Chapter 1
The U.S. Nuclear Weapons Program

1.1 *Overview*

Nuclear Matters: A Practical Guide provides an introduction to the U.S. Nuclear Weapons Program. It is designed for individuals who have a need to understand these matters and is intended to explain the various elements that constitute the Nuclear Weapons Program.

This reference book is **unofficial**. It was designed to be useful, but is neither authoritative or directive. The purpose of this book is to familiarize readers with concepts and terms associated with the U.S. Nuclear Weapons Program[1].

1.2 *The U.S. Nuclear Weapons Program*

The U.S. Nuclear Weapons Program is, first and foremost, a deterrent that minimizes the possibility that the U.S. will be attacked by nuclear weapons or other WMD.

The *U.S. Nuclear Weapons Program* represents the totality of all activities, processes, and procedures associated with the design, development, production, fielding, maintenance, repair, storage, transportation, physical security, employment, and, finally, dismantlement, disposal, and replacement of the nuclear weapons in the U.S. stockpile. The U.S. Nuclear Weapons Program also includes the various organizations and key offices within the Administration and the Congress that are a part of the approval and funding process. Finally, the U.S. Nuclear Weapons Program encompasses the infrastructure and resources—human and material—necessary to support the U.S. policy of deterrence.

1.3 *History of the U.S. Nuclear Weapons Program*

The nuclear weapons of the United States have constituted an essential element of the U.S. military capability since their initial development. The potential to harness nuclear energy for military use was first described in a letter signed by Albert Einstein (Figure 1.1) to President Franklin D. Roosevelt in August 1939. The letter 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 ominous statement that experimental work

[1] The information in this book is current as of October 2007.

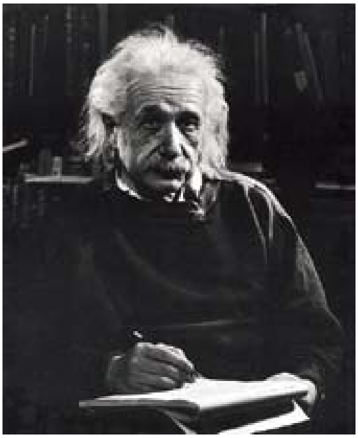

Figure 1.1 Albert Einstein

was being carried out in Berlin. Einstein's assertion that a device employing this principle would be too heavy to be carried by an aircraft gave some comfort, but this was short lived. In early 1940, Otto Frisch and Rudolph Peierls, working at Birmingham University in England, concluded that, if the fissile isotope U-235 could be separated from natural uranium, only about one pound would be needed for a bomb of huge destructive capacity. This proposition was endorsed by the government-appointed MAUD Committee in 1941, and shortly after, Prime Minister Winston Churchill authorized work to begin on Britain's atomic bomb project, codenamed *Tube Alloys*.

The first MAUD Report was sent from Britain to the U.S. in March 1941, but no comment was received from the U.S. A member of the MAUD Committee flew to the U.S. in August 1941 in a bomber to discuss the findings and to convince the U.S. that it should take the work of Frisch and Peierls very seriously. The National Academy of Sciences then proposed an all-out effort to build nuclear weapons. In a meeting on October 9, 1941, President Roosevelt was impressed with the need for an accelerated program, and by November had authorized the recommended "all-out" effort. A new 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 entrance of the United States into World War II.

Eventually, the U.S. established the "Manhattan Project," whose goal was to produce nuclear bombs in time to affect the outcome of WWII. In 1943, as outlined in the Quebec Agreement between the United States and the United Kingdom, the team of scientists working on the British project was transferred to the Manhattan Project to work collaboratively with their U.S. counterparts.

On July 16, 1945, the United States detonated its first nuclear explosive device called "the gadget" at the Trinity Site, which is located within the current White Sands Missile Range, near the town of Alamagordo, New Mexico. Twenty-one days later, on August 6, with President Harry S. Truman's authorization, a specially-equipped B-29 bomber named the *Enola Gay* (Figure 1.2) dropped a nuclear bomb, *Little Boy*, 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 (named *Bockscar*, Figure 1.3) dropped a second U.S. atomic weapon, *Fat Man* (Figure 1.4) on Nagasaki.

Figure 1.2 Enola Gay

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 U.S. land invasion of Japan. The atomic bombs dropped on Hiroshima and Nagasaki remain the only nuclear weapons ever used in combat. Their use permanently altered the global balance of power.

