

An Analysis of Technical and Policy Drivers in Current U.S. Nuclear Weapons Force Structure

By

Amanda Baker

Submitted to the Department of Nuclear Science and Engineering

In Partial Fulfillment of the Requirements

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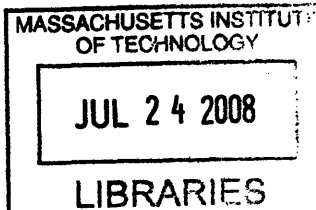
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Signature of Author: _____
Department of Nuclear Science and Engineering
May 9, 2008

Certified By: _____
Dwight L. Williams
MLK Visiting Professor of Nuclear Science and Engineering
Thesis Supervisor

Accepted By: _____
David G. Cory
Professor of Nuclear Science and Engineering
Chairman, NSE Committee for Undergraduate Students



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ABSTRACT

U.S. nuclear weapons force structure accounts for the number and types of strategic and nonstrategic weapon systems in various locations that comprise the nuclear arsenal. While exact numbers, locations, and detailed designs remain classified, motivations for the current and future of the nuclear arsenal is presented as a unique integration of logical technical and political information. The dynamic that results from military requirements, physical design limitations, and congressional response to balance deterrence with stockpile reductions has not produced the necessary level of change in the post-Cold War environment of the 21st century. As such, a stagnant position on nuclear weapons reductions diminishes the effect of U.S. global nonproliferation efforts.

TABLE OF CONTENTS

I. Introduction	7
1. Nuclear Weapons & Policy	7
1.1 Definition of a Nuclear Weapon	7
1.2 Nuclear Weapons in Defense Policy	10
2. Thesis Framework & Focus	12
II. Current Nuclear Force and Infrastructure	14
1. Overview	14
2. Strategic Nuclear Weapons.....	17
2.1 Intercontinental Ballistic Missile (ICBM).....	18
2.2 Submarine-Launched Ballistic Missile (SLBM)	20
2.3 Strategic Bombs.....	22
3. Nonstrategic Nuclear Weapons.....	23
3.1 Sea-Launched Cruise Missile	24
3.2 Nonstrategic Bombs.....	25
4. Infrastructure.....	25
4.1 Domestic.....	25
4.2 International.....	27
III. Future Directions in Nuclear Weapons Force Structure Policy	27
1. Deterrence & Reductions.....	27
2. Determinants of Force Structure Policy.....	28
2.1 The Military	29
2.2 Technical Experts.....	34
2.3 Congress	43
IV. Conclusion: The Effect on Nonproliferation	44

LIST OF FIGURES

Figure 1: Methods for Igniting a Fission Explosion: Gun Assembly (top) & Implosion (bottom)	8
Figure 2: Two-stage thermonuclear weapon system	9
Figure 3: Defense Policy Process Model	10
Figure 4: US Nuclear Arsenal.....	15
Figure 5: US Nuclear Stockpile.....	17
Figure 6: New Triad 2004.....	18
Figure 7: ICBM Force Development (1945-1990)	19
Figure 8: SLBM Force Development (1955-1990).....	21
Figure 9: W80-0 Warhead	24
Figure 10: A Dismantled B61	25
Figure 11: Locations of US nuclear weapons, 2006.....	26
Figure 12: Progressive Burial of the Nuclear Facility in Natanz, Iran	33
Figure 13: “Effect of increased mass of fissionable material in reducing the proportion of neutrons lost by escape”	36
Figure 14: FY2008 Directed Stockpile Work Funding.....	39
Figure 15: FY2008 Funding for Experiment and Simulation Campaigns	40

LIST OF TABLES

Table 1: Characteristics of ICBM Warheads Currently.....	20
Table 2: Characteristics of SLBM Warheads.....	21
Table 3: Characteristics of Strategic Bombs.....	23
Table 4: Activities within each Experiment and Simulation Campaign.....	41

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I. INTRODUCTION

1. NUCLEAR WEAPONS & POLICY

The analysis of nuclear weapons can be approached from two vantage points, physics and sociopolitical psychology. A nuclear weapon is the materialization of complex physical processes which induce a nuclear explosion harnessing an unprecedented amount of energy. The manipulation of fear that results from their potential ramifications explains the use of nuclear weapons in national defense. In an effort to explain the logic behind the interest in and importance of nuclear weapons analysis, this section provides an overview of this two-toned approach to nuclear weapons.

