rapidly assemble two subcritical fissile components into one supercritical mass. This assembly may be structured in a tubular device in which an explosive is used to drive one subcritical mass of fissile material from one end of the tube into another subcritical mass held at the opposite end of the tube. When the two fissile components are brought together, they form one supercritical mass of fissile material capable of sustaining a multiplying chain reaction of fission events.

In general, the GA design is less technically complex than other designs. It is also the least efficient.[2] Figure C.8 illustrates how a GA weapon achieves supercriticality.

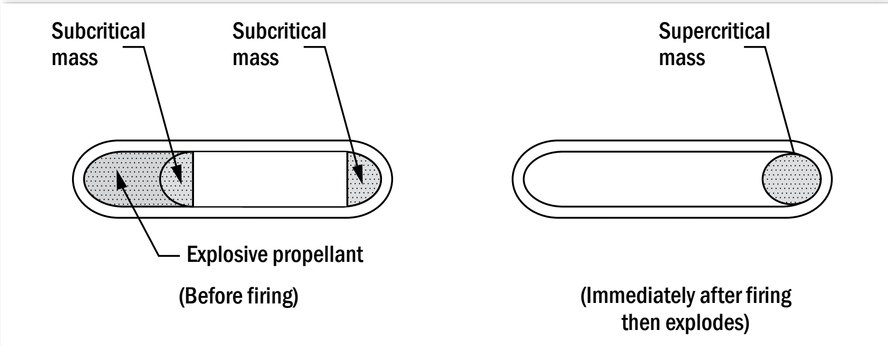

Figure C.8 TCG-NAS-2 Unclassified Illustration of a GA Weapon

C.5.3 Implosion Assembly Weapons

Implosion assembly (IA) weapons use the second method of achieving a supercritical mass, imploding one subcritical fissile component to achieve greater density and a supercritical mass. Here, a subcritical mass of HEU or weapons-grade Pu is compressed (the volume of the mass is reduced) to produce a supercritical mass capable of supporting a multiplying chain reaction. This compression is achieved by the detonation of specially designed high explosives surrounding a subcritical sphere of fissile material. When the high explosive is detonated, an inwardly directed implosion wave is produced. This wave compresses the sphere of fissile material. The decrease in the surface-to-volume ratio of this compressed mass plus its increased density are then sufficient to make the mass supercritical because the fissile nuclei will be much closer together. The proximity of the fissile nuclei increases

[2] *Technical efficiency* is measured by the amount of energy produced for a given amount of fissile material. Less efficient devices require a lot of material to produce a relatively smaller sized nuclear detonation.

the probability that any given neutron will cause a fission event while simultaneously decreasing the probability that a neutron will escape the critical mass rather than cause a fission event. See Figure C.9 for an illustration of an implosion assembly weapon.

In general, the implosion design is more technically complex than the GA design, and it is more efficient.

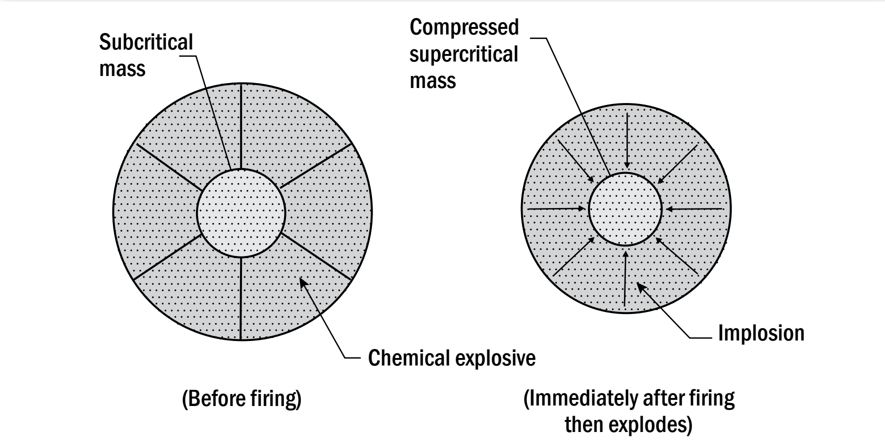

Figure C.9 TCG-NAS-2 Unclassified Illustration of an IA Weapon

C.5.4 Boosted Weapons

It is possible to increase the efficiency and yield for a weapon of the same volume and weight when a small amount of material suitable for fusion, 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. A small amount of fusion gas (measured in grams) in this environment 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 explosion) 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 it is also more efficient.

C.5.5 Staged Weapons

A more powerful and technically complex version of a boosted weapon uses both fission and fusion in stages. In the first stage, a boosted fission device called the primary releases the energy of a boosted weapon in addition to a large number of X-rays. The X-rays produced by the primary stage transfer energy to the secondary stage, causing that material to undergo fusion, which releases large numbers of high-energy neutrons. These neutrons, in turn, interact with the fissile and fissionable material to cause a large number of fission events, thereby significantly increasing the yield of the whole weapon. See Figure C.10 for an illustration of a staged weapon.

In general, the two-stage weapon design is more technically complex than the boosted weapon design. The two-stage design can produce much larger yields.

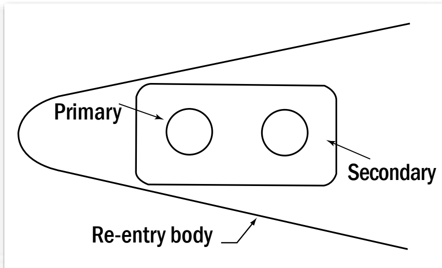

Figure C.10 TCG-NAS-2 Unclassified Illustration of a Staged Weapon

C.5.6 Proliferation Considerations

Generally, the smaller the size (volume, dimensions, and weight) of the warhead, the more difficult it is to get the nuclear package to function properly to produce a nuclear detonation, and the harder it is to achieve a higher yield.

The simplest and easiest design is the gun assembly design, followed by the implosion design. Because the boosted and two-staged designs are significantly more difficult, they are not practical candidates for any nation's first generation of nuclear weapons. There is no evidence that any nuclear-capable nation was able to produce either of these as their first workable warhead.

While the United States pursued both the GA and the implosion designs in the Manhattan Project, with one exception, other nations that have become nuclear-capable have focused on the implosion design for a number of reasons. First, the GA design is the least efficient design for producing yield per amount of fissile material. Second, the GA design has inherent operational disadvantages that are not associated with the other designs. Third, Pu is susceptible to predetonation in a GA design, requiring HEU for the GA weapon; however, HEU is extremely expensive because of the cost of the enrichment process. Pu, on the other hand, is produced in a reactor that can also be used for the simultaneous production of electrical power, which could positively affect a nation's economy in contrast to the economic drain associated with a costly enrichment process.

Up to this time, nations that have pursued a nuclear weapons capability have been motivated to design warheads to be small enough to be delivered using missiles or high-performance jet aircraft.[3] This is probably because, unlike the situation in the early 1940s, today almost all nations (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 to almost any potential adversary's target. For this reason, it is highly likely that the first generation weapons developed by proliferating nations will be low-yield weapons, typically between one and 10 kilotons (kt).[4]

[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 – 3,300 pounds), and approximately 750 to 1,000 kg (1,650 – 2,200 pounds) for the typical missile being proliferated, e.g., NODONG or SCUD-variant missiles.

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

Appendix D
U.S. Nuclear Weapons Life-Cycle

D.1 Overview

Nuclear weapons are developed, produced, and 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 Department of Defense (DoD) and the Department of Energy (DOE) (through the National Nuclear Security Administration (NNSA)) have specific responsibilities related to nuclear weapons life-cycle activities. The life-cycle process details the steps through which nuclear weapons development progresses from concept to production to retirement. Figure D.1 depicts the traditional joint DoD-NNSA nuclear weapons life-cycle phases. This chapter describes the most significant activities and decision points of the traditional phases in 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. No U.S. nuclear weapons have undergone the full life-cycle phase process since the W-88 finished Phase 5 in 1991. The United States has not produced new nuclear weapons since 1991.

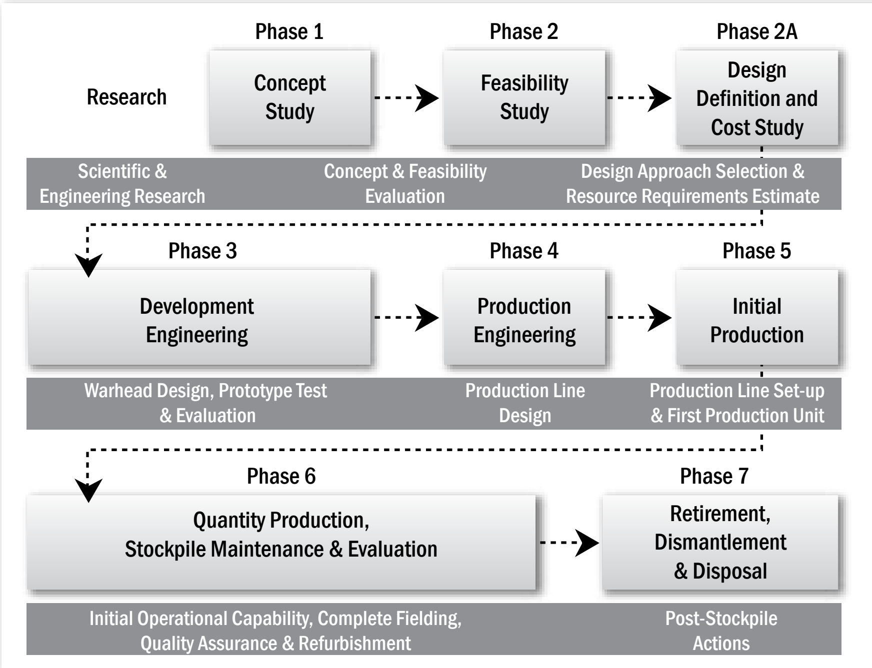

Figure D.1 Joint DoD-NNSA Nuclear Weapons Life-Cycle Phases

D.2 Phase 1 – Concept Study

Phase 1 of the joint nuclear weapons life-cycle process is a study to: preliminarily assess the effectiveness and survivability of a weapon concept, identify delivery system/nuclear warhead trade-offs, develop an initial program schedule, and develop draft documents for the military characteristics (MCs)[1] and the stockpile-to-target sequence (STS).[2]

A Phase 1 Study usually begins as a result of a major DoD program start for a nuclear weapons system, although the NNSA may also initiate a Phase 1 Study. Alternatively, a Phase 1 Study can begin by mutual agreement between a DoD component organization (a Military Service, the Defense Threat Reduction Agency (DTRA), the Joint Staff, or an Office of the Secretary of Defense (OSD)) and the NNSA. There is no formal requirement for any approval to start a Phase 1 Study. Normally, a Phase 1 Study Group (SG) is formed that consists of representatives from all interested agencies.

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

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

Usually, the results of the Phase 1 analysis are published in a Concept Study Report. Regardless of the results of a Phase 1 Study, there is no automatic commitment to proceed to the next phase.

D.3 Phase 2 – Feasibility Study

Phase 2 is a study to determine the technical feasibility of a weapon concept. At this stage, there may be many alternative concepts. The lead Military Service initiates the request to begin Phase 2, and the Nuclear Weapons Council Standing and Safety Committee (NWCSSC) considers the request. If the request is approved by the NWCSSC, both the DoD and the NNSA agree to participate. The DoD provides draft MCs and STS documents, major weapon and warhead parameters, and program milestones, including the date of the initial operational capability (IOC), warhead quantity at IOC, and total quantity required.

A Phase 2 Study is usually conducted by a Project Officers Group (POG). A senior OSD official appoints the lead Military Service to represent the DoD and forwards this request to the NWCSSC. A POG is conducted as a “committee” and is chaired by a Lead Project Officer (LPO) from the OSD-designated lead Military Service. POG members may come from any Military Service or NNSA organization with an interest in the program. The Joint Staff, DTRA, and the OSD may attend the meetings as observers.

Normally, before completing Phase 2, the NNSA issues a Major Impact Report (MIR) that provides a preliminary evaluation of the significant resources required for the program and the impact that the program may have on other nuclear weapons programs. At the conclusion of Phase 2, the findings are published in a report.

A Phase 2 Report may include a recommendation to proceed to Phase 2A. If appropriate, the lead Military Service will initiate a recommendation to proceed to Phase 2A. Regardless of the results of a Phase 2 Study, there is no automatic commitment to proceed to the next phase.

D.4 Phase 2A – Design Definition and Cost Study

NWCSSC approval is required to begin Phase 2A, which is a study conducted by the POG to refine warhead design definition, program schedule, and cost estimates.

At the beginning of Phase 2A, the NNSA selects the design team for the remainder of the program. The design team is one of two U.S. nuclear physics laboratories—either Los Alamos National Laboratory (LANL) or Lawrence Livermore National Laboratory (LLNL). The selected physics laboratory and its Sandia National Laboratories (SNL) counterpart participate in POG activities to refine requirements and resource trade-offs, establish a warhead baseline design, and estimate costs. In some cases, the NNSA may choose to retain two design teams beyond the beginning of Phase 2A.

At the end of Phase 2A, the NNSA publishes a Weapon Design and Cost Report (WDCR) that identifies baseline design and resource requirements, establishes tentative development and production schedules, and estimates warhead costs. The POG publishes a Phase 2A Report that: provides a trade-off analysis between DoD operational requirements and NNSA resources, identifies a division of responsibilities between the DoD and the NNSA, and makes a recommendation concerning continued development. The report also considers existing designs, required special nuclear material (SNM), and safety factors. The Phase 2A Report is transmitted to the NWCSSC.

D.5 Phase 3 – Full-Scale Engineering Development

Phase 3 is a joint DoD-NNSA effort to design, test, and evaluate the warhead to engineering standards. It is intended to develop a safe, reliable, producible, maintainable, and tested nuclear weapon design based on the requirements of the MCs and STS and the guidance in the Nuclear Weapons Stockpile Plan (NWSP). The start of Phase 3 is requested by the lead Military Service, reviewed by the NWCSSC and the NWC, and approved by the Secretary of Defense. The 2003 Defense Authorization Act requires the Secretary of Energy to request funding in the President's Budget for any activities relating to the development of a new nuclear weapon or modified nuclear weapon. This requirement effectively mandates congressional approval to proceed into and beyond Phase 3.

During Phase 3, the warhead is designed to meet the MCs and STS requirements with engineering specifications sufficiently complete to enter initial production. Prototypes of each component are tested and evaluated. Estimates of the schedule, technical risk, and life-cycle cost are refined.

In the past, a Phase 3 would include at least one developmental nuclear test to confirm that the design was meeting requirements. If significant redesign was required, a second developmental nuclear test may have been conducted.[3]

Prior to the completion of Phase 3, the DOE issues a Preliminary Weapon Development Report (PWDR). Based on this report, the DoD conducts a preliminary Design Review and

[3] In some cases, the second nuclear test may have been conducted after the beginning of Phase 4.

Acceptance Group (DRAAG) evaluation to determine if the expected warhead characteristics will meet DoD requirements.

The NWCSSC reviews each weapon program annually during Phase 3 and Phase 4. The POG addresses weapon system requirements relevant to weapon characteristics and required delivery schedules. The two departments review all issues related to the weapon development program.

D.6 Phase 4 – Production Engineering

Phase 4 consists of an internal NNSA effort to transition the developmental warhead design into a successful manufacturing process. During this phase, the required production line equipment and tools are designed to ensure that all required components can be produced. The NNSA notifies the NWCSSC, the POG, and the Military Services of the start date for Phase 4.

Non-nuclear test and evaluation of component prototypes continues through Phase 4. The POG continues to meet as needed to share information and to solve problems concerning competing characteristics and trade-offs.

At the end of Phase 4, the appropriate NNSA laboratories issue a Complete Engineering Release (CER) for each component, assembly, and sub-assembly. All relevant CERs must be issued before the start of Phase 5.

D.7 Phase 5 – First Production

Phase 5 is a transition period during which the NNSA procures raw materials, establishes the production line, starts producing components, evaluates the production processes and products, and makes modifications if necessary. Before a new weapon program can enter Phase 5, it must be authorized by the president; this is normally done as a part of the annual NWSP. The start is determined by the NNSA based on the production time required to meet the warhead IOC date. The NWC notifies the DoD of the NNSA decision to begin Phase 5. Normally, the NNSA produces all the components for the nuclear warhead, but in some cases, the DoD may produce some non-nuclear components necessary for warhead function (such as the parachute in certain gravity bombs).

During Phase 5, the NNSA tests and evaluates warhead components from the production line. The POG meets as required to solve any problems concerning competing characteristics and trade-offs.

Most warheads produced in Phase 5 are used for quality assurance (QA) testing. Some warheads produced in Phase 5 may be delivered to the DoD as war reserve (WR) warheads to meet the IOC. During this phase, the Nuclear Weapon System Safety Group (NWSSG) conducts a pre-operational safety study to determine the adequacy of safety features in the nuclear weapon system and reviews procedures for operation of the system.

Before the completion of Phase 5, the DOE issues a Final Weapon Development Report (FWDR). Based on this report, the DoD conducts a final DRAAG evaluation to determine if the warhead characteristics will meet DoD requirements.

Phase 5 culminates in the issuance of a Major Assembly Release (MAR) in which the NNSA formally states that the weapon is satisfactory for release to the DoD for specific uses. The MAR is prepared by the design physics laboratory and approved by NNSA Headquarters. Following issuance of the MAR, the first production unit (FPU) is released.

D.8 Phase 6 – Quantity Production and Stockpile Maintenance and Evaluation

The beginning of Phase 6 is determined by the NNSA after NWC approval of the final DRAAG Report. The NNSA notifies the NWCSSC, the POG, and the Military Services of the start date for Phase 6.

Normally, IOC occurs shortly after the start of Phase 6. The conditions to achieve IOC include the requirement that a specific number of WR warheads are deployed with an operationally certified military unit. IOC conditions usually differ for each warhead-type, and IOC dates are usually classified until after they occur.

During Phase 6, the production rate of WR warheads and components increases, and the warheads are stockpiled. In the past, the production portion of Phase 6 has lasted from a few years to ten years or more. Phase 6 continues beyond the production of the last warhead and lasts until all warheads of that type are retired.

During Phase 6, the NNSA continues to test and evaluate components as part of the Quality Assurance and Reliability Testing (QART) program, which includes stockpile laboratory tests (SLTs) and stockpile flight tests (SFTs). Normally, the NNSA would continue component production beyond those required for WR warheads to establish an inventory of components intended for future-year surveillance item rebuild under the QART program. (For more information on the QART program and its associated tests, see Appendix E: *Nuclear and Non-Nuclear Testing*.)

Each warhead-type is continuously reviewed in Phase 6. The POG meets as required to solve problems that arise during or after production. Some age-related changes affecting various nuclear warhead components are predictable and well understood. During Phase 6, these components are replaced periodically throughout the lifetime of the warhead and are called limited-life components (LLCs). LLCs are similar to the components of an automobile that must be replaced at periodic intervals, such as oil filters, brake pads, and tires. These components are replaced during scheduled LLC exchanges (LLCEs), which are analogous to scheduled maintenance on a car. LLCs in any given warhead-type may include power sources, neutron generators, tritium reservoirs, and gas-transfer systems. These components must be replaced before their deterioration adversely affects warhead function and personnel safety.

Safety, security, personnel reliability, use control, transportation, supply publications, accountability, inspections, emergency response preparation and exercises, and technical operations training are also performed during Phase 6.

D.8.1 The Phase 6.X Process

The NWC has a major role in the refurbishment and maintenance of the enduring nuclear weapons stockpile. Since 1992, the NWC has concentrated its efforts on research related to the maintenance of the existing weapons in the legacy stockpile and oversight of the refurbishment activities in the absence of underground nuclear testing. To manage and facilitate the refurbishment process, the NWC approved the Phase 6.X Procedural Guideline in April 2000.[4] Figure D.2 is an illustration of the 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 7. The basic process is used to develop a complete warhead, but the 6.X Process is intended to develop and field only those components that must be replaced as a part of the approved refurbishment program for a legacy warhead-type. Each refurbishment

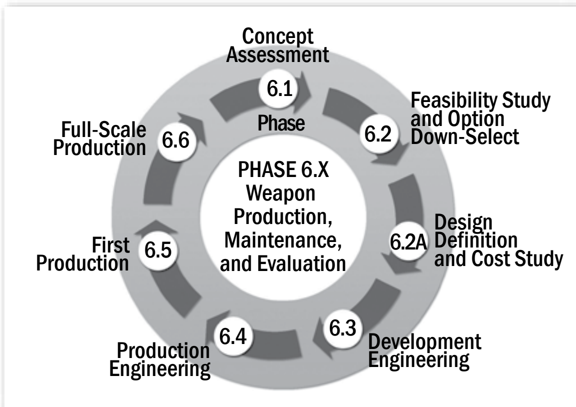

Figure D.2 Phase 6.X Process

[4] This description of the Phase 6.X Process is excerpted from the *NWC Procedural Guideline for the Phase 6.X Process*, April 2000.

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 alterations (alts) and modifications (mods),[5] including life extension programs (LEPs), for weapons in the existing stockpile. The NWC monitors progress to ensure that the stockpile continues to be safe and reliable.

D.8.2 Phase 6.1 – Concept Assessment

This phase consists of studies by the DoD, the NNSA, and the POG. A continuous exchange of information, both formal and informal, is conducted among various individuals and groups. This exchange results in the focusing of sufficient interest on an idea for a nuclear weapon or component refurbishment to warrant a program study.

For Phase 6.1 activities that are jointly conducted by the DoD and the NNSA, the NWCSSC is informed in writing before the onset of the activity.[6]

The DoD, the NNSA, or the POGs are free to develop ideas within the following limitations:

- should the DoD pursue an idea that would involve the modification or alteration of a nuclear warhead, the DoD must ask the NNSA to examine the feasibility of at least that part of the concept; and
- should the NNSA pursue an idea that would require developing a new or modified weapon delivery system or handling equipment, the NNSA must ask the DoD to examine the feasibility and impact of at least that part of the concept.

After the concept assessment phase for a Phase 6.X program is complete, the DoD, the NNSA, or a POG may submit a recommendation to the NWCSSC to proceed to Phase 6.2. The NWCSSC determines whether a Phase 6.2 Study should be authorized.

D.8.3 Phase 6.2 – Feasibility Study and Option Down-Select

After the NWCSSC approves entry into Phase 6.2, the DoD and the NNSA embark on a Phase 6.2 Study, which is managed by the POG for that weapon system. In a Phase 6.2

[5] Normally, a replacement of components is called a "mod" if it causes a change in operational characteristics, safety or control features, or technical procedures. A replacement of components is called an "alt" if it does not change these features, and the differences are transparent to the user (i.e., the military units).

[6] Technically, only the NWC has the authority to approve Phase 6.X program starts. In practice, the NWC may delegate this authority to the NWCSSC.

Study, design options are developed, and the feasibility of a Phase 6.X refurbishment program for that particular nuclear weapon is evaluated.

The NNSA tasks the appropriate DOE laboratories to identify various design options to refurbish the nuclear weapon. The POG analyzes each design option. At a minimum, this analysis considers the following:

- nuclear safety;
- system design, trade-offs, and technical risk analyses;
- life expectancy issues;
- research and development requirements and capabilities;
- qualification and certification requirements;
- production capabilities and capacities;
- life-cycle maintenance and logistics issues;
- delivery system and platform issues; and
- rationale for replacing or not replacing components during the refurbishment.

The Phase 6.2 Study includes a detailed review of the fielded and planned support equipment (handling gear, test gear, use control equipment, trainers, etc.) and the technical publications (TPs) associated with the weapon system. This evaluation ensures that logistics support programs can provide the materials and equipment needed during the planned refurbishment time period.

Military considerations, which are evaluated in tandem with design factors, include (at a minimum): operational impacts and benefits that would be derived from the design options, physical and operational security measures, and requirements for joint non-nuclear testing. During this phase, the MCs, STS, and interface control documents (ICDs) are updated as necessary.

Refurbishment options are developed by the POG in preparation for the development of the option down-select package. This package includes any major impacts on the NNSA nuclear weapons complex and is documented in an NNSA-prepared MIR.

The NNSA and the lead Military Service coordinate the down-select of the Phase 6.2-preferred option(s) and authorize the start of Phase 6.2A. The POG writes a Phase 6.2 Report and briefs the results to the NWCSSC, which considers the selected option(s) for approval.

D.8.4 Phase 6.2A – Design Definition and Cost Study

The NNSA works with the Labs and the facilities of the nuclear weapons production complex to identify production issues and to develop process development plans and proposed workload structures for the refurbishment. The labs continue to refine the design and to identify qualification testing and analysis in order to verify that the design meets the specified requirements.

With coordination through the POG, the lead Military Service develops the necessary plans in its area of responsibility (such as flight testing, maintenance and logistics, and the procurement of trainers, handling gear, and new DoD components). The POG incorporates NNSA and Military Service inputs into a joint integrated project plan (JIPP). The NNSA, the labs, and the production facilities develop an NNSA cost estimate for the design, testing, production, and maintenance activities for the projected life of the LEP refurbishment. These estimates are reported in the Weapon Design and Cost Report.