Figure 1.3 Bockscar

The U.S. enjoyed a nuclear monopoly until August 29, 1949 when the Soviet Union conducted its first nuclear test. Within a relatively short time after the end of World War II, the Soviet Union was recognized as a potential adversary. This geostrategic consideration, and the Soviet Union's development of a nuclear weapons capability, caused the U.S. to give a high priority to the quantity production of nuclear weapons.[2] By the early 1950s, the United States and the Soviet Union had both developed the more powerful hydrogen,

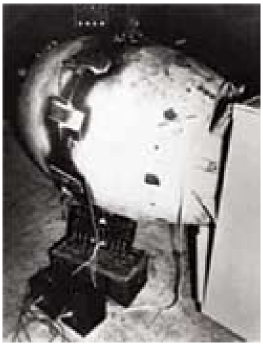
Figure 1.4 Fat Man

[2] All nuclear weapons in the current U.S. stockpile are designated either as a warhead, delivered by a missile (e.g., the W87 and the W76), or a gravity bomb, dropped from an aircraft (e.g., the B83 and the B61). The distinction between a warhead and a bomb is an important one at the engineering level because the design, engineering, and component production responsibilities between the military service and the DOE design laboratories may be different for a "W" versus a "B" weapon. However, at the national level, the stockpile plan and other programmatic actions must comply with approved treaties, current legislation, and national policy directives, most of which use the term warhead to mean all nuclear weapons, including Ws and Bs. In this book the term *warhead* is used to denote individual weapons without distinguishing between "W" or "B" designators, and the term *warhead-type* denotes a population of weapons with the same design. The terms *weapon* and *warhead* are used interchangeably in this book.

or thermonuclear, bomb. The United Kingdom, having resumed its nuclear weapons program in 1947, successfully tested an atomic bomb in 1952. Both the U.S. and the Soviet Union increased their stockpile quantities until each possessed nuclear weapons in sufficient quantities to achieve a "secure, second-strike capability," so 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 Mutually Assured Destruction (MAD), which provided deterrence for both nations.

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 available military delivery system. This was considered essential because of the possibility of Cold War escalation. Throughout the late 1950s, the United States was committed to increasing nuclear weapons quantities to enhance flexibility in the types of nuclear-capable military delivery vehicles.

By 1961, the U.S. nuclear weapons stockpile had grown to more than 20,000 warheads. 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 within the territory of U.S. allies in the North Atlantic Treaty Organization (NATO).

Beginning in the early 1960s, the U.S. shifted its priority from quantity to quality. From about 1960 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[3] for the military operator, modern characteristics included greater yield, smaller size[4], better employment characteristics[5], and more modern safety, security, and control features. A key part of this process was the use of nuclear testing to refine new designs in the development process, to test the yield of weapons

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3 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.

4 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 nuclear weapons being fired by cannon artillery or being human-portable.

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

within a year after fielding, and to define or repair certain types of technical problems related to nuclear components in weapons that were already fielded.

These modernization programs were achieved through continuous research and development efforts as well as the production of new warheads to replace aging and less sophisticated weapons, usually after the older warheads had been fielded for a period of 15-20 years. In addition, the U.S. utilized a complementary combination of non-nuclear and nuclear testing to refine designs in the development stage, certify weapon designs and production processes, validate safety, estimate reliability, detect defects, and confirm effective repairs.

1.4 End of Underground Nuclear Testing

In 1992, in anticipation of a potential comprehensive test ban treaty, the U.S. voluntarily suspended its program of Underground Nuclear Testing (UGT). The 1992 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 to those warheads planned for retention in the reduced stockpile under the proposed Strategic Arms Reduction Treaty (START) II.[6] 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.[7] The moratorium on UGT also resulted in suspending production of weapons with new, untested designs including those with newer safety improvements beyond those specified in the legislation. This created a shift toward a second paradigm, away from modernization and production (a cycle of newer-design warheads replacing older warheads) to a new strategy of retaining previously produced warheads indefinitely, without nuclear testing, and with no plans to replace the weapons.

In response to these new circumstances, the FY 1994 National Defense Authorization Act (P.L. 103-160), called on the Secretary of Energy to "establish a stewardship program to ensure the preservation of the core intellectual

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[6] Public Law 102-377, the FY93 Energy and Water Development Appropriations Act, specified three features as the desired safety features for all U.S. weapons: Enhanced Nuclear Detonation Safety (ENDS), Insensitive High Explosive (IHE), and Fire-Resistant Pit (FRP).