1.1 DEFINITION OF A NUCLEAR WEAPON

A nuclear weapon is broadly defined as a nuclear warhead within a weapon delivery system. The nuclear processes within the warheads differentiate them; an atomic bomb is generally considered a fission device and a thermonuclear weapon, a fusion device. However, modern weapons involve both fission and fusion reactions. In fission weapons, both reactions are involved in a process known as boosting. Fusion fuel in the center of the fissile pit releases neutrons upon implosion which increase the amount of splitting atoms, thereby increasing yield. In thermonuclear weapons, fusion usually occurs only after fission reactions release enough energy to induce the pressure and temperature conditions required to initiate fusion.

Fission weapons explode when fissile material, such as uranium-235 or plutonium-239, becomes supercritical via a gun-shot assembly or implosion device. These methods are shown in Figure 1 (1).

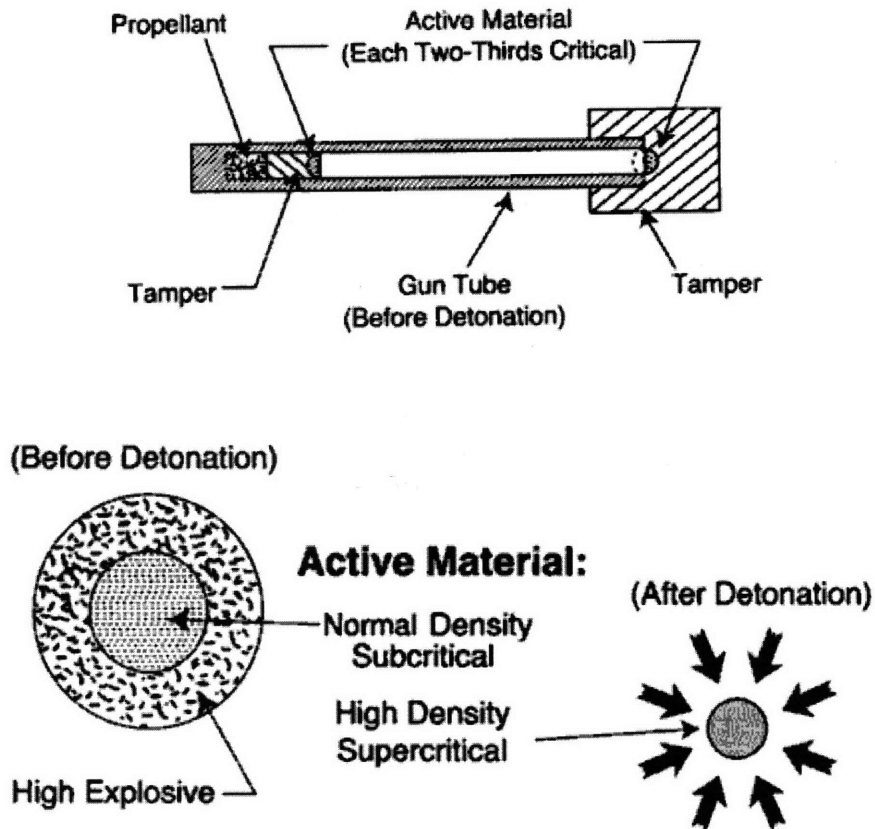
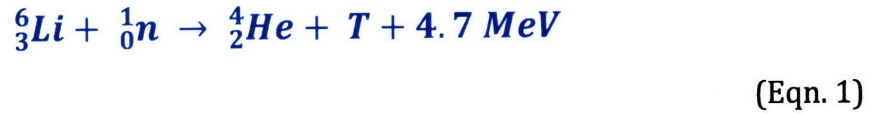


Figure 1: Methods for Igniting a Fission Explosion: Gun Assembly (top) & Implosion (bottom)
nuclearweaponarchive.org

In the gun assembly weapon, two separate pieces of fissile material are shot together to form a mass in which the rate of neutron production exceeds that of neutron loss. The same concept applies in the implosion technique during which the surrounding high explosive compresses the heavy metal increasing density while decreasing surface area. This effectively decreases the amount of fissile material required to produce comparable yields.

Alternatively, the fusion weapon explodes via a two or three-stage fusion assembly. Example fusion reactions that are applicable to nuclear weapons are represented below (2):



In Eqn. 1, Li-6 combines with a neutron to form a helium atom, tritium and energy. Eqn. 2 shows the fusion of deuterium and tritium to produce helium, a neutron, and energy. The schematic of a two-stage thermonuclear weapon is shown below in Figure 2 (1).