The POG presents this information together with the DoD cost estimate to the NWCSSC. Included is a recommendation to the NWCSSC about whether to proceed to Phase 6.3. The NWCSSC evaluates the request based on the results of the Phase 6.2/6.2A Report(s), the WDCR, and the Phase 6.2 MIR. The NWCSSC then determines whether Phase 6.3 should be authorized.

D.8.5 Phase 6.3 – Development Engineering

Phase 6.3 begins when the NWC prepares a Phase 6.3 letter requesting joint DoD and NNSA participation in Phase 6.3. The request letter is transmitted together with the draft MCs and STS to the DoD and the NNSA; the two must then respond to the NWC. If the DoD and the NNSA agree to participate in Phase 6.3, comments on the proposed MCs and STS are included in their positive responses to the NWC. The NNSA, in coordination with the DoD, conducts experiments, tests, and analyses to validate the design option(s). Also at this time, the production facilities assess the producibility of the proposed design, initiate process development activities, and produce test hardware as required.

The WDCR is then formally updated and called the Baseline Cost Report, which reflects the current design under development. The draft Addendum to the Final Weapon Development Report is also prepared. It reports on the status of the weapon refurbishment design and provides refurbishment design objectives, refurbishment descriptions, proposed qualification activities, ancillary equipment requirements, and project schedules.

The DoD DRAAG reviews the draft Addendum to the FWDR and publishes a Phase 6.3 preliminary DRAAG Report with its recommendations regarding the status of the project.

The report and recommendations are forwarded by the appropriate Military Service to the NWCSSC for approval.

During Phase 6.3, the MCs (and the STS if a change to a weapon subsystem or component is required) are approved by the NWCSSC, after which the POG updates the JIPP and a final Product Change Proposal (PCP) is prepared.

At the end of Phase 6.3, the weapon refurbishment design is demonstrated to be feasible in terms of safety, use control, performance, reliability, and producibility. The design is thereby ready to be released to the production facilities for stockpile production preparation activities. These activities are coordinated with parallel DoD activities (if required) in the POG. The lead Military Service may decide that a preliminary safety study of the system is required in order to examine design features, hardware, and procedures as well as aspects of the concept of operation that affect the safety of the weapon system. During this study, the Nuclear Weapon System Safety Group identifies safety-related concerns and deficiencies so that timely and cost-efficient corrections can be made during this phase.

D.8.6 Phase 6.4 – Production Engineering

When development engineering is sufficiently mature, the NNSA authorizes the initiation of Phase 6.4. This phase includes activities to adapt the developmental design into a producible design as well as activities that prepare the production facilities for refurbishment component production. During this phase, the acquisition of capital equipment is completed; tooling, gauges, and testers are properly 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. Phase 6.4 also defines the methodology for the refurbishment of the weapon and production of the components. Production cost estimates are updated based on preliminary experience from the PPI and product qualification.

At this point, provisions for spare components are made in conjunction with the DoD. Technical publications are updated and validated through an evaluation by the Laboratory Task Group and Joint Task Group. The NNSA Stockpile Evaluation Program (SEP) plan is updated, and the POG maintains and updates the JIPP.

Generally, Phase 6.4 ends after the completion of production engineering, basic tooling, layout, and adoption of fundamental assembly procedures, and when NNSA engineering releases indicate that the production processes, components, subassemblies, and assemblies are qualified.

D.8.7 Phase 6.5 – First Production

When sufficient progress has been made in Phase 6.4, the NNSA initiates Phase 6.5. During this phase, the production facilities begin production of the first refurbished weapons. These weapons are evaluated by the DoD and the NNSA. At this time, the NNSA preliminarily evaluates the refurbished weapon for suitability and acceptability. Except in an emergency, the preliminary evaluation does not constitute a finding that the weapons are suitable for operational use.

If the DoD requires weapons for test or training purposes before final approval by the NNSA, the weapons or items would be used with the understanding that the NNSA has not made its final evaluation. The POG coordinates specific weapons requirements for test or training purposes. The NNSA and the labs conduct a final evaluation after the completion of an engineering evaluation program for the weapon.

The POG informs the NWCSSC that the LEP refurbishment program is ready to proceed to IOC and full deployment of the refurbished weapon. The lead Military Service conducts a pre-operational safety study at a time when specific weapon system safety rules can be coordinated, approved, promulgated, and implemented 60 days before IOC or first weapon delivery. During this study, the NWSSG examines system design features, hardware, procedures, and aspects of the concept of operation that affect the safety of the weapon system to determine if the DoD nuclear weapon system safety standards can be met. If safety procedures or rules must be revised, the NWSSG recommends draft revised weapon system safety rules to the appropriate Military Departments.

The responsible labs prepare a final draft of the Addendum to the FWDR and submit the document for final DRAAG review. The DRAAG reviews the final draft of the Addendum and issues a final DRAAG Report with comments and recommendations to the NWCSSC through the lead Military Service. The DRAAG, in coordination with the lead Military Service and through the NWCSSC, informs the NNSA that the weapon meets (or does not meet) the requirements of the MCs.

After receiving comments from the DRAAG, the responsible labs complete the final Addendum to the FWDR. The labs then issue the final Addendum to the FWDR together with a certification letter. The POG also updates the JIPP.

After the evaluation of the limited production run and other reviews are completed, the NNSA issues a Major Assembly Release for the refurbished weapon. Upon approval of the final DRAAG Report by the NWCSSC and issuance of the MAR, the first refurbished weapons are released to the Military Service. With the MAR, the NNSA advises the DoD that the refurbished weapon is suitable for use and notes any limitations. This phase terminates with DoD acceptance of the refurbished weapon. The POG then requests approval from the NWC to proceed to Phase 6.6.

D.8.8 Phase 6.6 – Full-Scale Production

Upon NWC approval to initiate Phase 6.6, the NNSA undertakes the necessary full-scale production of refurbished weapons for entry into the stockpile. The POG prepares an End-of-Project Report for the NWCSSC to document the refurbishment activities carried out in the Phase 6.X Process. Phase 6.6 ends when all planned refurbishment activities, certifications, and reports are complete.

D.9 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 of the quantity of that warhead-type in the NWSP for any reason other than to support the QART program. However, the DOE may be required to initiate Phase 7 activities to perform dismantlement and disposal activities for surveillance warheads that are destructively tested under the QART program. This phase initiates a process that continues until all warheads of that type are retired and dismantled. From the DoD perspective, a warhead-type just beginning retirement activities may still be retained in the active and/or inactive stockpiles for a period of years.

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

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

While the 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 E
Nuclear and Non-Nuclear Testing

E.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 with which to certify the continued effectiveness of nuclear weapons without the use of nuclear testing.

E.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, NM, now called the *Trinity Site*. That test confirmed that the *Fat Man* implosion design weapon would function to produce a nuclear detonation. It 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 its 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. Most of these tests had a primary purpose of increasing the knowledge and data associated with nuclear physics and weapon design. Some of the tests were designed to develop nuclear weapons effects data, and a few were safety experiments. These tests were a mixture of underground, above-ground, high-altitude, underwater, and above-water detonations.

In 1958, the United States instituted a self-imposed moratorium on nuclear tests. In 1961, nuclear testing resumed, 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 under the *Plowshare* program,[2] seven tests to increase the capability to detect, identify, and locate nuclear tests under the *Vela Uniform* program, four tests 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 the legislation that ended the U.S. nuclear testing program, and led to the current policy restriction on nuclear testing.

E.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 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 capabilities. Because of this, only limited amounts of scientific data were gained in each of these events.

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[1] The United States and the United Kingdom were preparing to conduct a 25th test when President Clinton announced a moratorium on underground nuclear testing in 1992. Until that point, the nuclear relationship between the United States and 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 the nation ratified the Comprehensive Nuclear-Test-Ban Treaty in April 1998. See Chapter 8: *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.

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 above-ground detonations, which were routine at that time. The locations for these tests included the Nevada Test Site (NTS), the Enewetak Atoll, Bikini Island, the Pacific Ocean, and the Nellis Air Force Range in Nevada. Some of the highest yield detonations were produced by test devices that were 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 14.8 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 E.1 is a photo of the *Bravo* fireball shortly after detonation.

Figure E.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, etc., were based on two-dimensional models. These computer models became more capable as the scientific data base expanded and computing technology evolved.

E.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, including underground, underwater, and above-ground 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; Carlsbad, NM; the vicinity of Christmas Island in the East Indian Ocean; the Pacific Ocean; and Johnston Island in the Pacific. The last four tests of this group were conducted during the nine day period between October 27 and November 4, 1962. These were the last U.S. nuclear tests that produced above-ground or surface burst detonations.

In compliance with the Limited Test Ban Treaty (LTBT) of 1963, all subsequent U.S. nuclear test detonations were conducted deep underground. (For more information on the LTBT, see Appendix B: *International Nuclear Treaties and Agreements.*) Initially, there was some thought that 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 effectively.

In the 30 years between November 9, 1962 and September 23, 1992, the United States conducted 760 deep underground nuclear tests.[4] During this period, tests were performed for all of the previously discussed reasons. The locations for these tests included: the NTS; the Nellis Air Force Range in Nevada; the vicinity of Fallon, Nevada; the vicinity of Hattiesburg, Mississippi; the vicinity of Amchitka, Alaska; the vicinity of Farmington, New Mexico; the vicinity of Grand Valley, Colorado; and the vicinity of 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, and 23 others had zero or near-zero yield.

Generally, a device for a weapons-related underground nuclear test (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 that ran back to above-ground 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

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3 The AEC was a forerunner organization to the current National Nuclear Security Administration (NNSA), and DASA was a forerunner organization 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 are listed in the unclassified record with a yield between 20 and 200 kt.

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 they 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 floors approximately seven to eight feet apart and a temporary elevator to take technicians to the various levels 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 earth 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 E.2 for a photograph of a preparation site for an underground nuclear test.

Figure E.2
Underground Nuclear Test Preparation

Generally, a UGT device for an effects test was positioned in a long horizontal tunnel deep into the side of one of the mountains in the Yucca Mountain range at the north end of the NTS. Informally, this type of test was called a *horizontal test*. The tunnels were relatively large, usually more than 30 to 40 feet across, and ran several miles into the side of the mountain. Typically, the tunnel had a small-scale railroad track running from the entrance to the deepest part of the main tunnel, which included a train to support the logistics 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 (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.

[7] The collapse that caused the subsidence crater could occur at any time from minutes to months after the detonation; the time of the collapse was unpredictable.

On the test date, the NTS operations center would continuously monitor wind direction and wind 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.

The Threshold Test Ban Treaty (TTBT) was signed by the United States in 1974; the treaty was not ratified until 1990, but in 1976 the United States announced that 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. This compelled the weapons development 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 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 they 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 (ignition threshold, yield output, etc.) to certify several different secondary stage designs, which would produce yields greater than 150 kt. See Figure E.3 for a summary of U.S. nuclear tests by yield.

The second change was that to test any new warhead with a yield greater than 150 kt, the warhead would have to be reconfigured to ensure that it would not produce a yield in excess of 150 kt. Thus, the newest strategic warheads would not have a nuclear test (in their new configuration) for any yields above 150 kt.

By the 1980s, the U.S. nuclear test program had evolved into a structure that categorized tests as physics research tests, effects tests, warhead development engineering tests,

[8] Venting incidents occurred very few times during the history of U.S. underground nuclear testing. Venting can occur 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/cavities. Venting can also occur if the blast door for a horizontal UGT is not strong enough to contain the blast wave.

Time Period	Yield					
	Zero or Near-Zero	> 0 to 150 kt	Possible > 150 kt	> 150 to 500 kt	> 500 kt to 1 MT	> 1 MT
1945 - 1948	0	6	0	0	0	0
1951 - 1958	17	137	0	13	1	20
1961 - 11/04/62 *	0	79	0	4	8	9
11/9/62 - 03/17/76 **	5	391	79	9	14	4
May 76 - 1992	1	257	0	0	0	0
Total:	23	870	79	26	23	33

* Last U.S. above-ground or surface detonation.
** Last U.S. detonation above 150 kt.

Grand Total: 1,054 Nuclear Tests

Figure E.3 U.S. Nuclear Tests by Yield

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 key aspects of specific designs or to refine 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 that any final refinements in the design that were 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.

E.2.3 The 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 physics laboratories had acquired the most capable computers of the time and were expanding the computer codes to analyze fissile material compression, fission events, etc., 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 labs 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 safety improvements that might not have otherwise occurred.[9] The increased computational modelling capability with the 3-D codes also helped scientists to refine the near-term nuclear testing program to include tests that would provide maximum value-added to the base of scientific knowledge and data. Each year, the results of the nuclear testing program increased the labs' computational modeling capabilities.

E.2.4 End of Underground Nuclear Testing

In 1992, in anticipation of a potential comprehensive test ban treaty, the United States voluntarily suspended its underground nuclear testing program. Public Law 102-377, the legislation that ended U.S. nuclear testing, had several key elements, including 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. (For more information on START II, see Appendix B: *International Nuclear Treaties and Agreements*.) 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 enhancement elements, and it was decided that the United States would not conduct any further tests. The last U.S. underground nuclear test, *Divider,* was conducted on September 23, 1992 (Figure E.4).

The Fiscal Year 1994 National Defense Authorization Act (Public Law 103-160) called on the secretary of energy to "establish a stewardship program to ensure the preservation

[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.

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 Public Law 103-160, has served as a substitute for nuclear testing since 1992. (For more information on the Stockpile Stewardship Program, see Chapter 7: *U.S. Nuclear Infrastructure*.)

Figure E.4 Preparation for Divider, the Last U.S. Underground Nuclear Test

E.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 to 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 quality assurance through only the use of non-nuclear testing, surveillance, and—to the extent applicable—modelling. The Department of Energy (DOE) 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 the Department of Defense (DoD) and the DOE 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 programmed life. As the warheads in the stockpile age, the SEP has detected an increasing number of problems, primarily associated with non-nuclear components. This led to an expanded program of refurbishments, as required for each warhead-type, and a formal process to manage it. The SEP program has been very effective for quality assurance. Even though it has been almost 20 years since the last U.S. nuclear test, approximately one dozen different warhead-types serve as the backbone of the nation's nuclear deterrent, each with annual safety validations and very high reliability estimates.

Because the warheads of the stockpile continue to age beyond any previous experience, it is anticipated that the stockpile will reveal age-related problems unlike any other time in the past. As a part of proactive quality assurance management, the DOE has recently established a Surveillance Transformation Project (STP). Its focus is on the creation and maintenance of a knowledge-based, predictive, adaptable, and cost-effective evaluation program. This section of the appendix describes the many activities associated with the quality assurance of the U.S. nuclear weapons stockpile. These activities take place in multiple DOE locations, and many of them occur at the Pantex Plant in Amarillo, Texas (Figure E.5).

Figure E.5 Pantex Plant

E.3.1 The Evolution of Quality Assurance and Sampling

The Manhattan Project, which produced one test device and two war-reserve (WR) weapons that were employed to end World War II, had no formal, structured QA program. There were no safety standards or reliability requirements to be met. QA was the sum of all precautions thought of by weapons scientists and engineers and the directives of Dr. Oppenheimer and his subordinate managers. History proves that the Manhattan Project version of QA 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 QA 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 Chapter 5: *Nuclear Safety and Security*, for a detailed discussion of nuclear detonation safety and safety 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 D: *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 they provided an excellent sample size to calculate reliability and to stress-test the performance of key components in various extreme environments. This was unaffordable 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, that number was reduced to 22 per year and remained constant for approximately a decade. Over time, the random sample number was reduced to 11 per year to reflect fiscal and logistical realities. With the implementation of the Surveillance Transformation Project, each weapon system was re-evaluated with respect to 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.

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, reliability, or control is documented as an SFI. The QA community investigates, evaluates, and resolves SFIs.

The NMSEP is a part of today's Stockpile Evaluation Program. At the national level, random sample warheads drawn from the fielded stockpile are considered to be a part of the Quality Assurance & Reliability Testing (QART) program. Under the QART program, additional efficiencies are gained by sampling and evaluating several warhead-types as a warhead "family" if they have enough key components that are identical. Until 2006, each

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

warhead family had 11 random samples evaluated each year. The sample size of 11 per year enabled the QA program: to provide an annual safety validation; to provide a reliability estimate semi-annually; and to sample any randomly occurring problem was present in ten percent or more of the warheads of that type, with a 90 percent assurance, within two years.

Weapons drawn for surveillance sampling are returned to the NNSA Pantex Facility near Amarillo, Texas, 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 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.

E.3.2 Surveillance Transformation Project

Much of the current surveillance methodology is based on the original weapon evaluation programs, relying mainly on random stockpile sampling applied to flight tests, subsystem go/no-go testing, and selected component evaluations to search for design and manufacturing "birth" or aging defects. This approach gives a current snapshot of the condition of that warhead-type but provides little ability to predict future stockpile problems. The ability to predict a problem is becoming more important as the current warheads of the stockpile continue to age beyond the experience of stockpile scientists and engineers.

In June 2006, the NNSA chartered a complex-wide team to integrate efforts to develop a comprehensive plan for achieving surveillance transformation. The STP is a plan to define a road map to begin transformation to a more knowledge-based, predictive, adaptable, and cost-effective evaluation of current and future stockpile health. It sets the nuclear weapons complex on a course to transform surveillance across four major objectives:

- *Rigorous Requirements Basis*: create a strong technical requirements basis for stockpile evaluation;

- *Evaluating for Knowledge*: design and execute an evaluation program that responds to changing evaluation data needs over the weapon system life-cycle;
- *Predictive Assessment*: develop the capabilities to predict the state of health of the enduring stockpile through end-of-life projections, reliability assessments, predictive performance assessments in areas beyond reliability (i.e., safety/survivability/use control/nuclear performance), and risk-based responsiveness for replacement and refurbishment decisions; and
- *Premier Management and Operations*: create a strong program management team to make the best decisions based on defensible cost-benefit criteria.

With the implementation of STP, additional emphasis has been placed on component and material evaluation for the early detection of signs of aging. Identified aging mechanisms would then be used to predict when the changes as a result of aging would begin to negatively affect system performance so that prophylactic measures can be taken.

E.3.3 Stockpile Laboratory Testing

For each warhead family, the NNSA laboratory evaluation program strives to examine each possible operational use of the warhead, potential environmental conditions, safety and use control features, and the end-to-end process required for nuclear detonation. Several critical system-level functional performance aspects are verified and the data to support reliability assessments are obtained with capabilities to address the spectrum of environmental and operational conditions increasing with the current enhanced surveillance investments. The system-level testing program also examines safety components to determine if there is any concern for the overall safety of the weapon.

Laboratory non-destructive testing can include activities such as radiography and gas sampling. Stockpile lab testing includes, for example, fuzing mode tests, environmental sensing unit tests, trajectory sensing device tests, functioning of firing sets tests and neutron generators, performance of stronglinks and other safety devices, and for weapons so equipped, permissive action link (PAL) tests and command disable function tests. The NNSA testing program emphasizes testing at the highest possible system or subsystem levels. Diversification of tests is used as necessary to address certain aspects of weapon performance under specific use conditions and with maximum realism. Figure E.6 depicts a laboratory in which tests are performed.

Joint Integrated Laboratory Tests (JILTs) evaluate interconnected DoD and NNSA weapon components. For example, the DoD arming and fuzing mechanism would be tested in conjunction with a NNSA denuclearized warhead firing system. These system-level tests

Figure E.6 Gloveboxes

are conducted at either NNSA or DoD facilities.

Normally, the nuclear explosive package from the D-test unit is destructively tested to look for any changes in dimensions or material composition. Five key components are tested: the pit, the secondary, the detonator assembly, the high explosives, and the gas bottle system. The D-test unit is not rebuilt and is, therefore, not returned to the stockpile. The remainder of the samples can be reconstructed and returned to the stockpile if replacement components are available for rebuild. If components are not available for rebuild, those warheads are eliminated from the stockpile. These reductions are called QART consumption in the national-level stockpile planning documents. (See Chapter 2: *Stockpile Management, Processes, and Organizations* for a discussion of national-level stockpile planning documents.)

E.3.4 Stockpile Flight Testing

Flight testing of nuclear delivery systems is accomplished using warheads with inert nuclear components known as joint test assemblies (JTAs). JTAs use non-fissile nuclear components (surrogates) and/or instrumentation that replace the fissile components in the tested weapon. This precludes any possibility that the JTA can produce a nuclear detonation while providing critical information about performance in the actual combined environments experienced in flight. Typically, two to four JTA flight tests per weapon family are planned each year. The JTAs may be either high-fidelity JTAs (HF-JTAs) or instrumented JTAs (I-JTAs).

HF-JTAs replicate actual WR warheads as closely as possible, with the exception that the fissile material (plutonium and highly enriched uranium) and the tritium are removed and replaced with surrogates. HF-JTAs provide some data concerning the system as a whole, while I-JTAs provide more instrumented data about individual components and sub-assemblies. HF-JTAs demonstrate the functioning of the warhead in as complete a configuration as possible without a nuclear test. I-JTAs use data-recording instruments to record the in-flight performance of certain components. Normally, I-JTAs provide much more component and sub-assembly performance data than HF-JTAs. However, in order to have these data-recording instruments embedded in the warhead, the instruments may replace selected warhead components. Therefore, any one I-JTA will have selected warhead components replaced with data-recording instruments, while another I-JTA for the same weapon-type may have a different set of warhead components replaced with other instruments. As much as possible, the data-recording instruments are designed to have the same physical dimensions (height, width, length, weight, center-of-gravity, etc.) as the components they replace.

The Non-Nuclear Assurance Program (NNAP) ensures that actual nuclear weapons are not accidentally used in flight tests in place of the JTAs. The verification process includes inspections of tamper-evident seals and other indicators in conjunction with measurements taken by radiation detection instruments. For joint tests with the DoD, the NNSA provides the test assemblies with permanent "test" markings, tamper-evident seals, signature information, and radiation test equipment.

Flight tests are conducted at various locations in the United States including the Tonopah Test Range in Nevada, the Utah Test and Training Range in Utah and Eastern Nevada, Vandenberg Air Force Base (AFB) in California, and Eglin AFB in Florida. Stockpile flight tests (SFTs) involve JTAs built with components from WR weapons that have already experienced stockpile handling. These tests demonstrate the continued compatibility between the warhead and the delivery vehicle and verify weapons system function throughout the stockpile-to-target sequence.

E.3.5 Component and Material Evaluations

The NNSA is also undertaking a set of activities to baseline margins at a component level and to detect and assess changes in these components over time. Component and material evaluations provide a basis for assessing and projecting aging effects on system performance. These programs utilize components from production, from the stockpile, and from stores to understand failure mechanisms, margins, and the effects of aging on component and system performance, including safety, security, and reliability effects. These activities also provide a knowledge base that can inform planning for future stockpile modifications or LEPs, design decisions, and investigations of anomalies. Hardware utilized in these tests is not typically reintroduced into the stockpile.

E.3.6 Safety Validation and Reliability Estimates

Safety and reliability are evaluated based on the results of the stockpile laboratory testing (SLT), SFT, CME, other surveillance, computer analyses, and when required, the scientific and engineering judgment of the QA experts. The safety of each warhead-type in the stockpile is validated each year to ensure that it meets established safety standards. (Safety standards and certification are discussed in detail in Chapter 5: *Nuclear Safety and Security.*) Reliability is the probability that a warhead-type will function properly if employed as intended. Reliability estimates for each warhead-type are evaluated twice per year. They are estimates, not solely statistical calculations, because the sample size is not sufficiently large to preclude the possibility that scientific and engineering judgment may be included. Reliability is estimated for each mode of operation (e.g., surface bursts and laydown).

E.4 Conclusion

Though the program has evolved throughout the years, the United States has always performed quality assurance tests on its nuclear weapons. In the past, QA was composed of a combination of nuclear and non-nuclear testing. Since 1992, however, the United States has observed a self-imposed moratorium on nuclear testing. In order to continue QA on U.S. weapons, scientists have used existing test data (collected from those nuclear tests conducted prior to 1992) to develop models and simulations to evaluate nuclear weapons. For the past two decades, those models and simulations, when combined with the judgment of scientists and engineers, have been sufficient to certify the continuing effectiveness of nuclear weapons in the stockpile. Unfortunately, due to the age of the U.S. nuclear stockpile, the nation is moving beyond the era in which there exists past nuclear tests with which to compare current-day stockpile weapons using simulations and models. (For more information on the past life-cycle of nuclear weapons, see Chapter 1: *Nuclear Matters History and Policy*.) When coupled with the fact that many of the scientists and engineers who participated in nuclear testing have retired, this movement into an era beyond what is known (because it was verified by past UGT data) creates a situation in which it becomes harder to certify the effectiveness of the stockpile. Because of this, efforts to ensure that options are in place for life-extension programs are being pursued at all levels of government to ensure that the U.S. nuclear deterrent remains safe, secure, and effective for as long as nuclear weapons exist. (For more information on the life-extension options being considered, see Chapter 2: *Stockpile Management, Processes, and Organizations.*)

Appendix F
The Effects of Nuclear Weapons

F.1 Overview

A nuclear detonation produces effects that are 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:[1]

- produces energy which, weight for weight, is millions of times more powerful than that produced by a conventional explosion;
- instantaneously produces a very large and very hot nuclear fireball;
- instantaneously generates an electromagnetic pulse (EMP) that can destroy or disrupt electronic equipment;
- transmits a large percentage of energy in the form of heat and light within a few seconds that can produce burns and ignite fires at great distances;

[1] 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 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.