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

and technical competencies of the United States in nuclear weapons." In the absence of nuclear testing, the Stockpile Stewardship Program was directed to: 1) support a focused, multifaceted program to increase the understanding of the enduring stockpile; 2) predict, detect, and evaluate potential problems due to the aging of the stockpile; 3) refurbish and remanufacture weapons and components, as required; and 4) maintain the science and engineering institutions needed to support the nation's nuclear deterrent, now and in the future. This "science-based" approach, which has served as a substitute for nuclear testing since 1992, has developed and matured and now includes computer simulations, experiments, and previous nuclear test data (combined with the judgment of experienced scientists and engineers). See Chapter 4, *Nuclear Weapons Program Infrastructure*, for a more complete description of this science-based approach.

Since early 1993 the U.S. Nuclear Weapons Program has been essentially "stuck" in a continuous loop that represented only a small segment of what was previously a full cycle of perpetual production and replacement. During this time, the truncated process consisted primarily of activities associated with the continuous assessment, maintenance/repair, and refurbishment of the weapons. See Chapter 2, *Life-Cycle of U.S. Nuclear Weapons*, for a detailed discussion of the nuclear weapons life-cycle process.

As a "technological hedge" against the catastrophic failure of a warhead-type for which there would no longer be a planned replacement weapon, the stockpile plan (the annually-updated document signed by the President that authorizes modifications in stockpile quantities and composition) was modified to include a new category of inactive warheads for reliability replacement. Prior to the UGT moratorium and the suspension of new production, these weapons would have been retired from the stockpile, dismantled, and disposed of. Under the new plan, if one warhead-type developed a catastrophic problem that affected all warheads of that type (and could not be corrected because of the inability to conduct UGT), another warhead-type could be re-activated as a replacement.

Because the U.S. suspended both production of new weapons as well as underground nuclear testing by 1992, confidence in the effectiveness of all U.S. nuclear weapons could no longer be founded on the perpetual modernization and upgrade of the warhead-types in the stockpile. Instead, the U.S. nuclear program relied on a non-nuclear Quality Assurance and Reliability Testing (QART) program to validate safety, estimate reliability, and detect component problems for each warhead-type. See Chapter 6, *Quality Assurance and Non-Nuclear Testing*, for details of the QART program.

Most of the warheads in the current U.S. nuclear weapons stockpile were designed and fielded to meet Cold War requirements and have been retained well beyond their original programmed life-span. U.S. leaders are reassessing the size and structure of the stockpile as a part of a transition to the potential development and production of a new warhead design. However, unlike previous development programs, this will be accomplished without nuclear testing.

It is the policy of the United States to achieve an effective strategic deterrent at the lowest level of nuclear weapons consistent with national security and commitments and obligations to U.S. allies. In 2001, the President directed that the United States reduce the number of operationally deployed strategic nuclear weapons from about 6,000 to 1,700-2,200 by 2012—a two-thirds reduction. Corresponding reductions in the nuclear stockpile will result in the lowest stockpile quantities since the Eisenhower Administration.

Several factors have permitted these dramatic reductions from the Cold War nuclear arsenal built and maintained from the 1950s to the 1990s. For several decades, the Soviet Union represented a large, intractable, ideologically motivated adversary; its fall has allowed the U.S. to reassess its nuclear force requirements. In 2001, the President also directed the transition to a new set of military capabilities more appropriate for credible deterrence in the 21st Century. This "New Triad" of strategic capabilities, composed of non-nuclear and nuclear offensive strike forces, missile defenses, and a responsive national security infrastructure, reduces U.S. reliance on nuclear weapons while mitigating the risks associated with drawing down U.S. nuclear forces. Figure 1.5 illustrates the transition from the traditional U.S. Nuclear Triad to this New Triad.

Nuclear weapons, however, will continue as a lynchpin of U.S. national security for the foreseeable future. All of the activities associated with U.S. nuclear weapons contribute to the continued safety, security, and reliability of the U.S. nuclear deterrent. Perhaps most importantly, the U.S. Nuclear Weapons Program enhances the perceived credibility of U.S. nuclear forces. These tasks have always been challenging. Today there are a number of new challenges.

1.5 New Challenges

Senior government leaders, and many of the managers at the National Weapons Laboratories[8], have concerns about the state of the nation's nuclear stockpile. Several of these concerns have overlapping considerations. Some of the more significant concerns include:

- Aging warheads in an era of no nuclear testing;

[8] U.S. national weapons laboratories include Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories.