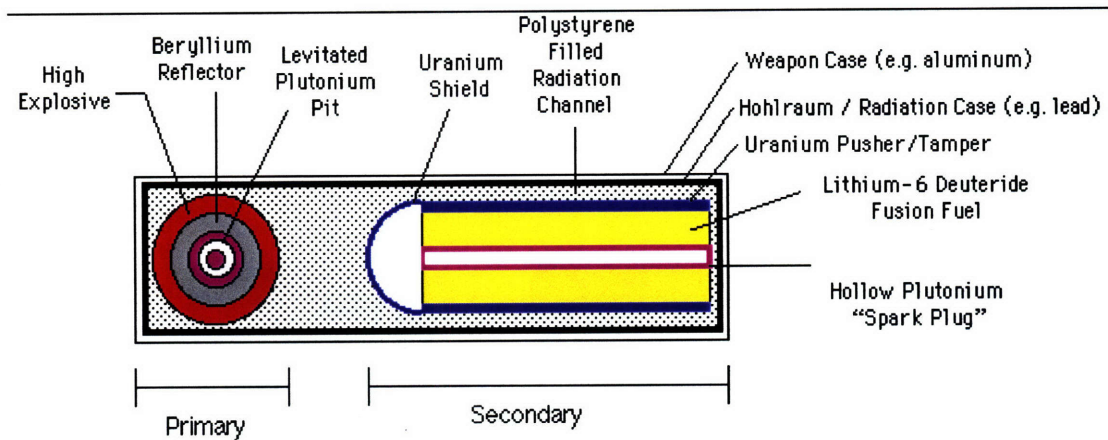


Figure 2: Two-stage thermonuclear weapon system
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The two-stage fusion weapon shown above has a fission primary on the left and a fusion secondary on the right. In this particular system, the conventional explosive, the outermost part of the primary sphere, results in the implosion of a plutonium

core. The middle layer in the primary consists of beryllium, which serves as a reflector to decrease the percentage of neutrons lost. X-rays produced from the fission reactions flood the interior of the aluminum weapon case, a polystyrene filled radiation channel that separates the primary from the secondary. The temperature and pressure conditions that result are high enough to ignite a fusion reaction in the lithium-deuteride fuel.

1.2 NUCLEAR WEAPONS IN DEFENSE POLICY

Defense policy encompasses the governmental decisions, actions, and strategies to protect and actively defend the welfare of the country, its institutions, and its citizens. The most severe form of defense is the use of weapons of mass destruction, notably nuclear weapons. One model of the policy-making process consists of four stages: input, communications channels, conversion structures, and output, illustrated in Figure 3 (3).

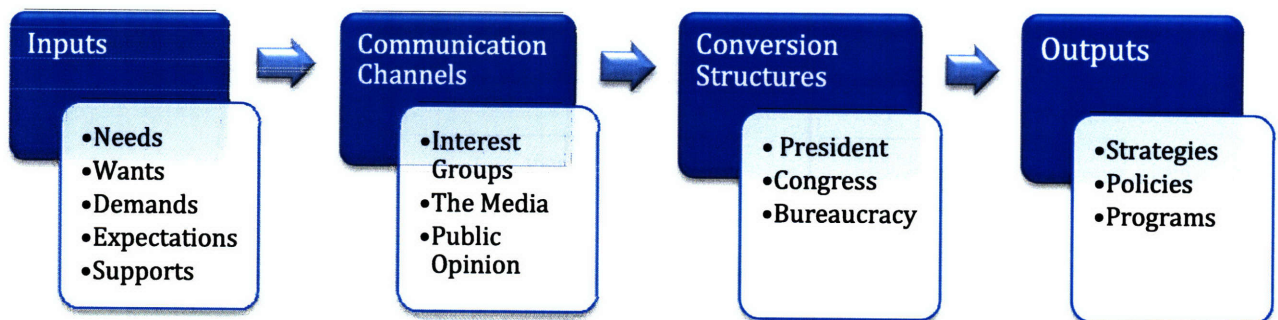


Figure 3: Defense Policy Process Model [3]