- emits, within the first minute, highly penetrating prompt nuclear radiation that can be harmful to life and damaging to electronic equipment;
- creates, if it occurs in the lower atmosphere, an air blast wave that can cause casualties and damage at significant distances;
- creates, if it is a surface or near-surface burst,[2] a shock wave that can destroy underground structures;
- emits residual nuclear radiation over an extended period of time;[3] and
- can provide extended interference with communications signals.

Figure F.1 is a photograph of the nuclear fireball and "mushroom" cloud produced by the 21 kiloton (kt) test device "Dog" on November 1, 1951; the device was detonated at the Nevada Test Site as part of Operation Buster-Jangle.

Figure F.1 Nuclear "Mushroom" Cloud

It is important to understand the effects of nuclear weapons for two reasons. First, the United States must have trained specialists who are knowledgeable and capable of advising senior leaders about the predictable results and the uncertainties associated with the employment of U.S. nuclear weapons. Second, given that adversary nations have nuclear weapons capabilities and terrorists are known to be seeking nuclear capability, the United States must have an understanding of how much and what types of damage might be inflicted on a populated area or military unit by an enemy use of one or more nuclear weapons.

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 weapon detonation can destroy unprotected or unhardened structures and systems and can harm or kill exposed personnel at great distances from the point of detonation, thereby affecting the successful outcome of a military mission or producing a large number of casualties in

[2] A *near-surface burst* is a detonation in the air that is low enough for the immediate fireball to touch the ground.

[3] Residual nuclear radiation may be harmful to humans if the detonation is close to the ground; if the detonation is exo-atmospheric, residual radiation may damage electronic components in satellites.

a populated area. Figure F.2 depicts Hiroshima after being attacked with a nuclear weapon on August 6, 1945.

Figure F.2
Hiroshima After the Nuclear Detonation

This appendix describes the effects of various nuclear detonations and the impacts of these effects on people, equipment, and structures.[4] See Appendix G: *Nuclear Survivability*, for a discussion of the programs established to increase the overall survivability of U.S. nuclear deterrent forces and to harden other military systems and equipment against the effects of nuclear weapons.

The effects of a nuclear weapon for people or objects close to ground zero are devastating. The survival of humans and objects at various distance from ground zero will depend on several factors. One factor that is especially significant for survival is the nuclear weapon's yield. If properly employed, any one nuclear weapon should defeat any one military target.[5] However, a few nuclear weapons with relatively low-yields (such as the yields of any nation's first generation of nuclear weapons) will not defeat a large military force (such as the allied force that operated in the first Gulf War). A single, low-yield nuclear weapon employed in a major metropolitan area will produce total devastation in an area large enough to produce tens of thousands of fatalities. It will 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 will depend on the response of various federal, state, and local government agencies.

The yield of the nuclear detonation significantly affects the distances of the damage zones; specifically, larger detonations can produce more casualties and damage. This concept is illustrated in Figures F.3, F.4, and F.5.

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[4] This appendix is written to be technically correct but also to be comprehensible through the use of terms and descriptions that can be understood by people without an academic education in the sciences. A greater level of technical detail can be found in the more definitive documents on the subject such as the Defense Nuclear Agency Effects Manual Number 1 (DNA EM-1) published by the forerunner organization to the current Defense Threat Reduction Agency (DTRA), or *The Effects of Nuclear Weapons*, 1977, by Samuel Glasstone and Philip Dolan.

[5] Proper employment includes using the required yield at the required location with an effective height of burst (e.g., a high-altitude detonation will 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 (e.g., biological agents) within a structure; 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 command post; or a communications site.

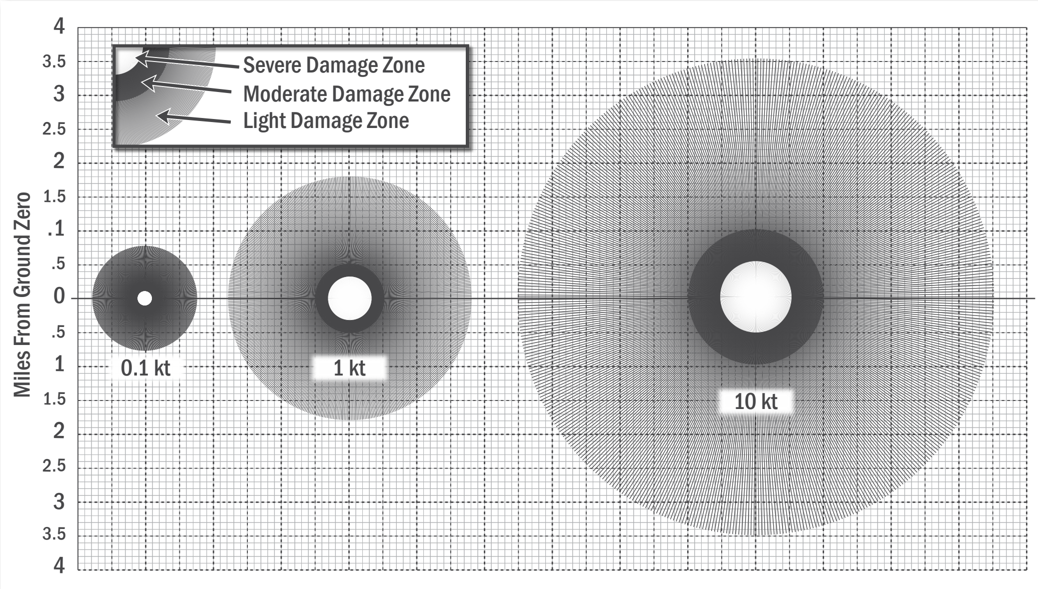

Figure F.3 Representative Damage Zones for 0.1, 1, and 10 kt Nuclear Explosions (circles are idealized here for illustration purposes)

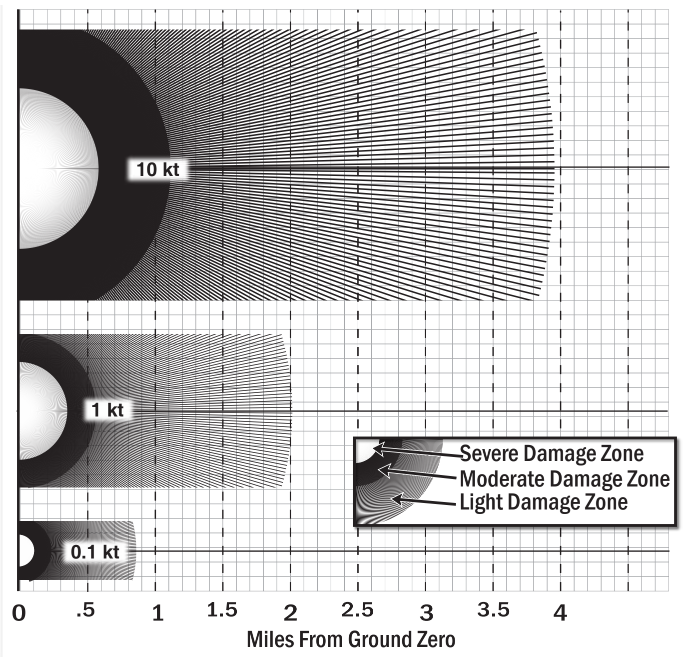

Figure F.4 Zone Distances for 0.1, 1, and 10 kt Nuclear Explosions are Shown for Zone Size Comparison

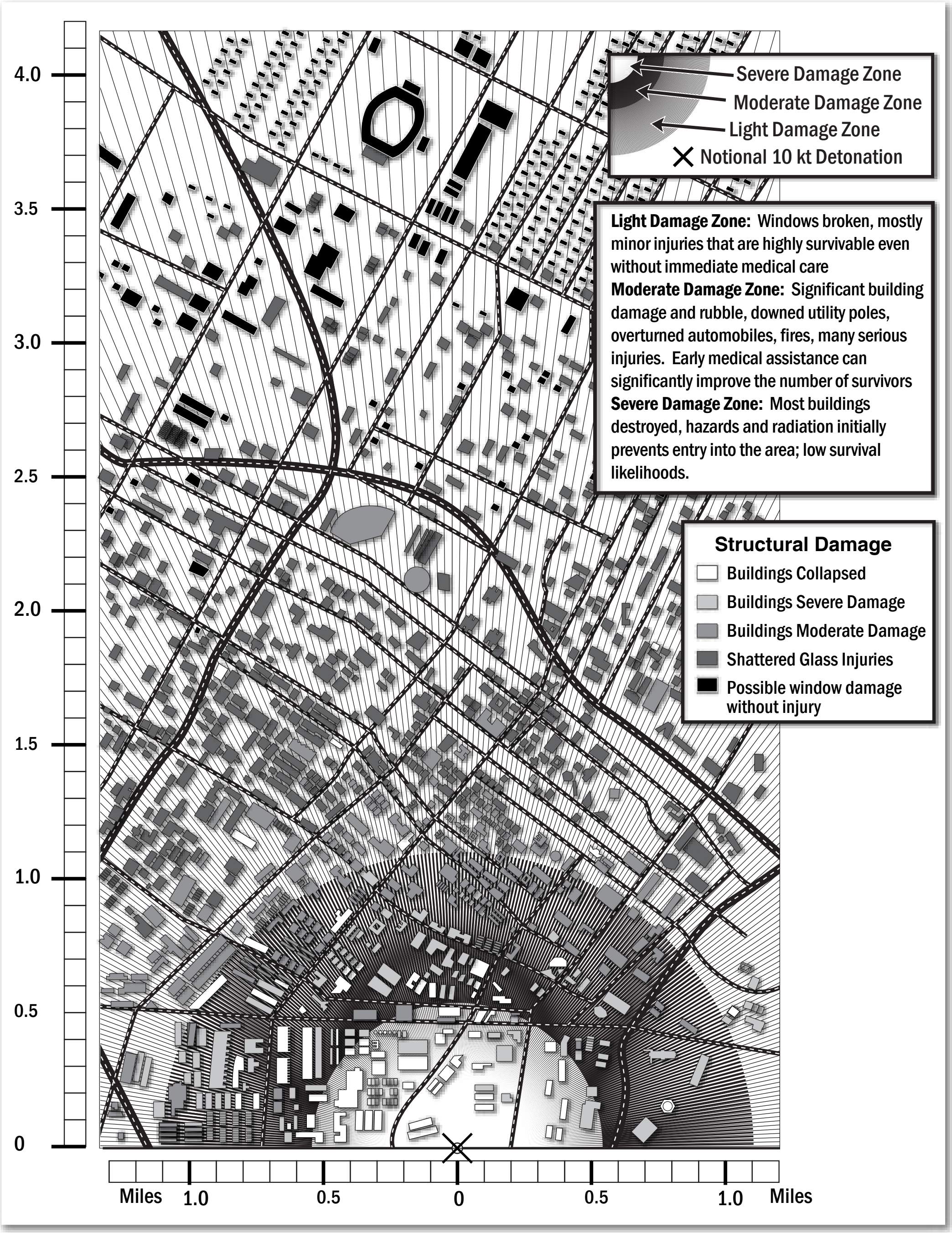

Figure F.5 Representative Damage Zones for a 10 kt Nuclear Explosion Overlaid on a Notional Urban Environment

F.2 General Concepts and Terms

An explosion of any kind generates tremendous force through the release of a large amount of energy into a limited amount of space in a short period of time. This sudden release of energy increases the temperature and pressure of the immediate area to such a degree that all materials present are transformed into hot compressed gases. As these gases seek equilibrium, they expand rapidly outward in all directions, creating a shock wave or blast wave that has tremendous destructive potential. In a conventional explosion, almost all of the energy goes into producing the blast wave; only a small percentage of the energy produces a visible thermal radiation flash.

A typical nuclear detonation will produce blast, thermal, and nuclear radiation. The distribution of energy is primarily a function of weapon design, yield, and height of burst (HOB). A nuclear weapon's output can be tailored to increase its ability to destroy specific types of targets, but a detonation of a typical fission-design weapon at or near the ground will result in approximately 50 percent of the energy producing air blast, ground shock, or both, 35 percent of the energy producing thermal radiation (intense light and heat), and 15 percent of the energy producing nuclear radiation. Figure F.6 depicts this energy distribution.

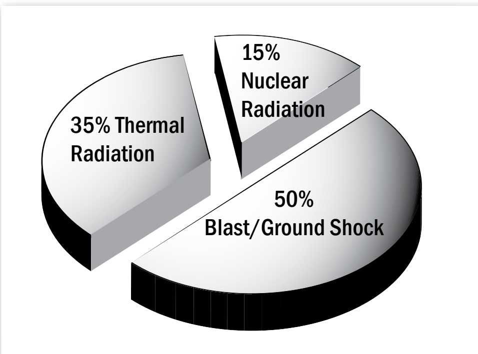

Figure F.6
Energy Distribution for a Typical Nuclear Detonation

The yield of a nuclear detonation is normally expressed in terms of an equivalent amount of energy released by a conventional explosive. A one kiloton nuclear detonation releases the same amount of total energy as 1,000 tons (approximately 2.2 million pounds) of the conventional explosive trinitrotoluene (TNT), or approximately 10^{12} calories of energy. A one megaton (MT) nuclear detonation releases the same amount of energy as one million tons of TNT.

F.3 The Nuclear Fireball

A typical nuclear weapon detonation will produce a huge number of X-rays, which heat the air around the detonation to extremely high temperatures, causing the heated air to expand and form a large fireball within a small fraction of a second. The size of the immediate fireball is a function of yield and the surrounding environment. Figure F.7 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 F.7 Approximate Fireball Size

The immediate fireball reaches temperatures in the range of tens of millions of degrees, i.e., as hot as the interior temperatures of the sun. Inside the fireball, the temperature and pressure cause a complete disintegration of molecules and atoms. While current targeting procedures do not consider the fireball to be one of the primary effects of a weapon, a nuclear fireball could be used to defeat special types of target elements; for example, a nuclear fireball could incinerate chemical or biological agents.

In a typical nuclear detonation, because the fireball is so hot, it immediately begins to rise in altitude. As it rises, a vacuum effect is created under the fireball, and air that had been pushed away from the detonation rushes back toward the fireball, causing an upward flow of air and dust that follows it. This forms the stem of a mushroom-shaped cloud.

As the fireball rises, it will also be blown downwind. Most of the dust and other material that was in the stem of the mushroom-shaped cloud will drop back to the ground around ground zero. If there is a strong wind, some of this material may be blown downwind. After several minutes the cloud will reach an altitude at which its vertical movement slows, and after approximately ten minutes, it will reach its stabilized cloud height, usually tens of thousands of feet in altitude.[6] After reaching its stabilized cloud height, the cloud will gradually laterally expand over a period of hours to days, thereby becoming much larger but also much less dense. Some of the material from the top of the cloud could be drawn to higher altitudes. After a period of weeks to months, the cloud will have dispersed to the extent that it covers a very large area; at this point, it will have very little radioactivity remaining.

F.4 Thermal Radiation

Thermal radiation is electromagnetic radiation in the visible light spectrum that can be sensed as heat and light. A typical nuclear detonation will release thermal radiation in

[6] A large-yield detonation would have a hotter fireball, and it would rise to a higher altitude than a low-yield detonation. A fireball from a one megaton detonation would rise to an altitude of between 60,000 and 70,000 feet.

two pulses. During low-yield detonations, the two pulses occur too quickly to be noticeable without special sensor equipment. For very large yield detonations (one megaton or more) on clear days, the two pulses could be sensed by people at great distances from the detonation (a few tens of kilometers), and the second pulse would remain intense for ten seconds or longer. Thermal radiation is maximized with a low-air burst; the optimum height of burst to maximize the thermal effect increases with yield.

F.4.1 Thermal Radiation Damage & Injury

Thermal radiation can ignite wood frame buildings and other combustible materials at significant distances from the detonation. 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 radiation. Anything that casts a shadow or reduces light, including buildings, trees, dust from the blast wave, heavy rain, and dense fog, provides some protection against thermal burns or the ignition of objects. Transparent materials, such as glass or plastic, will slightly attenuate thermal radiation. Figure F.8 identifies the different types of burns and their approximate maximum distances at selected nuclear yields.[7]

			Approximate Distances (km)		
Degree	Affected Area	Description & Symptoms	1 kt	10 kt	1 MT
3rd	Tissue under skin	Charred skin; Extreme pain	0.7	1.7	11.1
2nd	All layers of skin	Blisters; Severe pain	0.9	2.3	13.7
1st	Outer layers of skin	Red/darker skin; Moderate pain	1.0	2.8	19.0

Figure F.8 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 thirty minutes and may affect people at distances of tens of kilometers. On a clear day, dazzle can affect people at distances beyond those for first degree burns; however, it lasts for a shorter period of time. Because thermal radiation can be scattered and reflected in the air, flash blindness can occur regardless of whether an individual is looking toward the detonation. At distances at which 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. Further, if the yield is large enough and the

[7] The distances in Figure F.8 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.

duration of the second thermal pulse is longer than one second, some people might look toward the detonation and suffer retinal burns. Normally, retinal burns cause a permanent blindness to a small portion of the eye in the center of the normal field of vision.

A surface burst would reduce the incidence of both temporary blindness and retinal burns.

F.4.2 Thermal Radiation Employment Factors

In order for thermal radiation to cause burns or ignition, the individual or object must be in direct line of sight from the detonation. Thermal radiation is thus maximized with a low-air burst (rather than a surface burst) because the higher height of detonation provides direct line of sight to much greater distances.

Because thermal radiation can start fires and cause burns at such great distances, if a nuclear weapon were employed against a populated area, on a clear day, with an air burst at approximately the optimum height of burst, it is likely that the thermal effects would account for more casualties than any other effect. With a surface burst or if rain or fog were in the area, the thermal radiation effects would be reduced.

F.4.3 Thermal Radiation Protection

The effects of thermal radiation can be reduced with protective enclosures, thermal protective coatings, and the use of non-flammable clothing, tools, and equipment. Thermal protective coatings include materials that swell when exposed to flame (thus absorbing the heat rather than allowing it to penetrate through the material) and ablative paints, which act like a melting heat shield. Materials like stainless steel, as opposed to temperature-sensitive metals like aluminum, are used to protect against thermal radiation. Similarly, higher-temperature resins are used in forming fiberglass structures. 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—from direct exposure.

F.5 Air Blast

In the case of surface and low-air bursts, the fireball expands, pushing air or ground soil/rock/water immediately away from the point of the detonation.[8] Above the ground, a dense

[8] For a one kiloton, low-air burst nuclear detonation, the immediate fireball would be approximately 30 meters (almost 100 feet) in radius and approximately 60 meters (almost 200 feet) in diameter.

wall of air traveling at great speed breaks away from the immediate fireball. Initially, this blast wave moves at several times the speed of sound, but it quickly slows to a point at which the leading edge of the blast wave is traveling at the speed of sound, and it continues at this speed as it moves farther away from ground zero. Shortly after breaking away from the fireball, the wall of air reaches its maximum density of overpressure (over the nominal air pressure).[9] As the blast wave travels away from this point, the wall of air becomes wider and 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.

F.5.1 Air Blast Damage & Injury

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. Less overpressure can collapse the lungs, and at lower levels, it 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 very rapidly, causing injury or damage. Dynamic pressure can also strip a building from its foundation, blowing it to pieces.

As the positive phase of the blast wave passes an object, it is followed by a vacuum effect (i.e., the negative pressure caused by the lack of air in the space behind the blast wave). This is the beginning of the negative phase of dynamic pressure. The vacuum effect (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 ground zero. 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 F.9 shows the overpressure in pounds per square inch (psi) and the approximate distances associated with various types of structural damage.[10]

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[9] At a short distance beyond the radius of the immediate fireball, the blast wave would reach a density of thousands of pounds per square inch.

[10] The distances in Figure F.9 are based on an optimum height of burst to maximize the blast effect, and

		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 F.9 Air Blast Damage to Structures

F.5.2 Air Blast Employment Factors

If the detonation occurs at ground level, the expanding fireball will push 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 its destructive potential and becomes a mere gust of wind. However, 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 will lead to a greater than normal heating of that surface. The surface will then give off 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 (-50° Fahrenheit or colder) can lead to increased air blast damage distances. If a surface burst occurs in populated area or if there is rain and fog at the time of burst, the blast effect would probably account for more casualties than any other effect.

F.5.3 Air Blast Protection

Structures and equipment can be reinforced to make them less vulnerable to air blast; however, any structure or piece of equipment will be destroyed if it is very close to the

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.

detonation. High priority facilities that must survive a close nuclear strike are usually constructed underground, making them much harder to defeat.

Individuals who sense a blinding white flash and intense heat coming from one direction should immediately fall to the ground and cover their heads with their arms. This provides the highest probability that the air blast will pass overhead without moving them laterally and that debris in the blast wave will 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 if they remain on the ground until after the negative phase blast wave has moved back toward ground zero.

F.6 Ground Shock

For 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 will produce significantly more ground shock than a near-surface burst in which the fireball barely touches the ground.

F.6.1 Ground Shock Damage & Injury

Underground structures, especially ones that are very deep underground, are not vulnerable to the direct primary effects of a low-air burst. The shock produced by a surface burst, however, may damage or destroy an underground target depending on the yield of the detonation, the soil or rock type, the depth of the target, and its structure. It is possible for a surface detonation to fail to crush a deep underground structure but to have an effective shock wave that crushes or buries entrance/exit routes and destroys connecting communications lines. This could cause the target to be "cut-off" and render it, at least temporarily, incapable of performing its intended function.

F.6.2 Ground Shock Employment Factors

Normally, a surface burst or shallow sub-surface burst is used to attack deeply buried targets. As a rule of thumb, a one kiloton surface detonation can destroy an underground facility as deep as a few tens of meters. A one megaton surface detonation can destroy the same target as deep as a few hundreds of 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 that are usually between two and five times deeper than those destroyed through the employment of a surface burst.[11] Ground shock is the governing effect for damage estimation against any underground target.

F.6.3 Ground Shock Protection

Underground facilities and structures can be buried deeper to reduce their vulnerability to damage or collapse from a surface or shallow sub-surface detonation. Facilities and equipment can be built with structural reinforcement or other unique designs to decrease their vulnerability to ground shock. To ensure functional survivability, entrance and exit route requirements and communications lines connected to ground-level equipment must be considered.

F.7 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 that 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 would be larger and deeper; crater size is maximized with a shallow sub-surface burst at the optimum depth.[12] The size of the crater is a function of the yield of the detonation, the depth of burial, and the 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 the

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

[12] For a one kiloton detonation, the maximum crater size would have a burial depth between 32 and 52 meters, depending on the type of soil or rock.

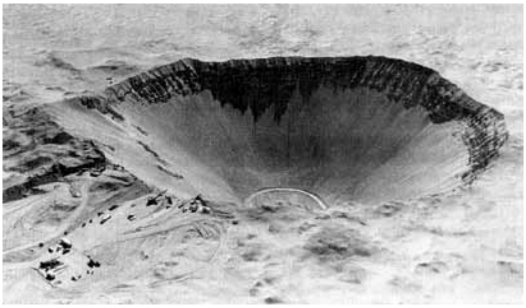

Figure F.10 Sedan Subsidence Crater

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 on 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 will form a crater on the surface, called a subsidence crater. Figure F.10 shows the Sedan Crater formed when a 104 kiloton explosive buried under 635 feet of desert alluvium was fired at the Nevada Test Site on July 6, 1962, displacing 12 million tons of earth. The crater is 320 feet deep and 1,280 feet in diameter.

F.7.1 Surface Crater Damage & Injury

If a crater has been produced by a recent detonation near the surface, it will probably be 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 would be very dangerous to enter the area on the surface directly above the detonation.

F.7.2 Surface Crater Employment Factors

Normally, the wartime employment of nuclear weapons does not use crater formation to attack targets. At the height of the Cold War, however, 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 would produce an obstacle that would be extremely difficult, if not impossible, for a military unit to cross.

F.7.3 Surface Crater Protection

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 will be formed until after the collapse occurs.

F.8 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, but surface interaction will generally mitigate the shock effect.

If the yield is large enough and the depth of detonation is shallow enough, the shock wave will rupture the water's surface. This can produce a large surface wave that will move away in all directions. It may also produce a "spray dome" of radioactive water above the surface.

F.8.1 Underwater Shock Damage & Injury

If a submarine is close enough to the detonation, the underwater shock wave will be 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.

F.8.2 Underwater Shock Employment Factors

Normally, nuclear weapons are not used to target enemy naval forces.

F.8.3 Underwater Shock Protection

Both surface ships and submarines can be designed to be less vulnerable to the effects of underwater nuclear detonations. However, any ship or submarine will be damaged or destroyed if it is close enough to a nuclear detonation.