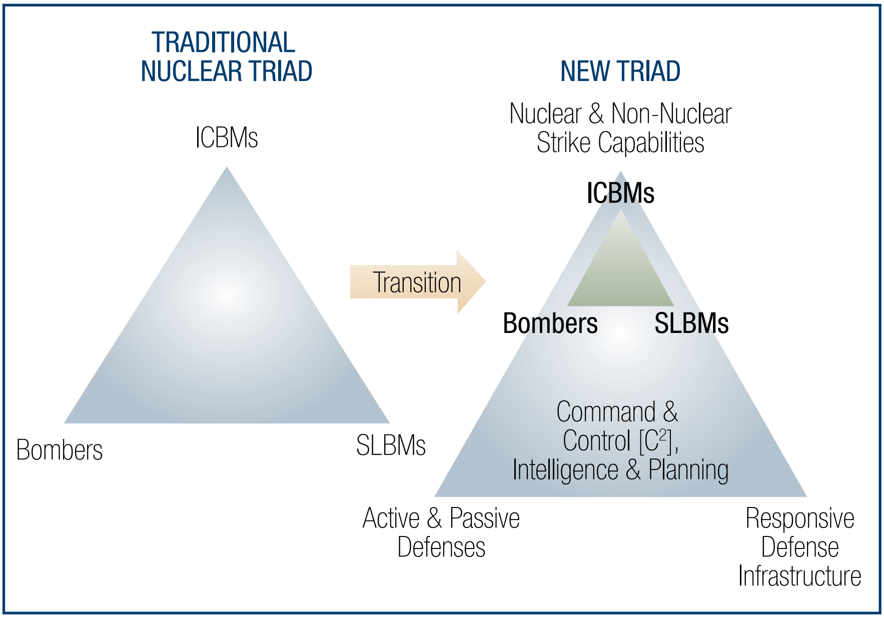

Figure 1.5 The New Triad

- Lack of modern safety, security, and control features in some warheads;
- Loss of technical expertise;
- Deteriorating nuclear complex infrastructure; and
- Quantity of warheads in the total stockpile.

1.5.1 Aging Warheads in an Era of No Nuclear Testing

Prior to 1992, when certain types of nuclear component problems were suspected, nuclear testing could be used to define, and if necessary, repair these problems. Currently, the U.S. Nuclear Weapons Program is focused on retaining and maintaining aging warheads without nuclear testing. This has caused increasing risks that should any warhead-type develop a catastrophic problem, without nuclear testing, it would be impractical, if not impossible, to resolve. See Appendix D, *Underground Nuclear Testing,* for a more detailed discussion of how nuclear testing contributed to solving certain types of suspected warhead problems, and how the nuclear testing program ended in 1992.

Jointly, the Department of Defense (DoD) and the Department of Energy (DOE) developed several strategies for mitigating these risks. These included:

- A program to develop a computer substitute for nuclear testing;
- The retention of inactive warheads to serve as possible replacements for other types of warheads in the event of a catastrophic failure;
- The possible production of new pits[9] for the production of new warheads of a previously tested design; and
- The retention of a nuclear testing capability at the Nevada Test Site in the event of a decision to resume nuclear testing in the future.

These mitigation strategies have been a part of stockpile planning for more than a decade, and new strategies are continually being developed. However, all of these initiatives combined will not preclude the possibility of one or more warhead-types from becoming non-operational because of a nuclear component aging issue.

1.5.2 Modern Safety, Security, and Control Features

The 1992 legislation that ended U.S. nuclear testing specified three modern safety features that should be incorporated into all U.S. nuclear warheads: Enhanced Nuclear Detonation Safety (ENDS); Insensitive High Explosive (IHE); and Fire-Resistant Pit (FRP). At that time, more than 90 percent of the total number of warheads in the stockpile had ENDS, approximately 50 percent had IHE, and less than 20 percent had FRP. Because the 1992 legislation allowed for only a limited number of tests to be conducted over a limited period of time, there was no credible way to modify any of the warheads that lacked these specific features; the tests required to certify the modification would have exceeded the number and timeframe permitted by the legislation.

In early 1993, the stockpile plan included the retirement of all warheads that lacked ENDS. In the mid-1990s, when Russia failed to accept the START II Treaty, the U.S. modified its planned drawdown, and some warheads without ENDS had their scheduled retirement dates extended. With the ratification of the Moscow Treaty (2003), the U.S. resumed more rapid stockpile reductions, and there will no longer be an issue of warheads lacking ENDS in the future.

As the stockpile draws down to the Moscow Treaty limits, some non-IHE warheads are being retired. Additionally, some IHE warheads are being retired because they are not required. The current stockpile still has a significant percentage of warheads without IHE, however, and the DoD and the DOE take extraordinary measures to ensure that the warheads are not subjected to accidents or damage from abnormal environments. Even so, the increased risk associated with the transportation of non-IHE warheads remains a concern.