The inputs are needs, wants, demands, expectations, and supports that highlight a necessity for change or innovation in the specific policy area. An example of an input in nuclear weapons policy is the increased expectation for weapons reductions in the post-Cold War environment. The inputs become apparent by the work of the communication channels. These influencing bodies include interest groups, the media, and public opinion. One such interest group that is responsive to the aforementioned input is the Arms Control Association. Conversion structures are the parts of the US government, the President, Congress, and the bureaucracy that take the information from both the inputs and communications channels to produce outputs. These outputs are the actual strategies, policies, and programs that respond to the original inputs. (3) This model of defense policy is unlike other policy areas in that these stages of decision-making occur between international and domestic environments, overlapping with both foreign affairs and security policy. Nuclear weapons policy is further differentiated from the rest of defense policy in that the inputs are highly controversial while the communications channels and conversion structures combine to include, and to a greater extent rely on, scientists, nuclear weapons experts, and the military. As opposed to other areas of US social policy, or even defense policy, the decisions concerning nuclear weapons are not largely dependent on an American social force. Legislators are then required to adapt their decision-making role in concert with the technical and military drivers. In effect, the singularity of nuclear weapons policy results from inherent complications in this model thus potentially diminishing the efficiency of the policy process.

Nuclear weapons policy encompasses several areas, such as declaratory, operational, force structure, security, and nonproliferation. (4) Declaratory policy determines what information is disclosed to the public. Operational policy determines when, where, and how different types of nuclear weapons are to be employed, or used. Force structure policy outlines the types and amounts of weapons in domestic and international locations that make up the arsenal. Security policy refers to the security and safety of the nuclear weapons, whether on a military base, a submarine, or in the dismantling process. Lastly, nonproliferation policy protects against the misuse of nuclear weapons, especially in regard to 'non-nuclear states' as determined by the Nonproliferation Treaty (NPT).

2. THESIS FRAMEWORK & FOCUS

The culmination of the Manhattan project into the first nuclear test in 1945 introduced a controversial era of nuclear weapons. A part of the federal budget and military agenda as well as a means to induce large-scale psychological fear, the issue of nuclear weapons continues to raise debate both politically and socially. The aftermath of 9/11 fueled innovation in government, such as the creation of the Department of Homeland Security in 2002, at the same time intensifying this nuclear fear and controversy. The catastrophic event ignited domestic and international concern of possible nuclear attack by a rogue nation or terrorist group. The resulting heightened security and defense atmosphere of the 21st century

further complicates and calls into question existing and changing US nuclear weapons policy.

In the second half of the 20th century, the US developed hundreds of nuclear weapon types, yet only few remain in today's arsenal. This thesis aims to answer the following questions:

- Which nuclear weapon types make up today's nuclear arsenal?
- What are the driving factors that shape nuclear force structure policy?
- What is the international effect of changes to US nuclear force structure?

Building on the foundations of nuclear physics and definition of force structure policy discussed in the previous sections, chapter 2 outlines the types of warheads in the stockpile and briefly overviews the domestic and international locations of weapon systems and stockpile work. Chapter 3 focuses on the technical and political motivations behind nuclear force structure in terms of military requirements, design limitations, and legislative control. This dynamic not only controls how nuclear force structure will be shaped in the future, but also the ability of the US to balance the need for deterrence with the pressure for reductions.

The objective of this thesis is first to provide an overview of the US arsenal, and second, to analyze the main influences on force structure. Force structure analysis is important for two reasons. First, dedication to the proper engineering of nuclear warheads is imperative to the safety and security of the country. Second, the US sets a precedent in the international community in regard to nuclear weaponry and the efforts of nonproliferation. The motivation for writing this thesis

stems from the foundations of nuclear engineering in that nuclear weapons couple the most fundamental with the most complex principles of physics in the design of a nuclear system. Thus, a technical and political understanding of the current status and future directions in force structure policy is essential in the ability to motivate change.

II. CURRENT NUCLEAR FORCE AND INFRASTRUCTURE

1. OVERVIEW

In order to fully understand force structure, and likewise what precisely constitutes the US nuclear arsenal, this section aims to clarify certain key terms. One commonly used distinction in the description of nuclear weapons is the strategic versus nonstrategic classification. The US nuclear arsenal, summarized in Figure 4 (5), includes both weapons systems.