F.9 Initial Nuclear Radiation

Nuclear radiation is ionizing radiation emitted by nuclear activity. It consists of neutrons, alpha and beta particles, and electromagnetic energy in the form of gamma rays.[13] Gamma rays are high-energy photons of electromagnetic radiation with frequencies higher than visible light or ultraviolet rays.[14] 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.[15]

Because neutrons are produced almost exclusively by fission events, they are produced in a fraction of a second, and there are no significant number of neutrons produced after that. Conversely, gamma rays are produced by the decay of radioactive materials; they will be produced for years after the detonation. Most of these radioactive materials are initially in the fireball. For surface and low-air bursts, the fireball will rise quickly, and within approximately one minute, it will be at an altitude high enough that none of the gamma radiation produced inside the fireball will have 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.

F.9.1 Initial Nuclear Radiation Damage & Injury

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 the section on the biological effects of ionizing radiation. The unit of measurement for radiation exposure is the

[13] *Ionizing radiation* is defined as electromagnetic radiation (gamma rays or X-rays) or particulate radiation (alpha particles, beta particles, neutrons, etc.) capable of producing ions (electrically charged particles) directly or indirectly in its passage through, or interaction with, matter.

[14] A *photon* is a unit of electromagnetic radiation consisting of pure energy and zero mass; the spectrum of photons include AM radio waves, FM radio waves, radar- and micro-waves, infrared waves, visible light, ultraviolet waves, X-rays, and gamma/cosmic rays.

[15] Both gamma rays and neutrons will be scattered and reflected by atoms in the air, causing each gamma photon and each 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 the ground zero, they will be traveling back toward the ground zero.

centi-Gray (cGy).[16] Figure F.11 shows selected levels of exposure, the associated near-term effects on humans, and the distances by yield.[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.

		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 F.11 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 will increase the risk of contracting any long-term cancer by approximately ten to fifteen percent and lethal cancer by approximately six to eight percent.[18]

Initial nuclear radiation can also damage the electrical components in certain equipment. See the section on transient radiation effects on electronics (TREE) below.

F.9.2 Initial Nuclear Radiation Employment Factors

The ground absorbs more gamma rays and neutrons than the air. Almost half of the initial nuclear radiation resulting from a surface burst will be quickly absorbed by the earth. In the aftermath of a low-air burst, half of the nuclear radiation will travel in a downward direction, but much of that radiation will be scattered and reflected by atoms in the air. This

[16] One cGy is an absorbed dose of radiation equivalent to 100 ergs of ionizing energy per gram of absorbing material or tissue. The term centi-Gray replaced the older term radiation absorbed dose (RAD).

[17] 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.

[18] 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.

will add to the amount of radiation traveling away from ground zero. 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., that there will be maximum initial radiation effect and that objects in the target area will not shield or attenuate the radiation.

F.9.3 Initial Nuclear Radiation Protection

Individuals can do very little to protect themselves against initial nuclear radiation after a detonation has occurred because initial radiation is emitted and absorbed in less than one minute. The Department of Defense has developed an oral chemical prophylactic to reduce the effects of ionizing radiation exposure, but the drug does not reduce the hazard to zero. Just as with most of the other effects, if an individual is very close to the detonation, it will be fatal.

Generally, structures are not vulnerable to initial nuclear radiation. Equipment can be hardened to make electronic components less vulnerable to initial nuclear radiation.

F.10 Residual Nuclear Radiation

Residual nuclear radiation consists of alpha and beta particles and gamma rays emitted from nuclei during radioactive material decay. There are two primary categories of residual nuclear radiation that result from a typical detonation: induced radiation and fallout. These categories of residual radiation also result from a deep underground detonation, but the radiation remains underground unless radioactive gases vent from the fireball or residual radiation escapes by another means, for example, through an underground water flow. An exo-atmospheric detonation creates a cloud in orbit that could remain significantly radioactive for many months.

For typical surface or low-air burst detonations, there are two types of induced radiation. The first type is neutron-induced soil on the ground, called an "induced pattern." Neutrons emitted from the detonation are captured by light metals in the soil or rock near the ground surface.[19] These atoms become radioactive isotopes capable of emitting, among other things, gamma radiation. The induced radiation is generally created in a circular pattern around the ground zero. It is most intense at ground zero immediately after the detonation. The intensity decreases over time and with distance from ground zero. In normal soil, it takes approximately five to seven days for induced radiation to decay to a safe level.

The second type of induced radiation is the production of carbon-14 by the absorption of fission neutrons in nitrogen in the air. Carbon-14 atoms can remain suspended in the air, are beta particle emitters, and have a long half-life (5,715 years).

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. However, the fireball will contain other types of radioactive particles that will also fall to the ground and contribute to the total radioactive hazard. These include the radioactive fissile material that did not undergo fission (no weapon fissions 100 percent of the fissile material) and material from warhead components that have been induced with neutrons and become radioactive.

Residual gamma radiation is colorless, odorless, and tasteless. Unless there is an extremely high level of radiation, it cannot be detected with the five senses.

F.10.1 Residual Nuclear Radiation Damage & Injury

Usually 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.

If a nuclear device is detonated in a populated area, it is possible that the induced radiation could extend to distances beyond building collapse. This is especially true with the employment of a low-yield device such as would likely be the case with a terrorist nuclear device. This could cause first responders who are not trained to understand induced radiation to accidentally move into an area that is still radioactively hot. Without radiation detectors, the first responders would not be aware of the radioactive hazard.

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

Between the early-1950s and 1962, when the four nuclear nations were conducting above ground nuclear testing, there was a two to three percent increase in total carbon-14 levels worldwide. Gradually, the amount of carbon-14 is returning to pre-testing levels. While there are no known casualties attributed to the increase, it is logical that any increase in carbon-14 levels over the natural background level could be an additional risk.

Normally, fallout should not be a hazardous problem for a detonation that is a true air burst. However, if rain or snow is falling 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 ground zero and downwind.

F.10.2 Residual Nuclear Radiation Employment Factors

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 will cause it to retain almost all of the weapon debris (usually one or at most a few tons of material) as it moves upward in altitude and downwind. In this case, very few particles fall to the ground at any moment, and there is no significant radioactive hot-spot on the ground caused by the fallout. The fireball will rise to become a long-term radioactive cloud. The cloud will travel with the upper atmospheric winds, and it will circle the hemisphere several times over a period of months before it dissipates completely. Most of the radioactive particles will decay to stable isotopes before falling to the ground. The particles that reach the ground will be 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 (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 (for example, a large bridge or a building), the fireball would have different properties. In addition to the three types of radioactive material mentioned above, the fireball would also include radioactive material from the ground (or from the structure) that was 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 one kiloton 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 (for a one kiloton detonation, 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 would begin to release a significant amount of radioactive dust, which would fall to the ground and produce a radioactive fallout pattern around ground zero and in areas downwind. The intensity of radioactivity in this fallout area would be hazardous for weeks. This is called early fallout, and it is 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.

F.10.3 Residual Nuclear Radiation Protection

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).[20] While the PPE will not stop the penetration of gamma rays, it will prevent the responder personnel from breathing in any airborne radioactive particles. Second, personnel should only be exposed to radioactivity for the minimum time possible to accomplish a given task. Third, personnel should remain at a safe distance from radioactive areas. Finally, personnel should use shielding when possible to further reduce the amount of radiation received. It is essential for first-responder personnel to follow the principles of PPE: time, distance, and shielding.

Equipment may be designed to be "rad-hard" if required. See Appendix G: *Nuclear Survivability*, for a discussion of the U.S. nuclear survivability program.

F.11 Biological Effects of Ionizing Radiation

Ionizing radiation is any particle or photon that can produce an ionizing event, i.e., strip one or more electrons away from their parent atom. It includes alpha particles, beta particles, gamma rays, cosmic rays (all produced by nuclear actions), and X-rays (not produced by nuclear actions).

F.11.1 Ionizing Radiation Damage & Injury

Ionizing events cause biological damage to humans and other mammals. Figure F.12 lists the types of biological damage associated with select ionizing events. Generally, 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 lead to casualties and death. See Figure F.11 for a description

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

Ionized Objects	Resulting Problem
Ionized DNA molecules	Abnormal cell reproduction
Ionized water molecules	Creates hydrogen peroxide (H_2O_2)
Ionized cell membrane	Cell death
Ionized central nervous system molecules	Loss of muscle control
Ionized brain molecules	Loss of thought process & muscle control

Figure F.12 Biological Damage from Ionization

of these problems at selected dose levels. Individuals who survive at these dose levels have a significantly higher probability of contracting mid-term and long-term cancers.

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 would experience mild threshold symptoms, i.e., transient mild headaches and mild nausea. At the 100 cGy level, approximately ten to fifteen percent of healthy adults would experience threshold symptoms, and a smaller percentage would experience some vomiting. Low levels of ionizing radiation exposure also result in a higher probability of contracting mid-term and long-term cancers. Figure F.13 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 F.13 Increased Cancer Risk at Low Levels of Exposure to Ionizing Radiation

F.11.2 Ionizing Radiation Protection

Protection from ionizing radiation can be achieved through shielding. Most materials will shield from radiation; however, some materials need to be present in significant amounts to reduce the penetrating radiation by half. Figure F.14 illustrates the widths required for

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]

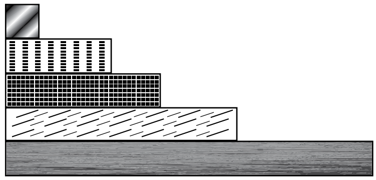

Figure F.14 Radiation Shielding

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").

F.12 Electromagnetic Pulse

Electromagnetic pulse (EMP) is a very short duration pulse of low-frequency (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 at high altitudes.[21] The interaction of gamma rays, X-rays, and neutrons with the atoms and molecules in the air generates an instantaneous flow of electrons, generally in a direction away from the detonation. These electrons immediately change direction (primarily because of the Earth's magnetic field) and velocity, emitting low frequency EMR photons. This entire process occurs almost instantaneously and produces a huge number of photons.

F.12.1 EMP Damage & Injury

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 that acts 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 will be destroyed. EMP can damage unprotected electronic equipment, including computers, vehicles, aircraft, communications equipment, and radars. EMP will not result in structural damage to buildings, bridges, etc.

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

EMP is not a direct hazard to humans. It is possible, however, that the indirect effects of electronics failing instantaneously in items such as vehicles, aircraft, and life-sustaining equipment in hospitals could cause injuries or fatalities.

F.12.2 EMP Employment Factors

A high-altitude detonation, or an exo-atmospheric detonation within a certain altitude range, will generate an EMP that could cover a very large region of the Earth's surface, as large as 1,000 kilometers across. A surface or low-air burst would produce local EMP with severe intensity, traveling through the air out to distances of hundreds of meters. Generally, the lower the yield, the more significant is the EMP compared with air blast. Unprotected electronic components would be vulnerable. Electrical lines and telephone wires would carry the pulse to much greater distances, possibly 10 kilometers, and could destroy any electronic device connected to the power lines.

Because electronic equipment can be hardened against the effects of EMP, it is not considered in traditional approaches for damage estimation.

F.12.3 EMP Protection

Electronic equipment can be EMP-hardened. The primary objective of EMP hardening is to reduce the electrical pulse entering a system or piece of equipment to a level that will 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 that operate in front of a ship's radars) also provides a significant degree of EMP protection.

Because the EMP is of such short duration, home circuit-breakers, typical surge-protectors, and power strips are useless against EMP. These devices are designed to protect equipment from electrical surges caused by lightning, but EMP is thousands of times faster than the pulse of lightning.

F.13 Transient Radiation Effects on Electronics

Transient radiation effects on electronics refers to the damage to electronic components exposed to initial nuclear radiation gamma rays and neutrons.

F.13.1 TREE Damage & Injury

The gamma rays and neutrons produced by a nuclear detonation are transient initial nuclear radiation that 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 harmful 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. While all electronics are susceptible to the effects of TREE, smaller, solid-state electronics such as transistors and integrated circuits are most vulnerable to these effects.

Although initial nuclear radiation may pass through material and equipment in a matter of seconds, the damage is usually permanent.

F.13.2 TREE Employment Factors

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. Because electronic equipment can be hardened against the effects of TREE, it is not considered in traditional approaches to damage estimation.

F.13.3 TREE Protection

Equipment that is designed to be protected against TREE is called “rad-hardened.” The objective of TREE hardening is to reduce the effect of the gamma and neutron radiation from damaging electronic components. 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 cheaper and more effective to design the EMP protection into the system during design development.

F.14 Blackout

Blackout is the interference with radio and radar waves resulting from an ionized region of the atmosphere. Nuclear detonations, other than those underground or far away in outer space, generate the flow of a huge number of gamma rays and X-rays that move in a general direction away from the detonation. These photons produce a large number of ionizing events in the atoms and molecules in the air, creating a very large region of ions. A large number of electrons are stripped away from their atoms, and move in a direction away from the detonation. This leaves a large number of positively charged atoms closer to the detonation, creating an ionized region with positively charged atoms close to the detonation and negatively charged particles farther from the detonation.

F.14.1 Blackout Damage & Injury

Blackout cannot cause damage or injuries directly. 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—could affect several aircraft simultaneously.

F.14.2 Blackout Employment Factors

A high-altitude or exo-atmospheric detonation would produce a very 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 if those signals travel through or near the ionized region. Under normal circumstances, this ionized region interference would continue 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 would produce a smaller ionized region of the lower atmosphere that could be as large as tens of kilometers in diameter. This ionized region could interfere with Very High Frequency (VHF) and Ultra High Frequency (UHF) communications signals and radar waves that rely on pin-point line-of-sight transmissions if those signals travel through or near the ionized region. Under normal circumstances, this low altitude ionized region interference would continue for a period of time up to a few tens of minutes after the detonation. Again, the ionized region can affect different frequencies out to different distances and for different periods of time.

F.14.3 Blackout Protection

There is no direct protection against the blackout effect.

F.15 Nuclear Weapons Targeting Process

Nuclear weapons targeting is a direct function of nuclear weapons effects. Nuclear weapons targeting accounts for the capability of U.S. nuclear weapons, the predictable effects of those weapons, and the damage expectancy that results. It is a process by which damage requirements to adversary targets are calculated to determine which weapons to use to defeat them. The nuclear weapons targeting process is cyclical. It begins 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 allied command guidance and priorities. These objectives direct joint force and component commanders and the targeting process continues through the combat assessment phase. Figure F.15 illustrates the nuclear targeting cycle and is followed by a brief description of each phase.

Figure F.15 The 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: Development of a target focuses 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: This phase integrates information concerning the target, the 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: This phase involves final tasking order preparation and transmission; specific mission planning and material preparation at the unit level; and presidential authorization for use.

Combat Assessment: The final phase is a joint effort designed to determine if the required target effects are consistent with the military campaign objectives. Nuclear combat assessment is composed of two segments, battle damage assessment and a re-attack recommendation.

F.15.1 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.

Damage criteria 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, they provide a means by which to evaluate whether the target or target sets were sufficiently damaged to meet operational objectives.

Radius of damage (RD) is that distance from the nuclear weapon burst at which the target elements have a fifty percent probability of receiving at least the specified (severe/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 will be damaged, response variability results. The RD depends on the type of target, the yield of the weapon, the damage criteria, and the height of burst of the nuclear weapon.

Circular error probable (CEP) is an indicator of the delivery accuracy of a weapon system and is used as a factor in determining probable damage to a target. CEP is the radius within which fifty percent of the weapons aimed at one point are expected to land. A weapon is expected to land within one CEP of an aimpoint for desired ground zero (DGZ) fifty percent of the time.

Probability of damage (PD) is the probability 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 probability that the weapon will arrive and detonate in the target area as planned. The PA is calculated as a product of weapon system reliability (WSR), pre-launch survivability (PLS), and probability to penetrate (PTP).

$$PA = (WSR) \times (PLS) \times (PTP)$$

- *WSR* is the compounded reliability based on test data provided by the National Nuclear Security Administration (NNSA) for the warhead and the Military Services for the delivery system.
- *PLS* is the probability that the selected weapon system will survive a first strike by the enemy.
- *PTP* is the probability that the weapon system will survive enemy air defense measures and reach the target.

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

$$DE = (PA) \times (PD)$$

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. Following are specific techniques for reducing collateral damage.

- *Reducing weapon yield:* The size of the weapon needed to achieve the desired damage is weighed against the associated danger to areas surrounding the target.
- *Improving accuracy:* Accurate delivery systems are more likely to strike the desired aimpoint, thereby reducing both 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 higher heights of burst to preclude any significant fallout, are a principal means of controlling or minimizing collateral damage.
- *Offsetting the desired ground zero:* Moving the DGZ away from target center may still achieve the desired weapon effects while avoiding or minimizing collateral damage.

Counter-value targeting directs the destruction or neutralization of selected enemy military and military-related targets such as industries, resources, and or/institutions that contribute to the ability of the enemy to wage war. In general, weapons required to implement this strategy need not be as numerous nor as accurate as those required to implement a counter-force targeting strategy because counter-value targets tend to be softer and less protected than counter-force targets.

Counter-force targeting is a strategy that employs forces to destroy the military capabilities of an enemy force or render them impotent. Typical counter-force targets include: bomber bases, ballistic missile submarine bases, intercontinental ballistic missile (ICBM) silos, antiballistic and air defense installations, command and control centers, and weapons of mass destruction storage facilities. Generally, the nuclear forces required to implement a counter-force targeting strategy are larger and more accurate than those required to implement a counter-value strategy. Counter-force targets generally tend to be harder, more protected, more difficult to find, and more mobile than counter-value targets.

Layering is a targeting methodology that employs more than one weapon against a target. This method is used to either increase the probability of target destruction or improve the probability that a weapon will arrive and detonate on target to achieve a specific level of damage.

Cross-targeting incorporates the concept of "layering," and also 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, submarine-launched ballistic missiles, or aircraft-delivered weapons increases the probability of achieving the desired damage or target coverage.

Appendix G
Nuclear Survivability

G.1 Overview

It is common to confuse nuclear weapons effects survivability with nuclear weapons 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. Thus, nuclear weapons effects survivability includes, but is not limited to, the survivability of nuclear weapons systems.

Nuclear weapons 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 weapons effects. The vast range of potential threats include: conventional and electronic weaponry; nuclear, biological, and chemical contamination; advanced technology weapons such as high-power microwaves and radio frequency weapons; terrorism or sabotage; and the initial effects of a nuclear detonation.

Put simply, nuclear weapons effects survivability refers to the ability of any and all personnel, equipment, and systems (including, but not limited to, nuclear systems) to survive nuclear weapons effects. Nuclear weapons system survivability refers to nuclear weapons systems being survivable against any threat (including, but not limited to, the nuclear threat). See Figure G.1 for a summary of the differences between nuclear weapons effects and nuclear weapons system survivability. An overlap occurs when the threat to the survivability of a nuclear weapons system is a nuclear detonation and its effects. Figure G.2 illustrates the intersection between nuclear effects survivability and systems survivability.

Nuclear Weapons Effects Survivabilty

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 Weapons System Survivabilty

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

Against the effects of ANY THREAT
- Nuclear Weapons
- Chemical, Biological Weapons
- Conventional Weapons
- Advanced Technology Weapons
- Special Ops Attack
- Terrorist Attack

Figure G.1 Nuclear Weapons Effects vs System Survivability

Nuclear weapons effects survivability refers to the capability of a system to withstand exposure to a nuclear weapons effects environment without suffering the loss of its ability to accomplish its designated mission. Nuclear weapons effects survivability may be accomplished by hardening, timely re-supply, redundancy, mitigation techniques (to include operational techniques), or a combination thereof. Systems can be nuclear hardened to survive prompt nuclear weapons 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 F: *The Effects of Nuclear Weapons*.)

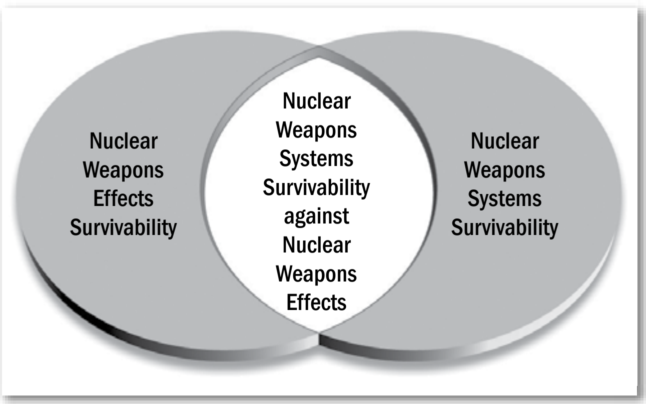

Figure G.2 Intersection of Nuclear Effects Survivability and Systems Survivability

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 weapons effects such as fallout, nor does it discuss nuclear contamination survivability.[1]

Mechanical and structural effects hardening consists of using robust designs, protective enclosures, protective coatings, and the proper selection of materials.

Electronics and electrical effects hardening involves using the proper components, special protection devices, circumvention circuits, and selective shielding. Nuclear weapons 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 weapons effects survivability. The impact of the nuclear weapons effects survivability approach on system cost, performance, reliability, maintainability, productivity, logistics support, and other requirements is examined to ensure maximum operational effectiveness consistent with program constraints. The different approaches to hardening are not equally effective against all initial nuclear weapons effects.

G.2 Nuclear Weapons Effects Survivability

Each of the primary and secondary environments produced by a nuclear detonation causes a unique set of mechanical and electrical effects. Some effects are permanent, and others are transient. Both can cause system malfunction, system failure, or loss of combat capability.

G.2.1 Nuclear Weapons 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.[2] The dominant nuclear environment refers

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 The *survival range* measures the distance from ground zero (GZ) necessary to survive nuclear weapons effects.

to the effects that set the survival range between the target and the explosion. Low-air, near-surface, and surface bursts will damage most ground targets within the damage radii. Also, high-altitude bursts produce high-altitude electromagnetic pulse (HEMP) effects over a very large area that may damage equipment with vulnerable electronics on the ground. Figure G.3 highlights the nuclear environments that dominate the survival for typical systems based on various heights of burst from space to below the Earth's surface.

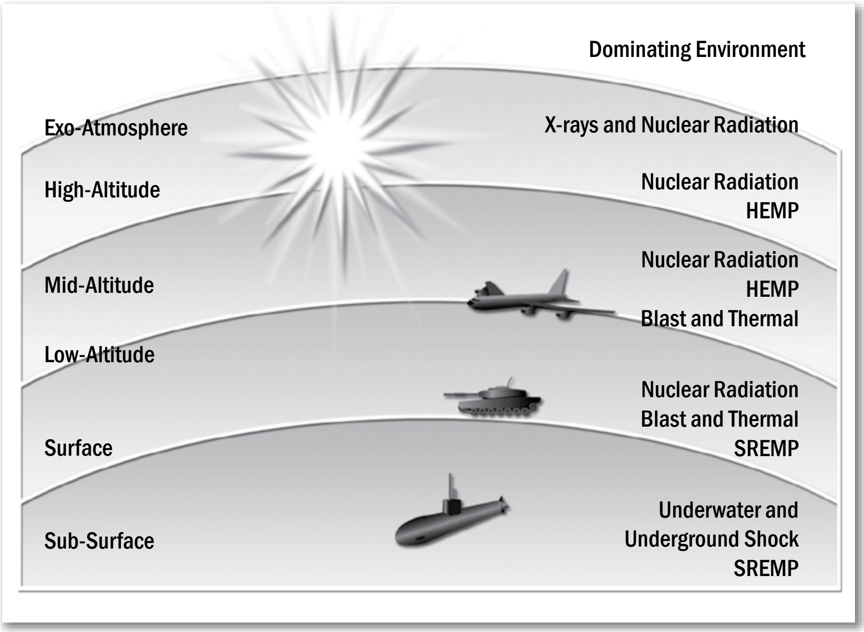

Figure G.3 Dominant Nuclear Environments as a Function of Altitude

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 explosion. 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. The final result of the EMP generated by the detonation is a tremendous surge of low frequency photons that can enter a system through designed and unintended antennas, generating a flow of electrical current that overloads and destroys electrical components and renders the equipment non-operational.

Underwater shock and ground shock are usually the dominant nuclear weapons effects for submerged submarines and buried shelters, respectively. HEMP is the dominant threat for surface-based systems located outside the target zone such as command, control, communications, and intelligence (C^3I) facilities or sophisticated electronics.

Nuclear weapons effects survivability requirements vary with the type of system, its mission, its operating environment, and the threat. For example, the X-ray, gamma ray, and neutron survivability levels used for satellites are very low compared with the survivability levels used for missiles and re-entry vehicles (RVs), or re-entry bodies (RBs). Satellite levels are usually set so that a single nuclear weapon, detonated in the region containing several satellites, will not damage or destroy more than one satellite. The levels used for RVs, on the other hand, 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 their 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. 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 and the total radiation dose delivered to personnel and electronics.

The area between ten kilometers down to the Earth's surface is somewhat of 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 air-blast, thermal radiation, and nuclear radiation effects.

On the Earth's surface, air blast and thermal radiation are the dominant nuclear weapons 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 threats with yields exceeding 10 kilotons (kt).

This is not necessarily true for blast-hard systems such as a battle tank or hardened shelter that can survive closer to a nuclear explosion. Very high levels of ionizing radiation usually require systems to be at greater distances from GZ to avoid personnel casualties and damage to electronic equipment. This is especially true for lower yield weapons. For example, a battle tank will probably survive at a distance of less than half of a kilometer from a ten kiloton explosion if the only consideration is structural damage. However, ionizing radiation from the detonation will affect the crew and the tank's electronics. Because thermal effects are easily attenuated and have a large variation of effect on the target, they are hard to predict. Consequently, thermal effects are not normally taken into consideration when targeting. Although they are a large part of a nuclear weapon's output, thermal effects do not govern survivability considerations for materiel objects, but they are always considered for exposed personnel.