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[9] A pit is the primary fissile component in U.S. warheads.

The FRP feature is included in only a relatively small percentage of U.S. warheads. This also remains a concern.

The current stockpile has modern security and control features built into all warhead-types that would be forward deployed outside the U.S. Other warheads operate within the U.S. as a part of a complete weapon system. Security and control features are either integrated into the warhead or included as part of the delivery system, using features such as a coded-control device (CCD). The fact that some warheads do not have these features imbedded in the warhead is a potential cause of concern.

For a more detailed description of safety, security, and control features, see Chapter 5, *Nuclear Weapons Surety*.

1.5.3 Loss of Technical Expertise

Another challenge is the competition for "talent," which is characterized by the increasing difficulty in attracting, training, and retaining the best and the brightest Americans to work in both civilian and military positions associated with nuclear weapons. A 2006 Defense Science Board Report on *Future Strategic Strike Skills* concluded that it appears that a serious loss of certain critical strategic skills may occur over the next decade.

The new generation of personnel within the U.S. nuclear community will face uniquely difficult challenges, especially in the pursuit of maintaining a safe and reliable stockpile without nuclear testing. If the leadership of the U.S. decides that it is necessary to return to nuclear testing, the new generation will do so with far fewer individuals who possess nuclear testing experience than those who were working in the 1960s, 1970s, and 1980s.

1.5.4 Deterioration of the Nuclear Complex Infrastructure

The U.S. nuclear weapons complex is aging. As the current practice of retaining warheads indefinitely with periodic refurbishment has evolved, the average age of the legacy warheads continues to increase along with the number of components required for refurbishment. Most U.S. nuclear weapons production facilities have been decommissioned. Others are well past their originally planned life, and are in need of repair and facility refurbishment. In addition, the increased demand for the production of refurbishment components may require significant expansion at some facilities. The lack of availability of some essential materials, coupled with changes in environmental and occupational safety standards, has resulted in facility closures[10] and has created sunset technologies for which certified substitutes must be found without the benefit of nuclear testing. All of these factors affect the capacity of the nuclear weapons complex. See Chapter 4, *Nuclear Weapons Program Infrastructure*, for a description of the current nuclear weapons complex.

1.5.5 Stockpile Quantities

As a part of its cooperation within the international community to achieve nonproliferation goals, the U.S. is committed to reducing its nuclear weapons stockpile and continuing its current policy of no nuclear testing. 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 the stockpile draws down to a smaller quantity with fewer types of weapons, the potential consequences of a catastrophic failure of any one warhead-type could be significantly magnified; the loss of one warhead-type would affect a larger percentage of the total stockpile. One strategy to mitigate this risk has been to retain inactive warheads to serve as replacements for another warhead-type that might develop such a catastrophic problem. Retaining these additional warheads has attracted criticism because stockpile quantities are higher than they otherwise might be if this "hedge" were not necessary. It also places an additional burden on the DoD to store and secure the inactive weapons. If these warheads were to be reactivated, it would require the DOE to expand ("surge") the work at key facilities to produce the components necessary for reactivation.

1.6 *Future of the U.S. Nuclear Weapons Program*

The United States is engaged in a fundamental rethinking of its strategic nuclear arsenal. The international security environment has changed. The current stockpile was developed for very different threats than those that exist

[10] There are many facilities that were once part of the DOE nuclear weapons complex that are now in the process of transition either to environmental clean up, materials storage, or return to civilian use. These facilities include: the Idaho Chemical Processing Plant at the Idaho National Engineering Laboratory, a reprocessing plant for spent reactor fuels; the Rocky Flats Environmental Testing Site, a nuclear component assembly and disassembly plant; the Mound Plant, a location that produced explosive and inert components, conducted diagnostic surveillance testing of nuclear and explosive components, and recovered tritium from retiring tritium components; the Pinellas Plant, a manufacturer of electrical and electronic components for nuclear weapons; and the Hanford Site, a former producer of weapons-grade plutonium.

today and are expected to emerge in the future. The Cold War is over; regional threats have risen; terrorism has assumed global and destructive proportions; technology has changed; and a significant number of adversaries have acquired WMD. These new threats require weapons that can hold at risk different targets than those for which the current stockpile was designed.

In addition to enhanced deterrence and military performance, stockpile transformation would also achieve enhanced safety and security of the U.S. nuclear arsenal. As discussed above, while all weapons in the current U.S. nuclear stockpile are safe and secure, not all weapons in the stockpile incorporate every available modern safety and security features. Moreover, additional features have been developed in the last decade that could be added to new weapon designs or to modified designs of existing weapons.