THE U.S. ARSENAL

TYPE/DESIGNATION	NO.	YEAR DEPLOYED	WARHEADS X YIELD (KILOTONS)	ACTIVE/SPARES
ICBMs				
LGM-30G MINUTEMAN III				
Mk-12	138	1970	1 W62 x 170	214/20
Mk-12A	250	1979	1-3 W78 x 335 (MIRV)	450/20
Mk-21/SERV	100	2006 (1986)	1 W87 x 300*	100/10
TOTAL	488			764/50
SLBMs**				
UGM-133ATRIDENT II D5				
Mk-4		1992	6 W76 x 100 (MIRV)	1,344/80
Mk-5		1990	6 W88 x 455 (MIRV)	364/20
TOTAL	288			1,728/100
BOMBERS				
B-52H Stratofortress	94/56***	1961	ALCM/W80-1 x 5-150	528/25
B-2 Spirit	21/16	1994	B61-7/-11, B83-1	555/25
TOTAL	115/72			1,083/50†
NONSTRATEGIC FORCES				
Tomahawk SLCM	325	1984	1 W80-0 x 5-150	100
B61-3, -4 bombs	n/a	1979	0.3-170	400
TOTAL	325			500
GRAND TOTAL				~4,075/200††

ACM: advanced cruise missile; ALCM: air-launched cruise missile; ICBM: intercontinental ballistic missile; MIRV: multiple independently targetable reentry vehicle; SLCM: sea-launched cruise missile; SLBM: submarine-launched ballistic missile.

* The W87 was previously deployed on the MX Peacekeeper, that last of which was deactivated in 2005.

** Two additional subs with 48 missiles are normally in overhaul and not available for deployment. Their 288 warheads are considered part of the responsive force of reserve warheads. Deployment of the W76-1/Mk-4A is scheduled to begin in March 2008.

***The first figure is the aircraft inventory, including those used for training, testing, and backup; the second is the primary mission aircraft inventory, the number of operational aircraft assigned for nuclear and/or conventional missions.

†The large pool of bombs and cruise missiles allows for multiple loading possibilities depending on the mission. We assume that half of the ALCM's have been withdrawn from operational status as a consequence of the Bush administration's 2007 stockpile decision. The ACM was retired in 2007.

†† Approximately 1,260 additional warheads are in reserve, and roughly 5,150 await dismantlement. Spares are not counted by the administration as operational warheads.

Figure 4: US Nuclear Arsenal [5]

The distinction between strategic and nonstrategic weapons is important, but not always clear cut. Range generally determines this difference, although the DOD

formally defines strategic missions versus nonstrategic nuclear forces as the following (6):

Strategic mission: A mission directed against one or more of a selected series of enemy targets with the purpose of progressive destruction and disintegration of the enemy's war making capacity and will to make war. Targets include key manufacturing systems, sources of raw material, critical material, stockpiles, power systems, transportation systems, communication facilities, and other such target systems. As opposed to tactical operations, strategic operations are designed to have a long-range rather than immediate effect on the enemy and its military forces.

Nonstrategic nuclear forces: Those nuclear-capable forces located in an operational area with a capability to employ nuclear weapons by land, sea, or air forces against opposing forces, supporting installations, or facilities. Such forces may be employed, when authorized by competent authority, to support operations that contribute to the accomplishment of the commander's mission within the theater of operations.

Based on these definitions, strategic weapons typically harness more energy and thus, destruction. Moreover, there are significantly less nonstrategic than strategic weapons. (7) As a result, most controversy and policy decisions about nuclear weapons in the US concern strategic, rather than nonstrategic, forces.

These terms classify the entire nuclear weapon system, which is roughly an explosive nuclear component within the delivery vehicle, such as a missile, that arms the jet, submarine, or other mode of military transportation. The nuclear material is referred to as the warhead, which is designated by a "W" or a "B" for bomb. (2) The specific types of warheads and bombs comprise the stockpile, which is tabulated in Figure 5 (8).

U.S. stockpile			
Type	Active	Inactive/Responsive	Total
WE2*	330	250	580
W78**	785	20	805
W76**	1,712	1,318	3,030
WE8	404	0	404
WE0-1**	1,450	361	1,811
B61-7	215	224	439
B61-11	20	21	41
B83-1/-3	320	306	626
WE0-U	100	194	294
B61-3**	200	186	386
B61-4**	200	204	404
B61-10	0	206	206
WE4*	0	383	383
WE7	0	553	553
Total	5,736	4,226	9,962

*Warhead type to be fully dismantled.
**Warhead type to be partially dismantled.