Surface-launched missiles are in a category by themselves because they operate in so many different environmental regions. Missiles have to survive the effects of air blast, thermal radiation, HEMP, ionizing radiation, SREMP, and even X-rays.

G.2.2 Nuclear Weapons Effects on Personnel

Several of the effects of nuclear weapons are a threat to personnel. Thermal radiation can cause burns directly to the skin or can ignite clothing. Fires can spread to other locations, causing people to be burned due to an indirect effect of thermal radiation. Initial nuclear radiation (gamma rays and neutrons) can cause a significant acute dose of ionizing radiation. Residual radiation can cause significant exposure for days to weeks after the detonation. The blast wave can cause immediate casualties to exposed personnel, or can impact and roll a vehicle causing personnel injuries inside the vehicle. EMP will not cause injuries directly, but it can cause casualties indirectly, e.g., instantaneous destruction of electronics in an aircraft in flight could cause persons in the aircraft to be killed or injured.

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 weapons 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 GZ where a piece of equipment might survive, an individual outside and unprotected might become a casualty. Therefore, his 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. Because EMP has no effects on personnel, all systems should, in theory, have an equal requirement for EMP survivability.

G.2.3 Nuclear Weapons Effects Survivability Measures

There are a number of measures that enhance nuclear weapons effects survivability of equipment. Some of these measures can be achieved after production and fielding, but most measures require hardening features that are most effective if they are a part of the design development from the beginning. These measures are also much cheaper if they are designed and produced as a part of the original system rather than as a retrofit design and modification.

Timely re-supply 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 weapons 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 that 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 techniques that can be used to reduce the vulnerability of military systems to nuclear weapons effects. These may include but are not limited to:

- *avoidance,* or 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 weapons effects survivability by destroying incoming nuclear weapons or causing them to detonate outside the susceptible area of the protected system; and
- *deception,* or 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; 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. 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. It may also introduce a requirement for production controls to support hardness assurance, especially in strategic systems.

Threat effect tolerance is the intrinsic ability of a component or a piece of equipment to survive some level of exposure to nuclear weapons effects. The exposure level that a piece of equipment will tolerate depends primarily on the technologies it employs and how it is designed. The nuclear weapons 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.

G.3 Nuclear Weapons System Survivability

Nuclear weapons 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 weapons 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 the delivery system or platform; and 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), the personnel operating the nuclear weapon system, the supporting command and control links, and the supporting logistical elements.

Nuclear weapons system survivability is concerned with the entire threat spectrum that includes, but is not limited to, nuclear weapons effects. The vast range of potential threats include: conventional and electronic weaponry; nuclear, biological, and chemical contamination; advanced technology weapons such as high-power microwaves and radio frequency weapons; terrorism or sabotage; and the effects of a nuclear detonation.

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.

Survivability of nuclear forces is defined in DoD Directive 3150.3, *Nuclear Force Security and Survivability*, as: "the capability of nuclear forces and their nuclear control and support systems and facilities in wartime to avoid, repel, or withstand attack or other hostile action, to the extent that essential functions (ability to perform assigned nuclear mission) can continue or be resumed after onset of hostile action."

It is often difficult to separate measures to enhance survivability from those that provide security to the force or its components. In a potential wartime environment, for example, hardened nuclear weapons containers as well as hardened weapons transport vehicles provide security and enhance survivability during transit. Many of the measures to enhance nuclear weapons system survivability and to protect against the effects of nuclear weapons can be the same. Hardening and redundancy, for example, as well as threat tolerant designs, re-supply, and mitigation techniques apply to both.

G.3.1 Nuclear Force Survivability

Until recently, DoD Directive 3150.3 governed nuclear force security and survivability program requirements. The directive is outdated and is expected to be cancelled. The scope and requirements outlined in DoD Directive 3150.3 has been broadened and covered by two documents: DoD Directive 5210.41, *Security Policy for Protecting Nuclear Weapons*, and its corresponding manual, DoD S-5210.41M, both pertaining to nuclear force security; and DoD Instruction 3150.09, *Chemical, Biological, Radiological, and Nuclear (CBRN) Survivability Policy,* which establishes processes for ensuring the survivability of CBRN mission-critical systems (which includes all U.S. nuclear forces) in a chemical, biological, and radiological (CBR) environment or a nuclear environment.

G.3.2 Nuclear Command and Control Survivability

Nuclear weapons systems include not only the nuclear weapons but also the associated command and control (C2) support. The security and survivability of weapons systems C2 is addressed in DoD Directive 3150.3, *Nuclear Force Security and Survivability*, DoD Directive 5210.41, *Security Policy for Protecting Nuclear Weapons,* DoD Manual 5210.41-M, *Nuclear Weapons Security Manual,* and DoD Instruction 3150.09, *The Chemical, Biological, Radiological, and Nuclear (CBRN) Survivability Policy.*

DoD Directive S-5210.81, *United States Nuclear Weapons Command and Control*, establishes policy and assigns responsibilities related to the U.S. nuclear command and control system (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 C2 functions. The Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)), in conjunction with the Military Services, establishes survivability criteria for related nuclear weapons equipment.

G.3.3 Missile Silos

ICBM systems are deployed in missile silos. The survivability of these silos is achieved through the physical hardening of the silos and through their underground location, which protects against air blast effects. The dispersal of the multiple missile fields also adds to system survivability by complicating any targeting resolution.

G.3.4 Containers

Nuclear weapons 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.

G.3.5 Weapons Storage Vault

A weapons storage vault (WSV) is an underground vault located in the floor of a hardened aircraft shelter. A WSV can hold up to four nuclear weapons and provide ballistic protection in the lowered position through its hardened lid and reinforced sidewalls. The United States calls the entire system (including the electronics) the *weapon storage and security system*. NATO calls it the *weapon security and survivability system*. Both the United States and NATO refer to the entire system by the same acronym, WS3. The WS3 is currently in use in Europe.

G.4 Tests and Evaluation

Nuclear weapons effects testing refers to tests conducted to measure the response of objects to the energy output of a nuclear weapon. Testing (using simulators and not actual detonations) is essential to the development of nuclear survivable systems and is considered throughout the development and acquisition process. These testing and analysis methods are well-established and readily available. Analysis plays an important role in nuclear weapons effects survivability design and development. Computer-aided 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, by the inability to model complex items or handle the large, non-linear responses often encountered in both nuclear weapons effects and digital electronics.

G.4.1 Testing

Because the United States is no longer conducting underground nuclear tests, all nuclear weapon effects testing is done by simulators. These simulators are usually limited to a relatively small exposure volume and generally used for single environment tests, such as X-ray effects tests, neutron effects tests, prompt gamma ray effects tests, and EMP effects tests. Free-field EMP, high explosive (HE), and shock tube tests are notable exceptions because they can be tested at the system level. Additionally, in certain situations, the Army can test full systems for neutron and gamma fluence, and total dose at its fast burst reactors (FBRs). Figure G.4 lists the types of simulators commonly used for nuclear weapons effects 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 ▪ FBR	▪ Components, circuits, and equipment
Total Dose Gamma Effects	▪ Cobalt 60 ▪ FBR	▪ Components, circuits, and equipment
Neutron Effects	▪ FBR	▪ 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 G.4 Simulators Commonly Used for Effects Testing

G.4.2 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 they are rapidly absorbed in the atmosphere, X-rays 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 and plasma radiation sources. Flash X-ray machines are used to simulate the effects from higher-energy hard (or hot) X-rays, and plasma radiation sources are used to simulate the effects from lower-energy soft (or cold) X-rays.

Flash X-ray machines, commonly referred to as FXRs, generate large amounts of electric power, which is converted into intense, short pulses of energetic electrons. The electrons are normally stopped in a metal target that converts a small portion of their energy into a pulse of X-rays. The resulting photons irradiate the test specimen. The electron pulse may also be used to simulate some X-ray effects. The output characteristics of FXRs depend on the design of the machine and vary considerably from one design to the next. Radiation pulse widths range from ten 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 matter of nanoseconds results in power levels ranging from billions to trillions of watts.

X-ray effects testing usually requires a machine capable of producing a trillion watts or more in power with an output voltage of around one million volts. The X-rays produced by a machine of this type tend 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.

Cold X-ray effects testing is designed to replicate surface damage to exposed components in space applications, and it is normally performed with a plasma radiation source (PRS). The PRS machine generates cold X-rays by driving an intense pulse of electric energy into a bundle of fine wires or a gas puff to 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.

Currently, there are a number of pulsed power facilities used to generate X-ray environments. The DOE operates both the Saturn and Z facilities. The DoD operates the Modulas Bremsstrahlung Source (MBS), Pithon, and Double Eagle facilities. These facilities are currently in various states of readiness based on predicted future use.

G.4.3 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; the effects do not lend themselves to strict analyses because they 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.

The two most popular machines used for gamma dose-rate testing are FXRs and linear accelerators, or LINACs. The FXRs used for dose-rate effects tests operate at significantly higher voltages than the 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 and is 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*.[3]

LINACs are restricted to piece-part size tests and are typically 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 low-output intensity.

Most dose-rate tests are active; that is, they require the test object to be powered up and operating for testing. Effects like component latch-up, logic upset, and burnout will not

[3] *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.

occur in the absence of power. Tests must be conducted in a realistic operating condition and the test object must be continuously monitored before, during, and after exposure.

Sandia National Laboratories operates the High-Energy Radiation Megavolt Electron Source (HERMES) pulsed-power facility to simulate prompt gamma environments at extreme dose rates for the DOE. The DoD currently operates smaller gamma-ray facilities used to test systems at lower levels. These include the PulseRad 1150 at Titan International and the Relativistic Electron Beam Accelerator (REBA) at White Sands Missile Range.

G.4.4 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. The most popular and widely used simulator for total-dose effects testing is the Cobalt-60 (Co60) 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 but not with the frequency or the confidence of the Co60 source.

G.4.5 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. The most popular device for simulating the effects of neutrons on electronics is a bare, all metal, unmoderated fast-burst reactor. A FBR produces a slightly moderated fission spectrum, which it can deliver in either a pulsed or steady-state mode. Both the Army and Sandia National Laboratories currently have a fast-burst reactor.

G.4.6 EMP 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-powered 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 the White Sands Test Range in New Mexico. These facilities can test most systems.

G.4.7 Air-Blast Effects Testing

The military relies more on structural analyses for determining air-blast effects than on testing. This is due to the confidence engineers have in computer-aided structural analyses and to 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 that consists 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 high explosive test or in a large shock tube.

Shock tubes vary in size from small laboratory facilities to very large, full-scale devices. The Defense Threat Reduction Agency (DTRA) Large Blast/Thermal Simulator (LBTS) (currently in caretaker status) can accommodate test objects as large as a helicopter. It can simulate 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 the "Stallion Range," in White Sands, New Mexico. These tests were used to validate the survivability/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 have had to be extrapolated for survivability against higher yield weapons and for non-ideal air-blast effects. Structures constructed of heat sensitive materials, like fiberglass and aluminum (which lose strength at elevated temperatures), are normally exposed to a thermal radiation source before the arrival of the shock wave.

G.4.8 Thermal Radiation Effects Testing

The majority of thermal radiation effects testing is performed with high intensity flash lamps, solar furnaces, liquid oxygen, and powered aluminum flares, called thermal radiation sources (TRS). Flash lamps and solar furnaces are normally used on small material samples and components. TRS is used for larger test objects and was 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.

G.4.9 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. There is a family of machines, such as hammers, drop towers, and slapper plates, for simulating shock effects on various weights and sizes of 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.

Appendix H
Classification

H.1 Overview

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

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

H.2 Information Classification

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

H.2.1 National Security Information

National security information is protected by Executive Order (EO) 13526. EO 13526 prescribes a uniform system for classifying, safeguarding, and declassifying national security information. EO 13526 states that national security information may be classified at one of the following three levels:

- *Top Secret* 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* 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* 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.

H.2.2 Atomic Energy (Nuclear) Information

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

- Restricted Data is all data concerning: design, manufacture, or utilization of atomic weapons; the production of special nuclear material; or the use of special nuclear material 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)* or *national security information (intelligence information)*.

- Formerly Restricted Data is jointly determined by the DOE and the Department of Defense (DoD) to relate primarily to the military utilization of atomic weapons and that can be adequately safeguarded as defense information (for example, 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 re-categorized as national security information refers to information that is jointly determined by the DOE and the Director of National Intelligence to be information that concerns the atomic energy programs of other nations and that can be adequately safeguarded as defense information (for example, 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 atomic energy (nuclear) information.

The DoD System for Controlling Atomic Energy (Nuclear) Information

DoD policy governing access to and dissemination of RD is stated in DoD Directive 5210.2. 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 the components of a thermonuclear or implosion-type fission bomb, warhead, demolition, munition, or test device.[1] In addition, the DoD currently recognizes the designations of Sigma 14, Sigma 15, and Sigma 20, as defined by the DOE, as an additional subset of Restricted Data.

The DOE System for Controlling Atomic Energy (Nuclear) Information

The DOE policy of categorizing Restricted Data into defined subject areas is known as the *sigma system*. This categorization system separates RD information into common work groups to enforce need-to-know limitations. The sigma system applies strict security procedures to narrowly focused information areas. There are currently thirteen sigma categories, each of which contains a specific subset of RD information. Sigma categories 1-13 are defined by DOE Order 5610.2 Chg 1:

- Sigma 1: Information relating to the theory of operation (hydrodynamic and nuclear) or complete design of thermonuclear weapons or their unique components.
- Sigma 2: Information relating to the theory of operation or complete design of fission weapons or their unique components. This includes the high explosive system with its detonators and firing unit, pit system, and nuclear initiation system as they pertain to weapon design and theory.
- Sigma 3: Manufacturing and utilization information not comprehensively revealing the theory of operation or design of the physics package. Complete design and

[1] Sigma 1 and Sigma 2 generally, but not completely, equate to DoD CNWDI.

operation of nonnuclear components but only information as prescribed below for nuclear components. Utilization information necessary to support the stockpile to target sequence. Information includes:

a. General external weapon configuration, including size, weight, and shape;
b. Environmental behavior, fuzing, ballistics, yields, and effects;
c. Nuclear components or subassemblies that do not reveal theory of operation or significant design features;
d. Production and manufacturing techniques relating to nuclear components or subassemblies; and
e. Anticipated and actual strike operations.

- Sigma 4: Information inherent in preshot and postshot activities necessary in the testing of atomic weapons or devices. Specifically excluded are the theory of operation and the design of such items. Information includes:
  a. Logistics, administration, other agency participation;
  b. Special construction and equipment;
  c. Effects, safety; and
  d. Purpose of tests, general nature of nuclear explosive tested, including expected or actual yields and conclusions derived from tests not to include design features.
- Sigma 5: Production rate and/or stockpile quantities of nuclear weapons and their components.
- Sigma 6, 7, 8: These are no longer in use; they are subsumed by sigma 5.
- Sigma 9: General studies not directly related to the design or performance of specific weapons or weapon systems, e.g., reliability studies, fuzing studies, damage studies, aerodynamic studies, etc.
- Sigma 10: The chemistry, metallurgy, and processing of materials peculiar to the field of atomic weapons or nuclear explosive devices.
- Sigma 11: Information concerning inertial confinement fusion that reveals or is indicative of weapon data.
- Sigma 12: Complete theory of operation, complete design, or partial design information revealing either sensitive design features or how the energy conversion takes place for the nuclear energy converter, energy director, or other nuclear directed energy weapon systems or components outside the envelope of the nuclear source but within the envelope of the nuclear directed energy weapon.

- Sigma 13: Manufacturing and utilization information and output characteristics for nuclear energy converters, directors, or other nuclear directed energy weapon systems or components outside the envelope of the nuclear source, not comprehensively revealing the theory of operation, sensitive design features of the nuclear directed energy weapon, or how the energy conversion takes place. Information includes:
  a. General, external weapon configuration and weapon environmental behavior characteristics, yields, and effects.
  b. Component or subassembly design that does not reveal theory of operation or sensitive design features of nuclear directed energy weapons categorized as sigmas 1, 2, or 12.
  c. Production and manufacturing techniques for components or subassemblies of nuclear directed energy weapons that do not reveal information categorized as sigmas 1, 2, or 12.

Sigmas 14 and 15 define use control and are governed by DOE Manual 452.4-1A:

- Sigma 14: That category of sensitive information (including bypass scenarios) concerning the vulnerability of nuclear weapons to a deliberate unauthorized nuclear detonation.
- Sigma 15: That 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. It may include weapon design features not specifically part of a use control system. (Note: Not all use control design information is sigma 15.)
- Sigma 14 or 15 Access Authorization: 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 nuclear weapon data (NWD).

Sigma 20 is a relatively new sigma category defined by DOE Order 457.1.

- Sigma 20: A specific category of nuclear weapon data that pertains to sensitive improvised nuclear device information.

H.3 Classifying Documents

In order to properly classify a document, an individual must have classification authority. There are 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 it may be a derivative classification action.

H.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). The original classification authority (OCA) also serves as the declassification authority or sets the date for automatic declassification. Within the DoD and the DOE, only appointed government officials can classify national security information. Further, only DOE officials can have original classification authority for RD information. In an exceptional case, 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.

H.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 can use derivative classification authority on national security information and RD and FRD information. These individuals are any employees or designated contractors with proper access to and training on classified materials.

H.4 Security Clearances

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

H.4.1 Department of Defense 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 that they have the proper "need to know"[2], to view information classified at those levels, as defined by EO 13526.

H.4.2 Department of Energy Security Clearance Levels

Corresponding to the information restrictions and guidelines in the *Atomic Energy Act of 1954*, the DOE established a security clearance system (implemented through DOE Order 472.1B) 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.

H.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, Figure H.1 shows the closest possible illustration of the overlap of atomic and national security information between the two departments.

DOE	DoD
L	C/S-NSI/FRD or C-RD
Q	Secret-RD
Q (w/ TS authority)	TS-RD
RD, FRD (Sigma System)	RD, FRD
Sigma 1 & 2	CNWDI
UCNI	UCNI

Figure H.1
Overlap of Atomic and National Security Information

H.5 Accessing Classified Information

There are two basic requirements to access classified information: appropriate clearance and "need to know." Both must be present for an individual to view classified information; rank, position, or clearance is not sufficient criteria from which to grant access. Personnel security clearance levels correspond to the security classifications. An individual may have

[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, or possession of classified information in order to perform tasks or services essential to the fulfillment of an official United States government program. Knowledge, 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.

a Confidential, Secret, Top Secret, or Top Secret/Sensitive Compartmented Information (SCI) clearance in the DoD; an individual may have L, Q, or Q with TS authority in the DOE. Each of these clearance levels also has an interim status, which allows the cleared person to view but not create or control documents at that level. Once the individual is given a final clearance, he/she is able to control documents for that level of classification. For example, within the DoD, individuals will not be afforded access to RD until they have been granted a final secret clearance. 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.

"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.

To be given access to Top Secret or Secret RD/FRD or Q level information an 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 DOE, the DoD, the Nuclear Regulatory Commission (NRC), and the National Aeronautics and Space Administration (NASA) have the authority to grant RD/FRD access. To access CNWDI information, individuals require authorization and a briefing.

H.6 Marking Classified Documents

There are two types of documents that require classification markings: originally classified documents and derivatively classified documents.

H.6.1 Originally Classified Documents

EO 13526 requires certain essential markings on originally classified documents. DoD 5200.1-R stipulates marking requirements for classified documents. This section will explain each marking and how it is appropriately placed in a classified document. The essential markings are: portion marking, overall classification, "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) is used for Unclassified, (C) for Confidential, (S) for Secret, and (TS) for Top Secret. 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.

After portion marking, the classifier must determine the overall classification of the document. The document is classified at the highest level of the portion markings contained within the document. 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. The most common practice is to mark all internal pages with the overall document classification.

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 of the following classification categories:

a. military plans, weapons systems, or operations;
b. foreign government information;
c. intelligence activities (including covert action), intelligence sources or methods, or cryptology;
d. foreign relations or foreign activities of the United States, including confidential sources;
e. scientific, technological, or economic matters relating to the national security;
f. United States government programs for safeguarding nuclear materials or facilities;
g. vulnerabilities or capabilities of systems, installations, infrastructures, projects, plans, or protection services relating to the national security; or
h. 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:[3]

1. 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; or
2. When a specific date or event cannot be determined, identify the date that is 10 years from the date of the original classification; or
3. 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.

H.6.2 Derivatively Classified Documents

Derivative classification is the act of incorporating, paraphrasing, restating, or generating in new form, information that is already classified and marking the newly developed material consistent with the markings of the source information. The source information ordinarily consists of a classified document or documents or a classification guide issued by an OCA. It is important to note that the DoD can only derivatively classify documents containing RD.

Derivative Classification Using a 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,

[3] Whenever possible, the original classifying authority should select the declassification instruction that will result in the shortest duration of classification.

the derivative document should reflect the longest period of classification of any of 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, this is a brief description of the source document used to determine the classification of the information. Documents whose 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.

H.6.3 Marking Restricted Data and Formerly Restricted Data 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, AEA 1954.

Additionally, documents containing RD and FRD should have abbreviated markings ("RD" or "FRD") 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 Directive 5210.2 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.

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

For Official Use Only and Official Use Only are terms used by the DoD and the DOE, 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 listed below:

1. Information that pertains solely to the internal rules and practices of the agency.
2. Information specifically exempted by a statute establishing particular criteria for withholding. The language of the statute must clearly state that the information will not be disclosed.

3. 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 like information in the future, or protect the government's interest in compliance with program effectiveness.
4. Interagency memoranda that are deliberative in nature; this exemption is appropriate for internal documents that are part of the decision making process and contain subjective evaluations, opinions, and recommendations.
5. Information, the release of which could reasonably be expected to constitute a clearly unwarranted invasion of the personal privacy of individuals.
6. 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.
7. Certain records of agencies responsible for supervision of financial institutions.
8. Geological and geophysical information concerning wells.

The DoD and the DOE also use the term Unclassified Controlled Nuclear Information. DoD defines UCNI as unclassified information pertaining to security measures (including plans, procedures, and equipment) for the physical protection of DoD special nuclear material, equipment, or facilities. While this information is not formally classified, it is restricted in its distribution. DoD UCNI policy is stated in DoDD 5210.83. The DOE uses the term UCNI in a broader manner than the DoD. Designating DoD information as UCNI is governed by 10 USC 128; designating DOE information as UCNI is governed by 42 USC 2168 et seq.

While protecting information critical to the nation's security is a priority, the U.S. government is also committed to open government through the accurate and accountable application of classification standards. An equally important priority is the assurance of routine, secure, and effective declassification. Strict adherence to the classification principles described above is extremely important to ensure the achievement of these goals while protecting the country's national security information.

Appendix
Programming, Planning, and Budgeting

I.1 Overview

The budget system of the United States government provides the means for the president and Congress to decide how much money to spend, what to spend it on, and how to raise the money needed. The allocation of resources among federal agencies is determined through the budget system. While the system focuses primarily on dollars, it also allocates other resources, such as federal employment positions.

Within the federal budget system, the acquisition and funding of nuclear weapons systems and activities and technologies related to countering nuclear threats (CNT) are complex processes involving many organizations in the executive and legislative branches of the federal government. Each organization performs specific activities and uses particular processes for the acquisition and funding of nuclear weapons, the CNT mission, and their associated systems and supporting infrastructure.

I.2 The Federal Budget

The process for creating the federal budget is set forth in the Budget and Accounting Act of 1921 and the Congressional Budget and Impoundment Control Act of 1974. The acts have been amended several times, but the legislation remains the basic blueprint for budget procedures.

The federal budget is divided into 20 functional and subfunctional categories so that all budget authority[1] and outlays[2] can be categorized according to the national needs being addressed. National needs are grouped in 17 broad areas to provide a coherent and comprehensive basis for analyzing and understanding the budget. Three additional categories do not address specific national needs but are included to cover the entire budget. Each functional and subfunctional category is assigned a numerical identification code. The National Defense budget function is identified by the numerical identification code "050." This account is divided into sub-accounts: 051 for Department of Defense (DoD) national security funding; 052 for classified budgeting for certain specific national security activities; 053 for the National Nuclear Security Administration (NNSA) defense programs; and 054 for defense-related activities in other departments. Figure I.1 illustrates the breakdown of the 050 National Defense Account.

The federal budget provides a plan to prioritize and fund government activities. The president, the Office of Management and Budget (OMB), and various federal departments and agencies have major roles in developing the *Budget of the United States Government*, which is often called the "president's budget."

I.2.1 The President's Budget

The OMB is the principal executive branch oversight agency for the federal budget. It consolidates the budget proposal for the president after consulting with senior advisors, cabinet officials, and agency heads. The OMB also apportions funds to federal agencies after Congress completes the budget process and the president signs the various appropriations bills into law.

Initial development of the president's budget begins with preliminary discussions between the OMB and the departments (including the DoD and the DOE); these discussions are held in the spring, about 17 months prior to the start of the fiscal year. The OMB issues policy directions and planning guidance to the agencies for the upcoming budget request.

The DoD, the DOE, and other agencies submit their budget requests to the OMB on the first Monday after Labor Day of the year before the start of the fiscal year covered by the

[1] *Budget authority* refers to the authority to incur legally binding obligations of the Government.

[2] *Outlays* refer to the liquidation of the Government's obligations; outlays generally represent cash payments.

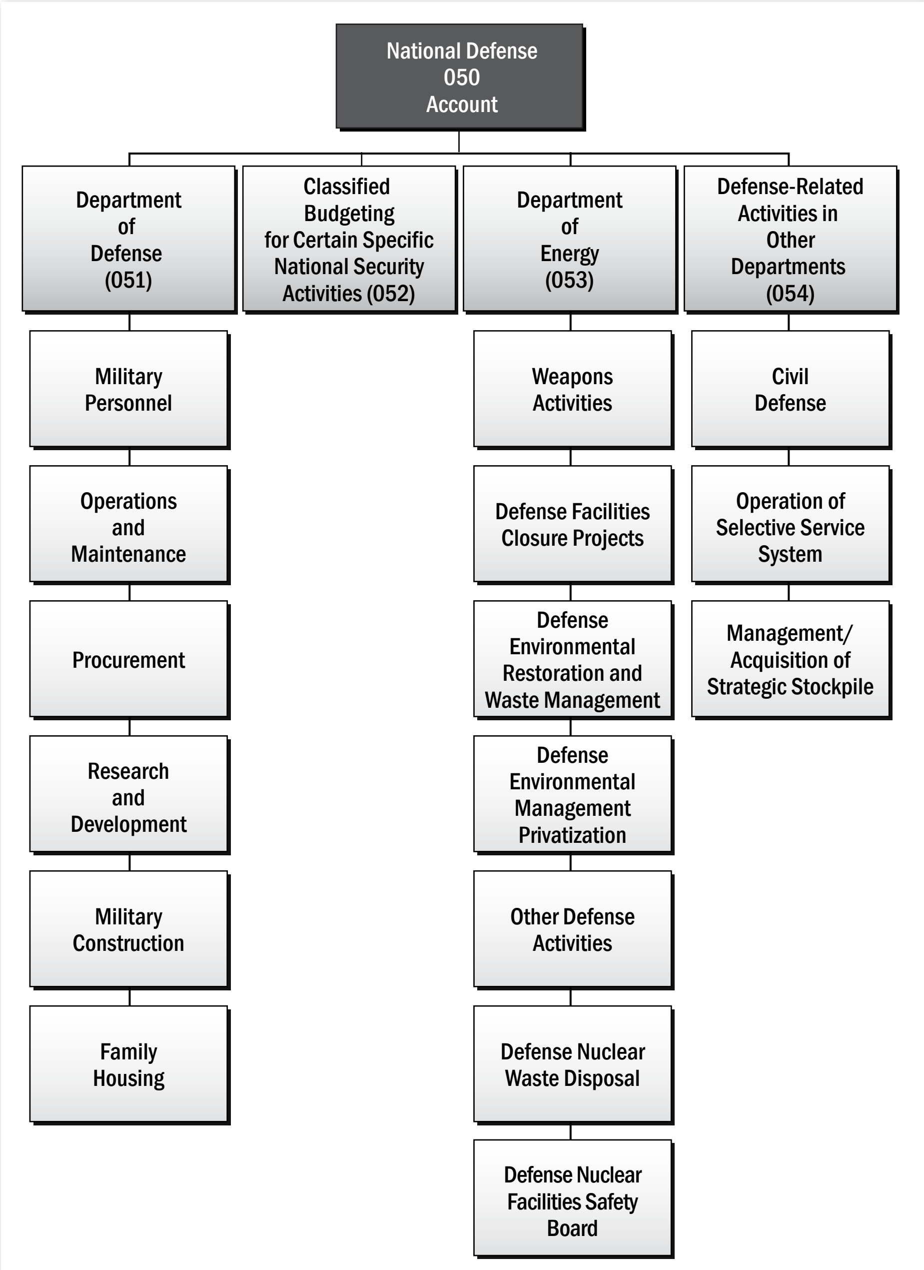

Figure I.1 The 050 Account

budget request; this submission occurs about 13 months before the start of the fiscal year in question. In the fall, OMB staff representatives review the agencies' budget proposals, hold hearings with the agencies, and review the economic outlook and revenue estimates to prepare issues for the OMB director's review. The director briefs the president and senior advisors on proposed budget policies and revenue estimates and recommends a complete set of budget proposals based on a review of all agency requests.

The president makes decisions on broad policies so that, in late November (about 10 months prior to the start of the fiscal year), OMB passes back budget decisions to the departments and agencies on their budget requests in a process called "passback." The passback includes decisions concerning funding levels, program policy changes, and personnel ceilings; the agencies may appeal any decisions with which they disagree. If OMB and an agency cannot reach agreement, the issue may be taken to the secretaries of the departments and to the president.

The president submits the budget request to Congress by the first Monday in February, nine months prior to the start of the fiscal year. The president's budget consists of several volumes delineating the president's financial proposals with recommended priorities for the allocation of resources by the federal government. The president also submits a mid-session review of his budget to Congress by July 15 each year. Also called a *supplementary budget summary*, the document includes updated presidential policy budget estimates, summary updates to the information in the budget submission, and budget-year baseline estimates. The president may revise his recommendations any time during the year.

I.2.2 Congressional Budget Resolution

Congress considers the president's budget proposals and either approves, modifies, or rejects them. Congress can change funding levels, eliminate programs, or add programs not requested by the president. Congress can add or eliminate taxes and other sources of receipts, or it can make other changes that affect the amount of receipts collected.

Initial House and Senate Budget Committee hearings are held during the month of January leading up to the submission of the president's budget during the first week of February. During February, the Congressional Budget Office publishes its annual report on the president's budget, and the House and Senate Budget Committees develop their versions of a budget resolution. Ideally, these resolutions are brought to the House and Senate floors for markup[3] at the end of February and adopted by early April. Leading

[3] *Markup* refers to the process by which congressional committees and subcommittees debate, amend, and rewrite proposed legislation—in this case, authorization and appropriations bills.

Budget Committee members from both chambers then develop a conference report on the budget representing a consensus agreement on the legislation between House and Senate negotiators. This conference report is the blueprint for broad spending and tax decisions that will be made during the remainder of the year. Ideally, the conference report on the budget resolution is adopted by April 15, just less than six months from the start of the fiscal year.

The budget resolution is not formally a law. It is a concurrent resolution, which does not require the president's signature. The aggregate levels of revenues, budget authority, outlays, and the committee allocations in the budget resolution are guidelines and targets against which subsequent fiscal legislation such as appropriation acts and authorizing legislation is measured.

I.2.3 Authorization

Authorization Acts provide the legislative authority to establish or maintain a federal government program or agency. Authorizations define the scope and provide the recommended maximum funding levels to the Appropriations Committees for the various programs.

Authorizing Committees have discretion regarding the legislative changes they recommend. These committees, moreover, are not bound by program changes that are recommended or assumed by the Budget Committees. They are required, however, to recommend legislation addressing budget authority and outlays for each fiscal year.

Authorizing legislation may originate in either chamber and may be considered at any time during the year. The Authorizing Committees and Subcommittees hold hearings to review agency programs and policies. It is possible, though rare, for an agency to operate without an authorization, but it cannot function without an appropriation.

The House and Senate Armed Services Committees provide annual legislative authorization for the federal government programs associated with national defense. The House and Senate Armed Services Committee and the seven standing subcommittees are responsible for the development of the annual National Defense Authorization Act (NDAA).[4] Between January and April, the House and Senate Armed Services Committees hold hearings to

[4] The NDAA serves two purposes: it establishes, continues, or modifies existing defense programs, and it provides guidance for defense appropriators, all of which allows Congress to appropriate funds for defense programs. The NDAA also authorizes funding for defense-related activities at the NNSA and other agencies.

determine the defense authorization levels. The Subcommittees on Strategic Forces have jurisdiction over strategic forces and the Department of Energy (DOE) national security programs. House markup of the authorization act occurs between April and May; the Senate markup follows. The two houses meet in conference after completion of their markup; the authorization bill is then finalized and forwarded to the president for signature so that it can be passed into public law by the new fiscal year.

I.2.4 Appropriations

Appropriation acts set the terms and conditions for the use of federal funds. The congressional Appropriations Committees provide budget authority and outlays through 13 general appropriations areas. The Appropriations Subcommittees, which correspond to each of the 13 general appropriations areas, initially recommend the level at which programs within their jurisdiction will receive appropriations. The House and Senate Energy and Water Development Subcommittees have jurisdiction over nuclear weapons funding (nuclear warheads and supporting activities) at the DOE, and the House and Senate Defense Subcommittees have jurisdiction over DoD nuclear weapons funding (delivery systems).

The House and Senate Appropriations Committees and Subcommittees hold hearings from the end of January through mid-May each year. If the Budget Committees have not finalized a budget resolution on the budget before May 15, the Appropriations Committee may begin their markup of appropriations legislation. All Appropriations Subcommittees are required to pass their respective appropriations bills on or before June 10 each year and then forward them to the full Appropriations Committees for further consideration before sending the bill to the full House and Senate for consideration. The House targets June 30 as a completion date for appropriations bills, but in practice, debate can continue within the legislative bodies until the July/August timeframe. After the chambers pass their respective appropriations bills, House and Senate representatives meet in conference and develop a conference report on appropriations.

After the House and Senate approve the final conference report it is forwarded to the president. The president has ten days to approve or veto the bill. If the bill is signed, the bill and the conference report form the legal basis for an agency's use of funds. If the bill is vetoed, Congress may either override the veto with a two-thirds affirmative vote in each chamber, or it may modify the bill and send it back to the president for signature or veto. Figure I.2 illustrates the congressional budget process for nuclear weapons- and CNT-related programs.

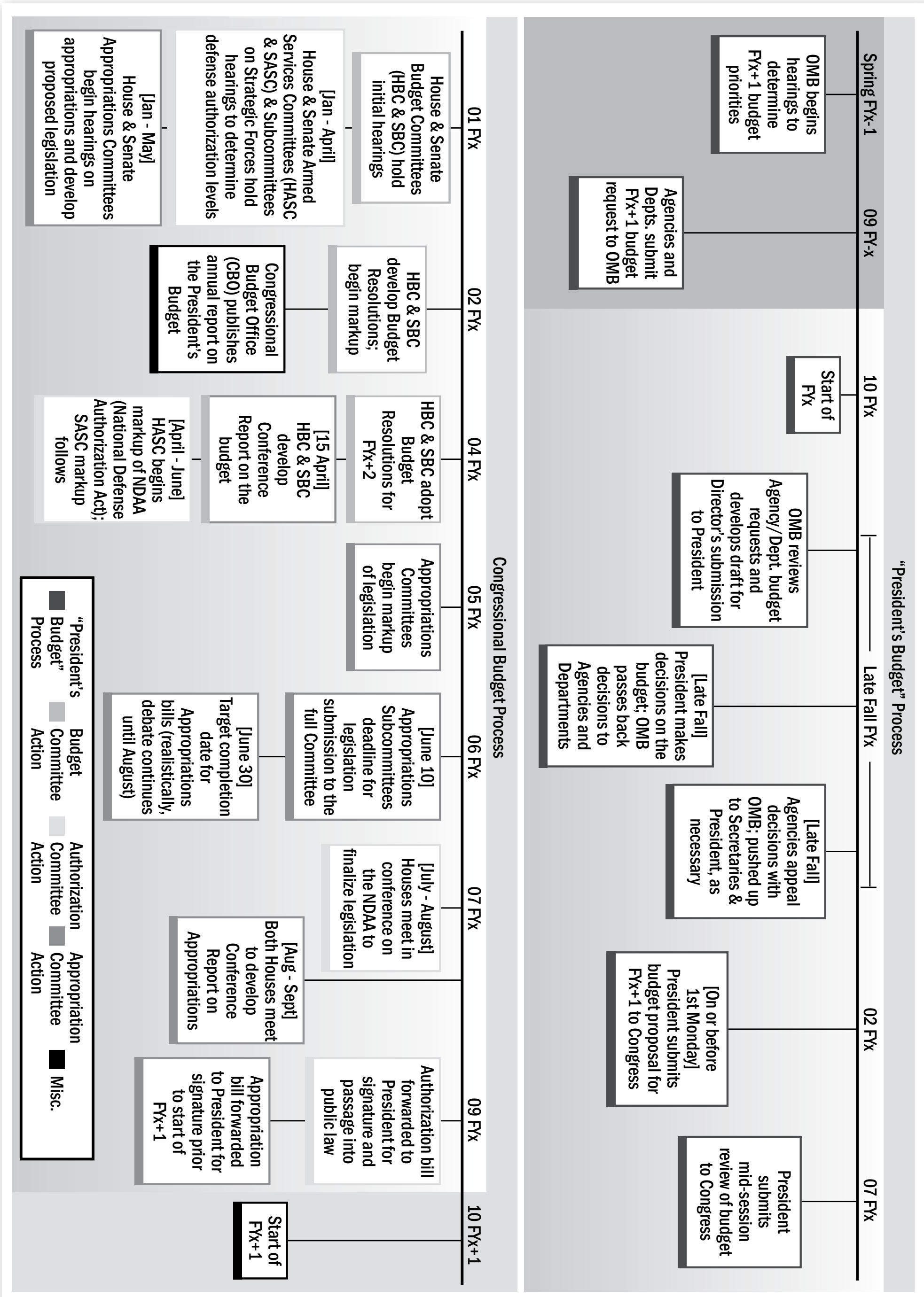

Figure I.2 Congressional Budget Process for Nuclear Weapons-Related Programs

I.2.5 Continuing Resolution

If Congress and the president have not completed action on the regular appropriation acts by the start of the fiscal year (October 1), action must be taken to ensure that federal agencies and programs continue to function. Enacted as a joint resolution, a continuing resolution (CR) is an interim appropriation act that sets forth a specified level of funding for an agency for the full year, up to a specified date, or until regular appropriations are enacted. Spending may be set at any level, but if it is enacted to cover the entire fiscal year, the resolution will usually specify amounts provided for each appropriation account. In recent years OMB has automatically apportioned funds based on the number of days included in the continuing resolution. CRs are, however, difficult for those operating under them. In addition to the inherent uncertainty associated with them, continuing resolutions allow funding only at the lower levels approved by the House and the Senate, prevent new starts, and preclude significant funding increases over the previous year.

A CR has an expiration date at which time it must be extended by additional congressional action if no appropriation bill has been enacted. Unlike the congressional budget resolution, the president must sign all CRs into law.

I.3 The DoD and the NNSA Role in the Budget Process

The DoD and the NNSA have processes in place to plan, program, and budget resources for inclusion in the president's budget. The DoD process is known as the Planning, Programming, Budgeting, and Execution (PPBE) system; and the NNSA process is called the Planning, Programming, Budgeting, and Evaluation (PPBE) process.

I.3.1 Department of Defense PPBE

For the DoD, planning includes the definition and examination of alternate strategies as well as various analyses of conditions, threats and technologies, and economic assessments. The Defense Planning Guidance (DPG) forms the basis of the planning portion of the DoD Planning, Programming, Budgeting, and Execution system. The DPG contains guidance concerning the key planning and programming priorities to execute the *National Military Strategy* and other documents produced by the Joint Staff. The DPG provides guidance and fiscal constraints to the Military departments, U.S. Special Operations Command (USSOCOM), and the defense agencies for the development of the DoD Program Objective Memorandum (POM).

Programming includes the definition and analysis of alternative forces, weapons, and support systems, as well as their multi-year resource implications and option evaluations.

The Program Objective Memorandum is the DoD document that expresses the fiscally constrained, total program requirements for the years covered in the DPG. It describes the rationale for proposed changes to U.S. forces as included in the Future-Years Defense Program (FYDP), which is the official database of all major force programs established by the military. The POM is sent to the Office of the Secretary of Defense (OSD) in August of even-numbered years. The composite POM is reviewed by the Joint Staff, the OSD, and the OMB, and issues are discussed and alternatives are developed. Some issues are elevated to the Defense Resources Board (DRB) where decisions are finalized and recorded in Program Decision Memoranda (PDM) in the late fall.

Budgeting includes the formulation, justification, execution, and control of the funds necessary to support the DoD and its missions. Each Military Department and Defense Agency and USSOCOM develops its own budget estimate submission. The budget estimate submissions include data from the prior year, the current year, and two additional budget years.

Historically, Program Budget Decisions (PBDs) were used to document approval of the estimates for inclusion in the president's budget. Each PBD consists of a discussion of the subject area, issues, and a series of alternatives. The deputy secretary of defense selects an alternative or directs a new one, and the signed PBD is then released. An appeal can be made to the PBD through a reclama process that follows the same channels as the PBD. The deputy secretary of defense makes all final decisions. Resource Management Decisions (RMDs) were first issued to the Military Services in the spring of 2009 to promulgate budget changes directed by the Obama Administration. They have replaced both PDMs and PBDs.

Once final budget decisions are made, the DoD budget becomes part of the president's budget that is submitted to Congress. After Congress approves the budget and the president signs the appropriations acts, the OMB apportions the funds to the DoD for execution.

DoD Distribution of Funds

Appropriations are the most common method of providing budget authority to the DoD, which results in immediate or future outlays. Most defense budget authority is provided by Congress in the form of enacted appropriations, or appropriations bills in which a definite amount of money is set aside to pay incurred or anticipated expenditures.

After funds, or budget authority, are appropriated to the DoD by Congress, the OMB apportions budget authority to the DoD Comptroller. The DoD Comptroller distributes the funds to the Military Service and agency comptrollers. In turn, Military Service and agency comptrollers distribute budget authority to combatant command or agency comptrollers who then distribute it to program management offices. As the budget authority flows through the comptrollers, a small percentage of the funds may be withheld for contingency purposes; these funds are unofficially referred to as “taxes” or “withholds.”

The DoD budget is organized into separate budget titles that include approximately 75 appropriations. Each budget title is unique because resources are requested and applied for different purposes under different legal and regulatory constraints and for different time periods. Major DoD appropriations categories include: Research, Development, Test, and Evaluation (RDT&E); Procurement; Shipbuilding and Conversion (SCN); Operations and Maintenance (O&M); Military Personnel (MILPERS); Military Construction (MILCON); and other related agencies. Each appropriation has a legal time limit, or “life,” within which funds can be obligated, or legally reserved to make a future payment of money.

Four appropriations categories directly relevant to nuclear weapons funding are O&M, Procurement, RDT&E, and other related agencies:

- O&M funding finances the cost of operating and maintaining the Armed Forces with the exception of military personnel pay, allowances, and travel costs. Included in the funding are amounts for training and operation costs, civilian pay, contract services to maintain equipment and facilities, fuel supplies, and repair parts. O&M funding has a life of one year.
- Procurement funds support the acquisition of aircraft, ships, combat vehicles, and all capital equipment. The Procurement budget resources contribute to achieving DoD goals of maintaining readiness and sustainability, transforming the force for new missions, and reforming processes and organizations. Procurement funds have a life of three years; an exception to this is Navy SCN, whose procurement funding life is extended to five years.
- RDT&E funds support modernization through basic and applied research, fabrication of technology-demonstrated devices, and development and testing of prototypes and full-scale preproduction hardware. RDT&E work is performed by government laboratories and facilities, contractors, universities, and nonprofit organizations. RDT&E funds have a life of two years.
- The DoD also supports several other national agencies (such as the NNSA) and includes their requirements in the president’s budget submission to Congress. The amount of funding for these efforts is negotiated with the other agencies and the OMB.

As discussed above, appropriations have life-cycles during which they can incur new obligations. An appropriation whose period of availability for incurring new obligations has expired is not closed; instead it is in an "expired account." For five years after the time the appropriation expires, both the obligated and unobligated balances of that appropriation are available to make expenditures on existing obligations and adjustments to existing obligations. At the end of the five-year expiration period, the appropriation is closed and the funds can no longer be used. Figure I.3 illustrates obligations and outlays periods.

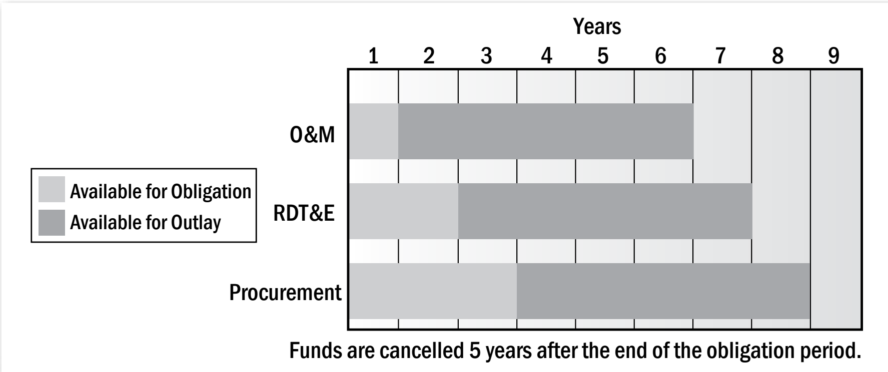

Figure I.3 Obligation and Outlay Periods

I.3.2 National Nuclear Security Administration PPBE

The NNSA manages the government's nuclear weapons activities and CNT programs, supports the Naval nuclear propulsion program, and is the primary responder to any nuclear or radiological incident. These programs are carried out at a nationwide complex of Government-Owned, Contractor-Operated (GOCO) laboratories, production plants, and testing sites, which employ about 3,000 federal employees and 30,000 management and operating contractors. The annual funding for these activities in FY 2009 was just over $9 billion.

The NNSA Planning, Programming, Budgeting, and Evaluation process is a continuous cycle for: establishing goals; developing, prioritizing, funding, and executing programs; and evaluating performance results to provide feedback for future planning. At the NNSA, planning and programming are primarily a headquarters function. Execution and evaluation of the programs are accomplished by the field elements.

The NNSA Strategic Plan provides the foundation for all NNSA planning. It also establishes the mission, vision, and issues in addition to providing the goals, strategies, and strategic indicators for the five NNSA program elements. Each of the five program elements has a single goal in the Strategic Plan. These program elements are: Defense Programs, Defense Nuclear Nonproliferation, Naval Reactors, Infrastructure and Security, and Management and Administration. Multi-year plans are developed between headquarters program managers and the field elements. The program plans are the primary documents used to make key programming decisions and to develop the NNSA budget. Strategic guidance is provided yearly to start the annual planning and programming processes.

Programming is a headquarters-driven process to develop, prioritize, and integrate the five NNSA Programs. The process begins with the strategic guidance, the current Future-Years Nuclear Security Program (FYNSP), and a program and fiscal guidance document. These enable the headquarters elements to update baseline programs and projects as well as to explore and prioritize excursions from the baseline. Programming is conducted with fiscal awareness and concludes with a Program Decision Memorandum that records decisions for presentation to the DOE and the OMB. In the budgeting phase, planning and programming are brought into a fiscally constrained environment.

Budget execution and evaluation is carried out by the management and operating contractors at the NNSA sites with oversight from federal program and site managers.

Nuclear weapons acquisition in the NNSA complex is part of a highly integrated workload for the science-based stewardship of the nuclear weapons stockpile. Planning and budget information for weapons system acquisition is contained in selected acquisition reports that are included in all phases of the PPBE process and available to decision makers.

FAQs

Chapter 1: Nuclear Matters History and Policy

Q1 What is the U.S. nuclear deterrent?

The U.S. nuclear deterrent is the totality of the United States' nuclear stockpile (warheads and bombs); the launch platforms and delivery systems that convey the warheads and bombs to their intended targets; the infrastructure and human resources necessary to support the weapons; the command, control, communications, and intelligence that informs the nuclear forces; the policy and guidance structure that directs the nuclear forces; and the legislative and executive branch entities that govern nuclear-related policies. An essential part of the U.S. nuclear deterrent is the level of confidence in and the credibility of U.S. nuclear weapons—the belief that they will work if and when the United States needs them.

Q2 How does the nuclear deterrent fit in with the rest of U.S. defense strategy?

The U.S. nuclear deterrent remains an important element of the overall U.S. national security strategy. The 2010 Nuclear Posture Review (NPR) affirmed the need to continue to reduce the role of nuclear weapons in U.S. national security and U.S. military strategy while maintaining a safe, secure, and effective deterrent as long as those weapons exist. To that end, the United States has committed to continuing to strengthen its conventional capabilities with the objective of making the deterrence of a nuclear attack on the United States or its allies and partners the sole purpose of U.S. nuclear weapons.

Q3 Who is in charge of nuclear weapons? Is there one person who has overall oversight?

Only the president can make the decision to use U.S. nuclear weapons. Nuclear weapons in the current stockpile and a small number of weapons that are retired awaiting dismantlement are generally under the control of the Department of Defense (DoD), in the custody of the Military Services (today only the Navy and the Air Force have custody of nuclear weapons). Weapons that are being repaired, monitored for quality assurance, or in the dismantlement process are generally in the custody of the Department of Energy (DOE).

Q4 What is the Nuclear Posture Review?