Figure 5: US Nuclear Stockpile [8]

The difference between a nuclear weapon and a nuclear warhead is attributed to the presence of a delivery system; the weapon includes the warhead and its associated delivery system. Whether the delivery system is long-range or short to medium - range categorizes the nuclear weapon as strategic and nonstrategic respectively.

2. STRATEGIC NUCLEAR WEAPONS

Strategic nuclear weapons, which deliver long-range capabilities, include intercontinental ballistic missiles, submarine-launched ballistic missiles, and heavy bombers. The three types of strategic nuclear weapons made up the former

“nuclear triad”. Currently, they constitute only one part of the “new triad”, shown in Figure 6, established by the 2004 Nuclear Posture Review.

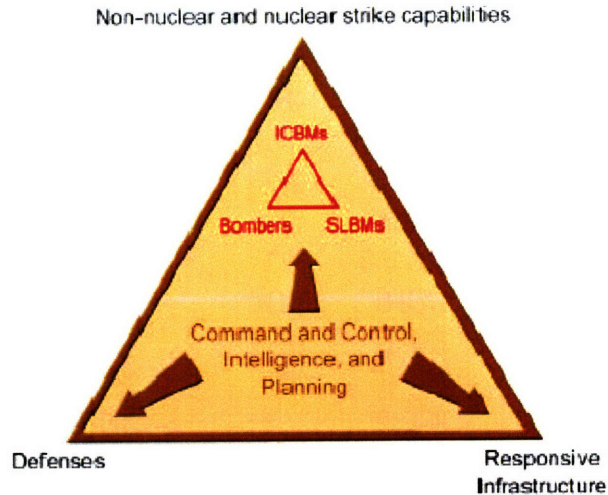


Figure 6: New Triad 2004 [9]

Prior to 2004, nuclear forces were arranged in the triad shown at the top of the pyramid, consisting of solely ICBMs, SLBMs, and bombers. The Bush administration attempted to decrease the emphasis on nuclear weapons by arranging them in concert with conventional weapons.

2.1 INTERCONTINENTAL BALLISTIC MISSILE (ICBM)

Historically, intercontinental ballistic missiles have had ranges between six and eight thousand miles. (2) The missile systems have evolved from the complicated Atlas system, of which only certain modifications were briefly deployed from 1960 to 1965, to the currently deployed Minuteman III missiles, as shown in Figure 7 (1):

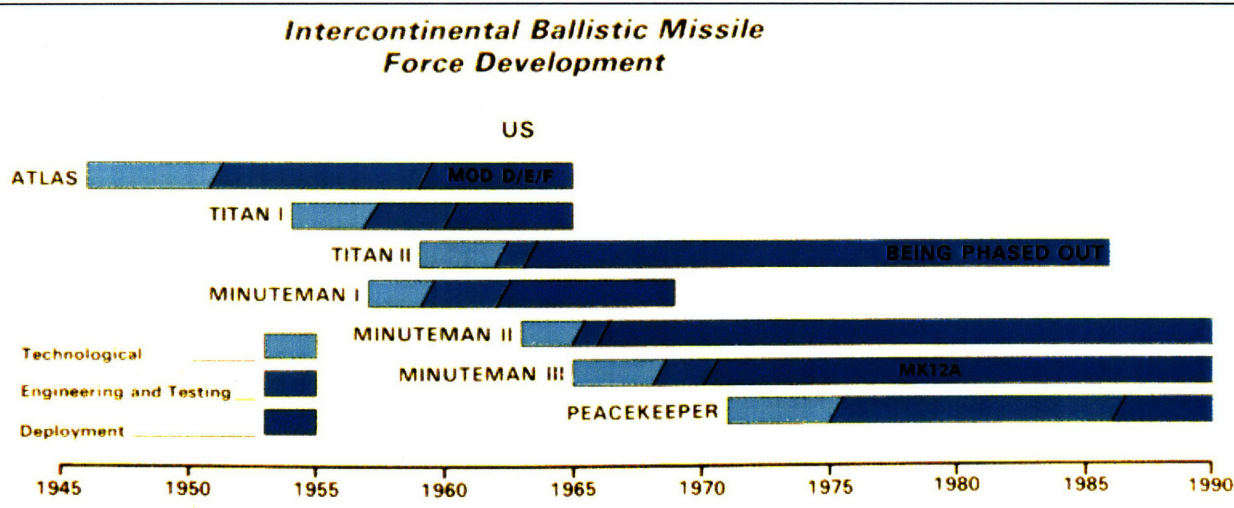


Figure 7: ICBM Force Development (1945-1990) [1]