The Nuclear Posture Review is a legislatively mandated review that establishes U.S. nuclear policy, strategy, capabilities, and force posture for the next five to ten years. The most recent NPR was completed in 2010; prior to that review, NPRs were completed in 1994 and 2001.

Q5 What are the main conclusions of the 2010 NPR?

The 2010 NPR outlines the U.S. approach to implementing the president's agenda for reducing nuclear dangers and pursuing the long-term goal of a world without nuclear weapons. Because this goal will not be reached quickly, the report explains how the United States will sustain a safe, secure, and effective nuclear deterrent as long as nuclear weapons exist. The findings and recommendations of the 2010 NPR support five key objectives:

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 reassurance of U.S. allies and partners; and
5. Sustaining a safe, secure, and effective nuclear arsenal.

Q6 What steps is the United States taking to pursue a goal of a world without nuclear weapons?

In pursuit of its commitment the United States has concluded a verifiable New Strategic Arms Reduction Treaty (START) with Russia that limits both nations' nuclear forces to levels well below those provided for in previous treaties. Moving forward with these efforts, the United States is:

- pursuing entry into force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT);
- seeking negotiations on a verifiable Fissile Material Cutoff Treaty (FMCT) to halt the production of fissile material for use in nuclear weapons; and
- working to secure all vulnerable nuclear materials worldwide.

Q7 What is nuclear proliferation?

Nuclear proliferation is the spread of nuclear weapons, fissile material, and weapons-applicable nuclear technology and information anywhere in the world.

Q8 What is the U.S. nuclear umbrella and who is under it?

The U.S. nuclear umbrella is the nuclear protection that the United States extends to its partners and allies such as the nations of the North Atlantic Treaty Organization (NATO), Japan, and the Republic of Korea, among others. This means that the United States guarantees the same kind of national response to an attack on its partners and allies as it would make to an attack on the United States.

Q9 What is nuclear nonproliferation?

Nuclear nonproliferation refers to the strategies and activities undertaken to detect, dissuade, curb, and prevent state and non-state actor acquisition of nuclear materials, technologies, or nuclear devices. The United States is a global leader in nuclear nonproliferation activities and, along with 189 other countries, is a signatory of the Nuclear Nonproliferation Treaty (NPT). It is U.S. belief that, through the continued reduction of the role and numbers of U.S. nuclear weapons, the nation can put itself in a much stronger position to persuade its NPT partners to join in adopting the measures needed to reinvigorate the nonproliferation regime and secure nuclear materials worldwide.

Chapter 2: Stockpile Management, Processes, and Organizations

Q10 Is the United States planning to develop new nuclear warheads?

No, it is not U.S. policy to develop new nuclear warheads. A new nuclear warhead is defined as a weapon intended to support new military missions, provide new military capabilities, or use nuclear component designs not based on previously tested designs. It may be necessary, however, for the United States to develop new delivery systems to sustain elements of the nuclear deterrent in the future.

Q11 Are other countries producing new weapons?

Yes, most other nations that possess nuclear weapons are in the process of modernizing their stockpiles or producing new weapons.

Q12 Why does the United States need to spend money on nuclear weapons once they are built?

The United States spends money on nuclear weapons for the same reason that an individual spends money to service a car: to have the confidence that it will work when it is needed given that parts degrade over time. Similarly, the United States spends money on maintaining its nuclear stockpile; it is not enough to put nuclear weapons on a shelf, forget about them, and hope that they will work when and if the time comes. The United States must monitor its weapons and make sure they are kept in good working order to ensure they remain safe, secure, and reliable. The United States also needs to invest in the infrastructure that supports the maintenance of its weapons. That includes the buildings, the equipment, and the people who ensure that the nuclear stockpile remains safe, secure, reliable, survivable, and effective. In recent years, the United States has benefited from a "peace dividend" reduction in spending for our nuclear forces. The current level of spending on nuclear weapons is only a small fraction of what it was during the Cold War.

Q13 What is a nuclear warhead "life extension program"?

Life extension programs consist of planning for the systematic replacement of components prior to degradation in their performance (like replacing older tires on a car before they have a blow-out), producing the required components, and replacing them to refurbish the warhead for extended "shelf-life" and continued service in the stockpile. It involves testing, evaluating, and analyzing component aging for each specific warhead-type and making the necessary alterations and modifications to ensure continued warhead viability.

Q14 How will the United States sustain its nuclear stockpile without developing new warheads?

Life extension decisions about how to sustain specific warheads will be made on a case-by-case basis. In each case, the technical community will study all options for life extension to ensure reliability, safety, and security. Technical life extension options will span the following:

1. Refurbishment: the use of nuclear component designs previously produced for the warhead-type undergoing life extension.
2. Reuse: the use of nuclear component designs currently or previously in the stockpile but from different warhead-types.
3. Replacement: the use of nuclear component designs that have not been in the stockpile but that are based on previously tested designs.

Technical study results will be reported to the Nuclear Weapons Council (NWC), and the NWC will make recommendations on life extension to the secretaries of defense and energy. These recommendations will give preference to the refurbishment and reuse options. Based on these reports, the secretaries of defense and energy will advise the president on a recommended way forward. In those cases where the secretaries recommend a replacement plan, the president will conduct a special review of the plan in order to make a specific authorization. Congress will review and assess all plans to determine whether the recommended pathway forward is consistent with the national interest and national strategy as promulgated by the administration.

Q15 How does the DoD work with the DOE-NNSA on nuclear weapons issues?

The Department of Defense and the Department of Energy, through the National Nuclear Security Administration (NNSA), share joint responsibility for U.S. nuclear weapons. The responsibilities for nuclear weapons stockpile management were originally established in the Atomic Energy Act of 1946, which was later amended in 1954. The act reflected congressional desire for civilian control over the uses of nuclear energy, including nuclear weapons. Generally, the NNSA has primary responsibility for design, evaluation, production, quality assurance, repair, modification, refurbishment, dismantlement, disposal, and security for any warheads or components in DOE custody. At any given moment, the majority of the U.S. warheads are in the custody of the DoD, which has primary responsibility for establishing military requirements for nuclear weapons; developing, fielding, and maintaining the launch platforms and delivery vehicles; and performing certain activities for warheads in their custody, including providing security, performing limited-life component exchange maintenance, and performing launch operations if ever directed by the president.

Q16 What is the Nuclear Weapons Council?

The Nuclear Weapons Council is a joint Department of Defense and Department of Energy organization responsible for facilitating cooperation and coordination between the two departments as they fulfill their dual-agency responsibilities for U.S. nuclear weapons stockpile management.

Q17 What is the Nuclear Weapons Stockpile Plan?

The Nuclear Weapons Stockpile Plan (NWSP) authorizes the production, conversion, or elimination of specific types and quantities of nuclear weapons by specifying authorized weapons quantities to be in the stockpile at the end of each fiscal year. The NWSP is accompanied by a Presidential Directive; when the directive is signed, the NWSP goes into effect. The annual NWSP directive from the president is a major part of the centralized management and control of the overall U.S. nuclear stockpile.

Q18 What is a nuclear weapons-related component?

A nuclear weapons-related component is any part, component, instrument, or piece of equipment that is associated with a nuclear warhead or bomb and/or with the delivery system that goes with it. This includes items such as nuclear fissile material components and sophisticated components like radar fuzes, special tools, and equipment.

Q19 What is a limited life component?

A limited life component (LLC) is a nuclear weapons-related component that has a predictable, limited shelf life. LLCs may include power sources (most batteries have a limited shelf life), neutron generators, and tritium components. Because the designed lifespan of limited-life components is known, the United States is able to replace them before they fail and affect overall weapon performance—similar to the way one replaces the brakes on a car before they fail and cause an accident. The United States follows a strict schedule of replacing LLCs for each operational warhead, usually every few years, or more frequently if required.

Chapter 3: U.S. Nuclear Forces

Q20 What is the difference between strategic and non-strategic nuclear weapons?

Strategic nuclear weapons are nuclear weapons on nuclear-capable heavy bombers, intercontinental ballistic missiles (ICBMs), and submarine-launched ballistic missiles (SLBMs). All other nuclear weapons are non-strategic. These may include nuclear bombs for dual-capable (conventional and nuclear) aircraft, cruise missiles launched from submarines, surface ships, or land-based launchers, warheads for shorter-range systems (e.g., short-range missiles, cannon artillery) for nuclear air defense systems, and man-portable or vehicle-transported nuclear demolition devices. Some refer to non-strategic systems as “theater” or “tactical” weapons, although this terminology is no longer officially used by the U.S. Government. Currently, the United States has only two types of non-strategic nuclear weapons: bombs for dual-capable aircraft and warheads for sea-launched cruise missiles.

Q21 How many nuclear weapons does the United States have?

As of September 30, 2009, the U.S. nuclear weapons stockpile consisted of 5,113 warheads. This number represents an 84 percent reduction from the stockpile's maximum (31,255) at the end of fiscal year 1967.

Q22 What is the difference between the active and inactive stockpiles?

To minimize the cost of retaining and maintaining the nuclear stockpile, the United States divides it into two categories. The first category of active stockpile weapons consists of weapons that must be maintained in an operational status (fully capable of performing their design function) to fulfill the requirements of U.S. national deterrence policy when authorized by the president. This category also includes a small number of logistics warheads (used at operational bases for immediate replacement of warheads selected for quality assurance non-nuclear testing) to ensure the nation can always meet operational requirements. The second category, the inactive stockpile, consists of those warheads that are not immediately ready for use and whose function permits them to be retained in a non-operational status. This includes warheads to replace those eliminated for quality assurance testing and reliability replacement warheads (retained because of the U.S. policy of no nuclear testing and the extremely limited U.S. capacity to produce nuclear components). Because of their inactive status and the reduced maintenance costs this status entails, this category of weapons saves the United States a significant amount of money each year.

Q23 How does a nuclear weapon get to the target?

Nuclear weapons get to their intended targets via nuclear delivery vehicles. Typically, a nuclear delivery vehicle is a manned aircraft (for gravity bombs or cruise missiles) or a ballistic missile.

Q24 What kinds of nuclear weapons do we have?

Currently, the U.S. nuclear stockpile is composed of nuclear weapons designed to be delivered by strategic intercontinental ballistic missiles, strategic submarine-launched ballistic missiles, strategic and non-strategic cruise missiles, and strategic and non-strategic gravity bombs.

Q25 What's the difference between the different parts of the nuclear triad?

As the name implies, there are three different parts to the nuclear triad: the strategic bomber force, intercontinental ballistic missiles, and submarine-launched ballistic missiles. Each element of the nuclear triad provides a different aspect of deterrence, and the whole is greater than the sum of its parts. Bombers are highly visible for signaling purposes and can be called back should the situation warrant. ICBMs are always ready to respond. The nuclear submarine force—or "boomers"—are deployed at sea on a continuous basis with great dependability and stealth; they are the most survivable element of the nuclear triad.

Q26 Which U.S. Military Services have custody of nuclear weapons?

Only the Navy and the Air Force have custody of nuclear weapons. The Army and Marine Corps used to have nuclear weapons, but the United States does not currently have any nuclear warheads associated with Army and Marine Corps weapon systems.

Q27 Where are U.S. weapons located?

The exact locations of U.S. nuclear weapons are classified. Nuclear weapons are located within the continental United States, at sea on strategic submarines, and in foreign host nations with whom the United States has special agreements.

Q28 Does the United States move its nuclear weapons? How? Where?

Yes, the United States does move its weapons. U.S. nuclear weapons need to be monitored, repaired, relocated for logistical or operational reasons, modified, altered, retired, and dismantled. This requires that they be transported. Within the United States, nuclear weapons are moved via specially equipped trucks (the Department of Energy's Safeguards Transports). Outside the United States, nuclear weapons are transported via specifically equipped aircraft.

Chapter 4: Nuclear Command, Control, and Communications System

Q29 What is the nuclear command, control, and communications system?

The U.S. nuclear command, control, and communications (C3) system refers to the collection of DoD activities, processes, and procedures performed by appropriate military commanders and support personnel who—through the chain of command—allow for senior-level decisions to be made based on relevant information and subsequently allow those decisions to be communicated to forces for execution. The nuclear C3 system 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 purpose of the nuclear C3 system is to provide the president with the means to authorize the use of nuclear weapons in a crisis and to prevent unauthorized or accidental use.

Q30 What is nuclear command and control?

Nuclear command and control (C2) is the presidential exercise of authority and direction over nuclear weapons operations through established command lines. Nuclear C2 is provided through a survivable "thin line" of communications and warning systems that ensure dedicated connectivity from the president to all nuclear-capable forces. The fundamental requirements of nuclear C2 are that it must be assured, timely, secure, survivable, and enduring in providing the information and communications for the president to make and communicate critical decisions without being constrained by limitations in the systems, the people, or the procedures.

Chapter 5: Nuclear Safety and Security

Q31 What is the CoP?

As defined in National Security Presidential Directive 28 (NSPD-28), the Nuclear Command and Control System (NCCS) is the combination of facilities, equipment, communications, procedures, and personnel essential for planning, directing, and controlling nuclear weapons, weapon systems, and associated operations. In order to facilitate Interagency coordination to maintain a robust NCCS, NSPD-28 called for the creation of an NCCS Committee of Principals (CoP) composed of official representatives from each of ten NCCS Departments and Agencies.

Q32 Are U.S. nuclear weapons safe?

Yes. U.S. nuclear weapons are very safe. The Quality Assurance & Reliability Testing (QART) program provides assurance that in a normal environment, there is less than one chance in a billion that any given warhead would produce an accidental nuclear detonation. It also provides assurance that there is less than one chance in a million of a nuclear detonation even if the warhead were in an aircraft accident or struck by a bullet or lightning bolt.

Q33 Are U.S. nuclear weapons secure?

Yes. U.S. weapons are among the most secure items in the world. Physical security—knowing that U.S. weapons are safe from theft and unauthorized use—is a very high priority for the United States. Nuclear weapons security is composed of gates, guards, and guns as well as processes and procedures that ensure U.S. nuclear weapons will not fall into the wrong hands. Some of the rules and procedures, such as the Department of Defense Personnel Reliability Program, ensure that all personnel who handle or have control of any nuclear weapons are physically, mentally, and emotionally fit to be near them. Security also includes special components imbedded in some warheads that act like electronic locks and prevent unauthorized use by requiring the user to enter a special code to "unlock" the warhead for use.

Q34 How does the United States know where its weapons are at all times?

U.S. weapons in DoD custody are accounted for via an extremely thorough inventory and accounting system called *DIAMONDS*, run by the Defense Threat Reduction Agency, which tracks the maintenance status and location of each individual warhead by serial number. Organizations that have custody of nuclear weapons report any change in status or location to the database. Periodically, there are inventories taken as a double-check. When the NNSA has custody of a weapon, it is tracked using a database called the *Weapons Information System*.

Q35 Do terrorists have access to nuclear weapons?

No. To the best of our knowledge, there are no terrorist organizations that have access to any significant amount of fissile material or to nuclear devices. However, several known terrorist organizations have stated that they are attempting to acquire the materials and knowledge needed to assemble a nuclear threat device.

Q36 If a U.S. nuclear weapon was stolen, could a terrorist use it?

It is highly unlikely that a group of terrorists could steal, much less use, a U.S. nuclear weapon to produce a nuclear detonation. To function, U.S. warheads require unique electrical signals to be input through unique electrical circuits. If terrorists did not have the required equipment or lacked the technical knowledge about the specific electrical signals required, they would not be able to get the warhead to function. If they took the weapon apart without the required unique tools and technical knowledge, it is likely that they would destroy key weapon components, making the weapon unusable. If terrorists used explosives in an attempt to produce a nuclear detonation, they would most likely not produce one, but they might scatter the weapon's nuclear materials, causing a radioactive hazard to several acres in the immediate area and downwind. While this type of event might cause casualties, it would be thousands of times less significant than a nuclear detonation.

Q37 Can U.S. nuclear weapons detonate if touched?

No. Nuclear weapons are difficult to detonate, and U.S. nuclear weapons are designed to remain safe even if hit by a bullet, struck by lightning, or involved in an aircraft accident. In fact, all U.S. nuclear weapons are designed to be "one point" safe, meaning that if a weapon was to sustain a blow at any single point it would not produce a nuclear detonation.

Q38 What is use control?

Use control consists of the positive measures that allow for the authorized use and prevent or delay the unauthorized use of nuclear weapons. Use control is accomplished through a combination of weapon system design features, operational procedures, and security activities. Use control helps ensure both that U.S. operators cannot use a weapon in an unauthorized manner and that if terrorists were to gain possession of a U.S nuclear weapon, they could not use it.

Chapter 6: Countering Nuclear Threats

Q39 What is "countering nuclear threats"?

Countering nuclear threats (CNT) describes the efforts to prevent a nuclear attack against the United States, it allies, partners, and interests, or, in the event of an attack, to respond effectively, avoid additional attacks, and bring the perpetrators to justice. CNT efforts are diverse, and the broad scope of activities and tasks composing these efforts requires the involvement of many agencies within the federal government. Most CNT issues are national in scope and have implications for international security.

Q40 What is a nuclear threat device?

A nuclear threat device (NTD) refers to an improvised nuclear or radiological device, a foreign nuclear weapon of proliferation concern, or any nuclear device that may have fallen outside a foreign nuclear weapon state's custody.

Q41 Why is it important to maintain a scientific and technical understanding of the nuclear threat?

An in-depth understanding of the potential range of nuclear threat device designs informs all aspects of CNT activities, including material security, detection, interdiction, render safe/ unusable activities, post-event consequence management, and forensics and attribution efforts. The uncertainty associated with potential nuclear threat device designs includes questions about the composition and configuration of a device, how it will work, and how to safely and effectively disable it. Therefore, a scientific and technical understanding of the full range of the potential NTD design space is necessary and critical.

Q42 What is counterproliferation?

Counterproliferation refers to the strategies and activities employed after state or non-state actors have, or are presumed to have, obtained nuclear materials, technologies, or nuclear devices.

Q43 What is nuclear forensics, and why is it important?

Technical nuclear forensics (TNF) is the characterization and analysis of radiological and nuclear material and devices. TNF provides information on the source or origin of nuclear materials, device design, and the pathway of the materials or device to the incident site. This information contributes to attribution, which identifies who designed, constructed, supplied, transported, and used the material or device. If a nuclear or radiological event were to occur on U.S. soil, attribution would be essential for the president to respond appropriately to the event and to prevent subsequent similar incidents.

Q44 What constitutes a nuclear weapon accident? What is a "Broken Arrow"?

A nuclear weapons accident is an unexpected event involving nuclear weapons or nuclear components that could result in the burning of a nuclear weapon or nuclear component; radioactive contamination; a public hazard, actual or perceived; or a nuclear detonation. If an accident involving a nuclear weapon occurs, there are a series of code words used in internal Department of Defense communications to describe the nature of the accident. One of the more well-known of these is the term "Broken Arrow," which is a chairman of the Joint Chiefs of Staff term to identify and report an accident involving a nuclear weapon or warhead or nuclear component that results in a nuclear detonation or the release of radioactive materials.

Q45 Has there ever been an accidental U.S. nuclear detonation?

No. In the entire history of the U.S. nuclear weapons program, the United States has never had an accidental nuclear detonation.

Q46 Has the United States ever had a nuclear weapons accident?

Yes. The United States has had several nuclear weapons accidents, the most recent of which was in 1982 near Damascus, Arkansas. On a few occasions, accidents involving U.S. nuclear weapons have resulted in plutonium dispersal, which was subsequently cleaned up. No nuclear weapon accident has ever resulted in a nuclear detonation.

Q47 What happens if a nuclear weapon explodes accidentally?

Many U.S. warhead-types use insensitive high explosive to minimize the probability of an explosion; however, if an accident caused the high explosive component in a nuclear weapon to explode, it would most likely scatter the nuclear material, possibly over several acres. An accidental explosion would not likely cause a nuclear detonation resulting in nuclear yield. In the event of a nuclear weapon explosion, there would be a prompt and effective national emergency response and subsequent consequence management efforts to manage the damage done by the high explosive and any resulting nuclear contamination.

Q48 Why is the issue of a country having a nuclear reactor important in terms of nuclear weapons?

All of the known current-design nuclear power reactors in the world produce electrical power as a primary output, and they also produce fissile material as a part of the radioactive waste stream. Most power reactors use either natural uranium or low-enriched uranium (LEU) as fuel. As these reactors operate, some of the uranium is converted to plutonium, which can be used as the fissile material in a nuclear weapon. If nations owning and operating power reactors agree to special inspection programs, it significantly reduces the probability that the plutonium produced as a by-product could be used in a nuclear weapon. The United States supports inspection efforts by the International Atomic Energy Agency (IAEA), which was created to address this and other potential problems as a part of the international effort to control nuclear weapons proliferation.

Q49 Why is the issue of a country having an enrichment process important in terms of nuclear weapons?

Enrichment is a process used to increase the percentage of fissile atoms in uranium by eliminating the non-fissile atoms. Most of the world's nuclear power reactors (which do not include breeder reactors or ship-board propulsion reactors) use either natural low-enriched uranium. Natural uranium requires no enrichment. LEU production for power reactors usually requires a few hundred enrichment steps (called stages) in a modern industrial enrichment process. If the enriching nation uses thousands of steps or stages, the uranium can be enriched well beyond the level required for power reactors and can become highly enriched uranium (HEU). If the HEU continues in the enrichment process long enough, it will become weapons-grade HEU, which can be used as the fissile material in a nuclear weapon. If nations owning and operating enrichment processes agree to special inspection programs, the probability that the enrichment process will produce weapons-grade HEU for potential use in a nuclear weapon or a nuclear threat device is significantly reduced.

Q50 What is the "non-stockpile mission" as compared to the "stockpile mission"?

The "non-stockpile" mission refers to the collection of activities and ongoing efforts that relate to the nuclear security mission but do not pertain to the weapons of the U.S. nuclear deterrent. Thus, countering nuclear threat activities, including nuclear counterterrorism and nonproliferation work, fall under the rubric of the "non-stockpile" mission. This nomenclature reflects the fact that for almost its entire history, the nuclear security community in the United States has been focused on nuclear weapons and weapons-related activities. Since the end of the Cold War, however, the mission has expanded and evolved beyond the weapons, to include nuclear threat reduction work and other non-stockpile issues.

Chapter 7: U.S. Nuclear Infrastructure

Q51 What is the "Nuclear Security Enterprise"?

"Nuclear Security Enterprise" is a term used within the NNSA to refer to the totality of the NNSA infrastructure, including the human and capital resources that are required to support the U.S. nuclear deterrent and the activities that sustain the United States' ability to counter nuclear threats.

Q52 How are U.S. nuclear weapons produced?

The United States is not currently producing nuclear weapons. The United States has a very limited capability to produce nuclear components. As recognized by the Nuclear Posture Review, establishing a pit production capability (including plutonium processing) and a modern secondary production facility are important steps for the NNSA to achieve a modernized and responsive capacity to produce nuclear components for stockpile life extension. When this capability is achieved (and there are plans in place to reconstitute U.S. nuclear component production), it will mark the beginning of a new stockpile support paradigm whereby the NNSA can meet stockpile requirements through its production infrastructure, rather than through the retention of a large inactive stockpile.

Q53 Is there a problem recruiting new scientists and engineers to the nuclear field?

Yes. While there are some very well-qualified people entering the U.S. nuclear community as scientists and engineers, recruiting new technical personnel has become much more difficult since the end of the Cold War. The number of qualified technical people joining the national laboratories and entering key technical positions at other agencies each year is far less than it was years ago. The reduced numbers entering the field as scientists and engineers and the fact that many of the individuals with the greatest expertise have retired or are approaching retirement all contribute to a general reduction in the experience and knowledge base of the U.S. Nuclear Security Enterprise. To off-set this erosion of expertise, organizations within the nuclear community are making a greater effort to recruit and train the newest generation of scientists and engineers and to document and pass on the extensive amount of technical knowledge and data resulting from over six decades of sophisticated development and testing programs.

Q54 Without nuclear testing, how do we know that U.S. nuclear weapons will work?

The United States relies on non-nuclear laboratory and flight tests and the judgment of experienced nuclear scientists and engineers to ensure continued confidence in the safety, security, and effectiveness of the U.S. nuclear deterrent.

Q55 What does the United States do when problems are found with nuclear weapons?

If a problem is identified, the issue is thoroughly investigated to determine if the problem impacts the weapon’s safety, reliability, or performance. If there are, the problem is corrected, and/or the DoD is informed of the necessary changes to procedures or employment to offset any functional impact.

Chapter 8: International Nuclear Cooperation

Q56 Do U.S. allies have nuclear weapons?

Yes, some NATO allies *do* have nuclear weapons, including the United Kingdom and France. Most U.S. allies have agreed to forego a nuclear weapons capability in exchange for the protection of the U.S. nuclear umbrella, which provides extended deterrence. Thus, U.S. nuclear weapons protect both the United States and its partners and allies.

Q57 Does the United States share nuclear information with allies? How? Why?

Yes, the United States shares nuclear information with allies through Programs of Cooperation—legal frameworks for international information exchange. The United States participates in Programs of Cooperation with a number of international partners, including the United Kingdom, France, and the North Atlantic Treaty Organization. The United States uses these frameworks to share information with its partners about nuclear weapons-related matters, as well as about issues surrounding nuclear terrorism and nuclear proliferation. Additionally, the United States works closely with certain allies to ensure the common use of best practices and to enjoy the benefits of independent peer review.

Appendix B: International Nuclear Treaties and Agreements

Q58 What are nuclear weapon-free zones?

A nuclear weapon-free zone (NWFZ) is a specified region in which countries commit themselves not to manufacture, acquire, test, or possess nuclear weapons. Five such zones exist today. Countries in Latin America (the 1967 Treaty of Tlatelolco), the South Pacific (the 1985 Treaty of Rarotonga), Southeast Asia (the 1995 Treaty of Bangkok), Africa (1996 Treaty of Pelindaba), and Central Asia (the 2006 Treaty for the Central Asia Nuclear Weapon-Free Zone) have all foresworn nuclear weapons.

Q59 What is the Nuclear Nonproliferation Treaty?

The Treaty on the Nonproliferation of Nuclear Weapons, also known as the Nuclear Nonproliferation Treaty, was opened for signature in 1968 and entered into force in 1970. The NPT forms the cornerstone of the international nuclear nonproliferation regime. 189 nations are parties to the treaty. The NPT recognizes the five nuclear powers that existed in 1968: the United States, Russia, the United Kingdom, France, and China, and it prohibits all other signatory states from pursuing or acquiring a nuclear weapon capability. India, Israel, North Korea, and Pakistan are not parties to the NPT. In exchange for forgoing a nuclear weapons capability, the non-nuclear weapons states party to the NPT are guaranteed assistance with their civilian nuclear power programs by the five nuclear powers; this guarantee is known as the "Grand Bargain." The NPT was extended indefinitely in 1995.

Q60 Does the NPT require the United States to disarm?

According to Article VI of the NPT, the United States is committed to undertake efforts "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control." The United States is in full compliance with the terms of Article VI.

Q61 What are key points of New START?

The New Strategic Arms Reduction Treaty (START) requires significant reductions in the permitted number of deployed strategic warheads in the United States and Russia—to 1,550 per side. The treaty also provides for significantly lower limits on the number of deployed strategic delivery vehicles (deployed ICBMs, deployed SLBMs, and deployed nuclear-capable heavy bombers) and limits the total number of deployed and non-deployed ICBM and SLBM launchers and heavy bombers equipped for nuclear armaments. New START will enhance predictability regarding the strategic forces of both parties. The treaty includes provisions for data exchanges and notification regarding strategic offensive systems and facilities; it also includes provisions for on-site inspections and exhibitions for verification. Additionally, New START provides for continued use of and non-interference with national technical means of verification (NTM—also known as satellites). New START includes explicit provisions that prohibit interference with NTM and the use of concealment measures that may impede monitoring by NTM.

Appendix C: Basic Nuclear Physics

Q62 How do nuclear weapons work?

At the most basic level, nuclear weapons work when nuclei of special nuclear material (typically fissile weapons-grade plutonium or weapons-grade uranium) are split apart (fission events), releasing a very large amount of energy (thousands of times more than in a conventional explosion) in a very short period of time (approximately one millionth of a second). The total energy released may be increased by forcing the nuclei of very light atoms together in fusion events which produce high-energy neutrons that can produce additional fission events.

Q63 What makes a weapon "nuclear"?

A nuclear weapon is designed to release energy through nuclear processes (nuclear fission, nuclear fusion, or both) when detonated. A nuclear detonation produces a measurable amount of nuclear radiation and other effects, including blast, shock, thermal radiation, and electromagnetic pulse.

Q64 What is the difference between an atomic weapon, a thermonuclear weapon, and a nuclear weapon?

The term "nuclear weapon" encompasses all of these terms. The term "atomic bomb" was originally coined during World War II when the news media described the new weapon as "splitting atoms." Nuclear weapons actually work by "splitting" the nuclei of fissile atoms in a process called fission. Thus, the term "nuclear" is much more accurate than "atomic." A thermonuclear weapon is one that uses fusion in addition to fission to increase yield.

Appendix D: U.S. Nuclear Weapons Life-Cycle

Q65 What is the nuclear weapons life-cycle?

The nuclear weapons life-cycle is the cradle-to-grave process through which all U.S. nuclear weapons proceed from conception to dismantlement. The life-cycle process is divided into "phases" that progress from concept and feasibility evaluation through design, production, maintenance, quality assurance testing, modification, retirement, and dismantlement.

Q66 What does the United States do with nuclear weapons when it doesn't need or want them any more?

The United States retires its weapons, dismantles them, and disposes of the piece parts in a safe and secure manner. Retired weapons are securely stored until they are removed from military custody and are dismantled and disposed of properly. Weapons are transported to the DOE Pantex Plant in Amarillo, Texas for dismantlement. Plutonium and uranium parts are transported to and stored at two secure NNSA facilities. If it is practical, non-nuclear components are reused in other warheads or for testing. If not, they are disposed of in accordance with environmental restrictions and NNSA policy.

Q67 How does the United States dispose of nuclear material?

Currently, nuclear materials are stored in two secure NNSA locations until the United States decides on their final disposition. Some of the fissile material may be reused in future weapons, some may be converted and used in nuclear power reactors, and the remainder may be put in some permanent storage configuration.

Appendix E: Nuclear and Non-Nuclear Testing

Q68 Why did the United States ever conduct nuclear testing?

Between 1945 and 1992, the United States conducted nuclear testing for several reasons: to learn more about nuclear physics and how fissile materials compress, to learn about the effects of nuclear weapons and the distances the effects would extend from the detonation, to refine the designs of specific warheads while they were in engineering development, to test fielded warheads to determine if there were problems with detonation safety or yield and fix those problems if they existed, and to determine the nuclear vulnerability of U.S. deterrent systems so that the systems could be made more survivable. Since 1992, the United States has observed a voluntary moratorium on nuclear testing.

Q69 What was involved with an underground nuclear test?

In a typical underground nuclear test, a team of scientists and engineers built a nuclear test device and placed it in a deep vertical shaft (like a very deep well) with highly sophisticated sensing and transmitting instruments and then back-filled the shaft to prevent radioactive gases from escaping. When the detonation occurred, the instruments transmitted large amounts of scientific technical data (just before they were consumed by the detonation's fireball) through wires to receivers located some distance from the shaft. Afterward, the earth directly above the large cavity (produced by the fireball) collapsed downward, producing a "subsidence" crater on the surface.

Appendix F: The Effects of Nuclear Weapons

Q70 What are the major effects of a nuclear detonation?

The major effects of a nuclear detonation include: the instantaneous production of a very large, very hot fireball; the generation of an electromagnetic pulse (EMP) that can destroy or disrupt electronics; the spread of energy in the form of heat and light that can possibly produce burns or ignite fires; the emission of highly penetrating, prompt nuclear radiation; and the creation of air blast waves and shock waves.

Q71 What would happen if a nuclear threat device detonated in a major U.S. city?

The impact of a nuclear detonation would depend of a number of factors, including the yield of the device, the construction of the structures surrounding ground zero, and prevailing weather conditions. In all circumstances the impact at ground zero would be completely devastating.

Q72 What is EMP?

Electromagnetic pulse is a very short duration pulse of low-frequency (long-wavelength) electromagnetic radiation (EMR). It is produced when a nuclear detonation occurs at high altitudes (which can affect a large region of the Earth's surface hundreds of miles across for higher-yield detonations). EMP can damage unprotected electronics found in computers, phones, and vehicles. EMP is especially destructive to equipment using modern low voltage, solid-state components, which can be overloaded with a voltage beyond its designed capacity. Low levels of EMP can cause a disruption of processing or a loss of data. At increased EMP levels, certain electronic components and much of the nation's electrical grid can be destroyed. EMP will not produce structural damage and is not a direct hazard to humans; however, the indirect effects of long-term power failures and electronics failing instantaneously in vehicles, aircraft, and life-sustaining equipment in hospitals could cause injuries or fatalities.

Q73 Is the United States vulnerable to a terrorist EMP attack?

The United States is taking extraordinary measures to ensure that if a terrorist group gains possession of a nuclear device and attempts to move it into the United States, the country will have a high probability of detecting and intercepting it. Currently, terrorists do not have access to modern military or space program missiles to launch a weapon to a high altitude. If terrorists successfully transport a nuclear device to the United States and detonate it on the ground or above ground at altitudes that commercial aircraft fly, the EMP would not extend great distances from the detonation. If a nuclear device was detonated near the ground, the primary effects (thermal radiation, nuclear radiation, and air blast) would be so devastating that the effects of EMP would be insignificant. The significant resources dedicated to detecting and intercepting a nuclear device have a very high priority because of the primary effects of a possible terrorist nuclear detonation, not because of a concern about EMP.

Appendix G: Nuclear Survivability

Q74 What is nuclear survivability?

Nuclear survivability involves the ability to withstand a nuclear detonation. There are two different kinds of nuclear survivability, *nuclear weapons effects survivability* and *nuclear weapons systems survivability*. Nuclear weapons effects survivability refers to the ability of personnel and equipment to withstand the blast, thermal radiation, nuclear radiation, and electromagnetic pulse effects of a nuclear detonation. Nuclear weapons systems survivability refers to the ability of nuclear deterrent forces to survive against the entire threat spectrum that includes, but is not limited to, nuclear weapons effects and still be able to carry out their primary mission.

Appendix H: Classification

Q75 What are the various classification categories and levels?

There are two categories of classified information: national security information and atomic energy (nuclear) information. National security information is governed by presidential Executive Orders that prescribe a uniform system for classifying, safeguarding, and declassifying information related to national security. National security or atomic energy information may be classified at 3 levels, "Top Secret," "Secret," or "Confidential." Atomic energy information is governed by the Atomic Energy Act of 1954, as amended. The Atomic Energy Act characterizes classified nuclear information as "Restricted Data" and "Formerly Restricted Data," which is protected over and above national security information. There are additional caveats that can be added to classified information that further restrict dissemination, including the many caveats of "Sensitive Compartmented Information," which, as its name suggests, is information that is compartmented separately from other classified information for the purpose of protecting particularly sensitive information.

Q76 Who decides what is classified and what is not?

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 in the Federal Register, and U.S. government officials specifically delegated this authority by the president through an Executive Order. According to Executive Order 13526, those individuals who only reproduce, extract, or summarize classified information are not required to possess original classification authority, but they must respect the original markings in their derivative markings. All documents must have a declassification date or event entered into a "declassify on" line. The original classifying authority determines the "declassify on" date. Documents containing atomic energy or nuclear information do not have a declassification date or event.

Q77 Can the public ever see classified information?

There are two basic requirements to access classified information: appropriate clearance and "need-to-know." Even if an individual has the appropriate clearance, he or she cannot peruse classified information just out of curiosity. The uncleared public does not have access to classified information; however, members of the public, including activist groups and the press, can petition the government through the Freedom of Information Act to obtain access to previously classified documents.

Appendix I: Programming, Planning, and Budgeting

Q78 How are nuclear weapons-related items funded?

Only Congress has the authority to fund nuclear weapons-related items, which are appropriated through both the Department of Defense and the Department of Energy budgets. Department of Defense funding comes through the Defense subcommittees of the Congressional Appropriations Committees. Department of Energy funding comes through the Energy and Water Development subcommittees of the Congressional Appropriations Committees.

Glossary

<u>abnormal environment</u>

Those 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.

<u>alteration</u>

A 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

<u>atom</u>

The 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.

<u>atomic bomb</u>

A term sometimes applied to a nuclear weapon utilizing fission energy only.

<u>atomic mass</u>

The number of protons plus neutrons in the nucleus of an atom.

<u>atomic number</u>

The number of protons in the nucleus of an atom.

<u>authorization</u>

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.

<u>ballistic missile</u>

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

<u>blast wave</u>

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

budget authority
: *The authority to incur legally binding obligations of the government.*

channel
: *A joint arrangement between the United States and a foreign government for the exchange of specific project/program-type information.*

component
: *An assembly or any combination of parts, subassemblies, and assemblies mounted together in manufacture, assembly, maintenance, or rebuild.*

criticality
: *A 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
: *The minimum amount of fissionable material capable of supporting a chain reaction under precisely specified conditions.*

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
: *The 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
: *A 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
: *An isotope of hydrogen with one proton and one neutron in the nucleus of each atom.*

disassembly
: *The process of taking apart a nuclear warhead and removing one or more subassemblies, or 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 reassembly with either the original or replacement subassemblies / components.*

dismantlement
: *The 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

The 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

The 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.

electron

A 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

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

fire-resistant pit

The 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 a jet fuel fire of 1,200 degrees Celsius for several hours. Fire-resistant pits are only used in weapons with insensitive high explosive.

fireball

The 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

The 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

A 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

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

A 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

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

hydrogen bomb

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

igloo

An 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

A 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.

induced radiation

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

initial nuclear radiation

The 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

An 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

The total phases through which an item passes from the time it is initially developed until the time it is either consumed in use or disposed of as being excess to all known materiel requirements.

limited life component

A weapon component that decays with age and must be replaced periodically.

major assembly

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

markup

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

military characteristics

Those required characteristics of a nuclear weapon upon which depend its ability to perform desired military functions. Military characteristics include physical and operational characteristics but not technical design characteristics.

modification

A 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

A 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 security

A 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.*

<u>near-surface burst</u>
A detonation in the air that is low enough for the immediate fireball to touch the ground.

<u>neutron</u>
A neutral particle (i.e., with no electrical charge) of approximately unit mass, present in all atomic nuclei, except those of ordinary (light) hydrogen.

<u>nonproliferation</u>
Those 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.

<u>normal environment</u>
The 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.

<u>nuclear command and control</u>
The 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.

<u>nuclear command, control, and communications system</u>
The 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.

<u>nuclear command and control system</u>
The facilities, equipment, communications, procedures, and personnel that enable presidential nuclear direction to be carried out.

<u>Nuclear Posture Review</u>
A legislatively mandated review that establishes U.S. nuclear policy, strategy, capabilities, and force posture for five to ten years into the future.

<u>nuclear radiation</u>
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.

<u>nuclear threat device</u>
An 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

A 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

The energy released in the detonation of a nuclear weapon, measured in terms of the kilotons or megatons of trinitrotoluene 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

The 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

The 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.

outlays

The liquidation of the government's obligations, generally representing cash payments.

peak overpressure

The maximum value of overpressure at a given location that is generally experienced at the instant the shock (or blast) wave reaches that location.

photon

A unit of electromagnetic radiation consisting of pure energy and zero mass.

project officers groups

Joint Department of Defense–Department of Energy 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

The 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.*

<u>proton</u>
A 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.

<u>Quadrennial Defense Review</u>
A legislatively mandated review of Department of Defense strategy and priorities.

<u>quality assurance and reliability testing</u>
A quality assurance program that is part of a joint Department of Defense–Department of Energy stockpile evaluation program.

<u>quality assurance and reliability testing replacement warheads</u>
Warheads retained in the inactive stockpile to replace active stockpile warheads withdrawn for the Quality Assurance and Reliability Testing program.

<u>radioactivity</u>
The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of unstable isotopes.

<u>refurbishment</u>
All nuclear weapons alterations and modifications including life extensions, modernizations, and revised military requirements.

<u>reliability</u>
The probability, without regard to countermeasures, that a nuclear weapon, subassembly, component, or other part will perform in accordance with its design intent or requirements.

<u>reliability replacement warheads</u>
Warheads retained in the inactive stockpile that provide the assets to replace Active Stockpile Warheads should reliability or safety problems develop.

<u>residual radiation</u>
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.

<u>special nuclear material</u>
Plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235.

<u>staged weapon</u>
A weapon in which energy from the primary initiates the explosion of a secondary.

<u>stockpile flight test</u>
Joint Department of Energy–Department of Defense flight tests conducted periodically on weapon systems randomly selected from the stockpile.

<u>stockpile management</u>
The 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-to-target sequence

1. The order of events involved in removing a nuclear weapon from storage and assembling, testing, transporting, and delivering it on the target.

2. A 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

The 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

The 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

The activities involved in making sure nuclear weapons continue to meet established safety, security, and reliability standards.

thermal radiation

1. The 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

An adjective referring to the process (or processes) in which very high temperatures are used to bring about the fusion of light nuclei with the accompanying release of energy and high-energy neutrons.

thermonuclear weapon

A weapon 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 neutrons.

TNT equivalent

A 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.

transient radiation effects on electronics

Effects on electronics that are exposed to transient gammas, neutrons, and X-rays.

tritium

A 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 control

The 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

The 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

The explosion of a nuclear (or atomic) weapon with its center beneath the surface of the water.

use control

The 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

The activities involved in making sure nuclear weapons continue to meet established safety, security, and reliability standards.

weapon system

A 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

The 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

3-D	three dimensional
A	atomic weight
ABM	anti-ballistic missile
ADM	atomic demolition munitions
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AF/A10	United States Air Force Strategic Deterrence and Nuclear Integration Office
AFB	air force base
Alt	Alteration
ANFO	ammonium nitrate and fuel oil
ANMCC	Alternate National Military Command Center
AO	action officer
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
ASEAN	Association of Southeast Asian Nations
ATSD(AE)	Assistant to the Secretary of Defense for Atomic Energy
BEEF	Big Explosives Experimental Facility
C	Confidential
C2	command and control
C3	command, control, and communications
C3I	command, control, communications, and intelligence
C4I	command, control, communications, computers, and intelligence
CAC	Compartmented Advisory Committee
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
CDRUSSTRATCOM	Commander, United States Strategic Command
CDS	command disablement system
CEP	circular error probable
CER	Complete Engineering Release
cGy	centi-gray
CJCS	chairman of the Joint Chiefs of Staff
CME	component and material evaluation
CNT	countering nuclear threats
CNWDI	Critical Nuclear Weapon Design Information
Co	Cobalt
CoP	Committee of Principals
CR	continuing resolution
CTBT	Comprehensive Nuclear-Test-Ban Treaty
CTBTO	Comprehensive Nuclear-Test-Ban Treaty Organization
CTR	cooperative threat reduction

DAF	device assembly facility
DARHT	dual axis radiographic hydrodynamic test
DASA	Defense Atomic Support Agency
DASD(NCB/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
DNI	Director of National Intelligence
DNS	defense nuclear security
DoD	Department of Defense
DoDD	Department of Defense Directive
DOE	Department of Energy
DOJ	Department of Justice
DOS	Department of State
DP	Defense Programs

DPG	Defense Planning Guidance
DPPG	Defense Planning and Programming Guidance
DRAAG	Design Review and Acceptance Group
DRB	Defense Resources Board
DSW	Directed Stockpile Work
D-test	destructive test
DTRA	Defense Threat Reduction Agency
DUSD(A&T)	Deputy Under Secretary of Defense for Acquisition and Technology
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

FBI	Federal Bureau of Investigation
FBR	fast burst reactor
FEMA	Federal Emergency Management Agency
FIRP	Facilities and Infrastructure Recapitalization Program
FMCT	Fissile Material Cutoff Treaty
FOIA	Freedom of Information Act
FOUO	For Official Use Only
FPU	first production unit
FRD	Formerly Restricted Data
FRP	fire-resistant pit
FWDR	Final Weapon Development Report
FY	fiscal year
FYDP	Future-Years Defense Program
FYNSP	Future-Years Nuclear Security 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

H-2	deuterium

H-3	tritium
HE	high explosive
He-4	helium
HEAF	High Explosives Application Facility
HEDP	high energy density physics
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

IA	implosion assembly
IAEA	International Atomic Energy Agency
IC	intelligence community
ICBM	intercontinental ballistic missile
ICD	Interface Control Document
ICF	inertial confinement fusion
IFI	in-flight-insertion
IHE	insensitive high explosive
I-JTA	instrumented joint test assembly
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
ITW/AA	Integrated Tactical Warning/ Attack Assessment

JAC	Joint Advisory Committee
JAIEG	Joint Atomic Information Exchange Group
JASPER	Joint Actinide Shock Physics Experimental Research
JCIDS	Joint Capability Integration and Development System
JIPP	Joint Integrated Project Plan
JNWPS	Joint Nuclear Weapons Publications System
JOWOG	Joint Working Group
JROC	Joint Requirements Oversight Council
JS	Joint Staff
JS/J3	Joint Staff Director for Operations
JS/J5	Joint Staff Plans and Policy Directorate
JSR	Joint Surety Report
JTA	joint test assembly

JTSMG	Joint Theater Surety Management Group
KCP	Kansas City Plant
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
LEP	life extension program
LEU	low enriched uranium
LINAC	linear accelerator
LLC	limited life component
LLCE	limited life component exchange
LLNL	Lawrence Livermore National Laboratory
LPO	lead project officer
LRPA	Long Range Planning Assessment
LTBT	Limited Test Ban Treaty
MAD	mutual assured destruction
MAR	Major Assembly Release
MBS	Modulus Bremsstrahlung Source
MC	military characteristic
MCCC	Mobile Consolidated Command Center
MCCS	multiple-coded control switch
MDA	mutual defense agreement
MFD	military first destination
MG	Mighty Guardian
MILCON	Military Construction
MILPERS	Military Personnel
MIR	major impact report
MIRV	multiple independently targetable re-entry 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
NCTIR	nuclear counterterrorism incident response
NDAA	National Defense Authorization Act
NDB	nuclear depth bomb
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
NMCS	National Military Command System
NMSEP	New Material and Stockpile Evaluation Program
NNAP	Non-Nuclear Assurance 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
NSA	National Security Agency
NSE	Nuclear Security Enterprise
NSPD	National Security Presidential Directive
NSS	Nuclear Command and Control System Support Staff
NSS	National Security Staff
NTD	nuclear threat device
NTM	national technical means
NTNF	national technical nuclear forensics
NTS	Nevada Test Site
NWAIRS	Nuclear Weapons Accident Incident Response Subcommittee
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
NWPSS	Nuclear Weapons Physical Security Subcommittee
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

O&M	operations and maintenance
OAU	Organization of African Unity
OCA	original classification authority
ODNI	Office of the Director for National Intelligence
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
OSTP	Office of Science and Technology Policy
OUO	Official Use Only

PA	probability of arrival
PAL	permissive action link
PAP	Personnel Assurance Program
PBD	program budget decision
PCP	product change proposal
PD	probability of damage
PDD	Presidential Decision Directive
PDM	program decision memoranda
PLS	pre-launch survivability
PNET	Peaceful Nuclear Explosions Treaty
PNI	Presidential Nuclear Initiative
POC	Program of Cooperation
POG	Project Officers Group
POM	Program Objective Memorandum
PPBE	Planning, Programming, Budgeting, and Execution
PPBS	Planning, Programming, and Budgeting System
PPD	Presidential Policy Directive
PPE	personal protective equipment
PPI	process prove-in

PRC	People's Republic of China
PRP	personnel reliability program
PRS	Plasma Radiation Source
PSAP	Personnel Security Assurance Program
PSE	Physical Security Equipment
psi	pound per square inch
PTP	probability to penetrate
Pu	plutonium
PWDR	Preliminary Weapon Development Report
PX	Pantex Plant

QA	quality assurance
QART	quality assurance and reliability testing
QDR	Quadrennial Defense Review

RB	re-entry body
RD	Restricted Data
RD	radius of damage
RDD	radiological dispersal device
RDT&E	research, development, test, and evaluation
REBA	Relativistic Electron Beam Accelerator
RED	radiological exposure device
RMD	Resource Management Decision
ROSA	Report on Stockpile Assessments
RPD	Requirements and Planning Document
RS	readiness state
RTBF	Readiness in Technical Base and Facilities
RV	re-entry vehicle

S	Secret
SALT	Strategic Arms Limitation Talks
SASC	Senate Armed Services Committee
SCN	Shipbuilding and Conversion
SCT	Stockpile Confidence Test
SD	Statutory Determination
SEP	Stockpile Evaluation Program
SFI	significant finding investigation
SFT	stockpile flight test
SG	study group
SHAPE	Supreme Headquarters Allied Powers Europe
SLBM	submarine-launched ballistic missile
SLCM	sea-launched cruise missile
SLT	stockpile laboratory test
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)
SSP	Stockpile Stewardship Plan
SSP	Strategic Systems Programs
STA	Secure Transportation Asset
START	Strategic Arms Reduction Treaty
STP	Surveillance Transformation Project
STS	stockpile-to-target sequence

TACAMO	take charge and move out
TCC	Transformation Coordinating Committee
TNF	technical nuclear forensics
TNT	trinitrotoluene
TP	Technical Publication
TREE	transient radiation effects on electronics
TRS	thermal radiation source
TS	Top Secret
TSSG	trajectory-sensing signal generator
TTBT	Threshold Test Ban Treaty

U	Unclassified
U	uranium
U.S.	United States
UCNI	Unclassified Controlled Nuclear Information
UF6	uranium hexafluoride
UVF	Ultra High Frequency
UGT	underground nuclear testing
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(I)	Under Secretary of Defense for Intelligence
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
WDCR	Weapon Design and Cost Report
WDD	Weapons Dismantlement and Disposition
WMD	Weapons of Mass Destruction
WR	war reserve
WS3	weapon storage and security system *(United States)* weapon security and survivability system *(NATO)*
WSR	weapon system reliability
WSV	weapon storage vault

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