Not shown in the figure above is the period between 1990 and 2008, during which time Congress funded \$14 million towards the retirement of the Peacekeeper missiles. (10) In general, ICBMs have three phases: boost, ballistic, and reentry. The first phase uses fuel to propel the missile out of the atmosphere at which point it enters the second phase, the ballistic trajectory towards the target. The reentry vehicle in the third phase allows the missile to reenter the atmosphere after which the nuclear warhead is able to be detonated.

The ICBMs in the current stockpile are Minuteman III missiles carrying the W62¹/Mk-12, W78/Mk-12A, and W87/Mk-21 warheads/reentry vehicles (Figure 4: US Nuclear Arsenal). The characteristics of each warhead, such as yield, weight, and numbers per missile are included below in Table 1 (2):

¹ According to Figure 4, the W62 warheads are to be fully dismantled.

Table 1: Characteristics of ICBM Warheads Currently

Warhead/RV	Yield (kilotons)	Weight (lbs.)	No. per RV
W62/Mk-12	170	700-800	2-3
W78/Mk-12A	335-350	<800	2-3
W87/Mk-21	300-475 ²	--	10-12

Since the end of the Cold War, reductions have been made, as shown by the retirement of the Peacekeepers and downsizing of the current arsenal. Today’s arsenal holds “approximately 764 [warheads] with a goal of 500 warheads on 450 missiles by the end of 2012.” (5)

2.2 SUBMARINE-LAUNCHED BALLISTIC MISSILE (SLBM)

With a range comparable to ICBMs, submarine-launched ballistic missiles make up “close to 38 percent of the operational nuclear arsenal.” (5) Preceded by the Polaris, Poseidon, and Trident I as shown in Figure 7, today’s current SLBM force consists of Trident III/D-5 missiles carrying two types of warheads, the W76 and W88.

² The yield is increased to 475 kilotons through an additional sleeve of enriched U-235. (2; 18)

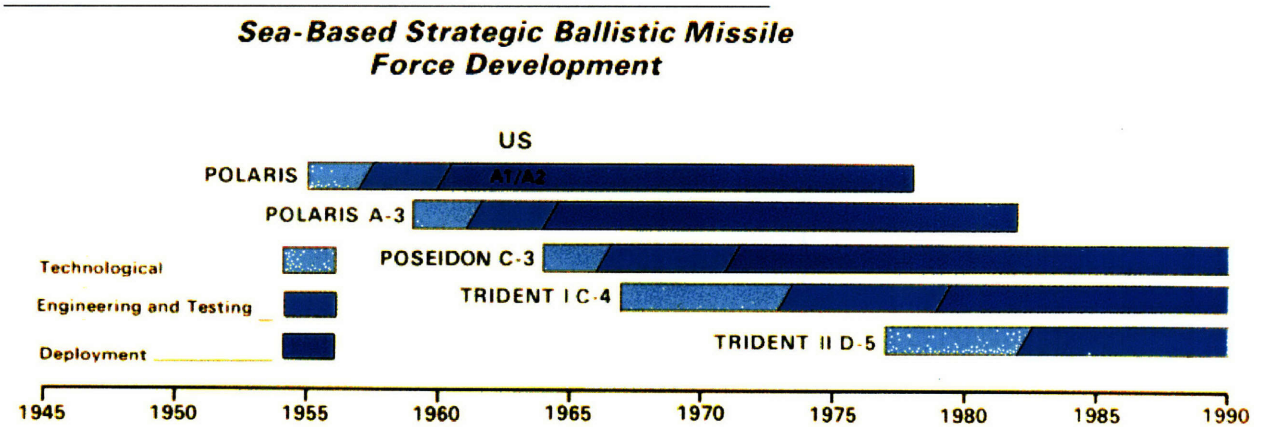


Figure 8: SLBM Force Development (1955-1990) [1]

Table 2 outlines characteristics of the two warheads: the W76/Mk-4 and the W88/Mk-5.

Table 2: Characteristics of SLBM Warheads

Warhead/RV	Yield (kilotons)	Weight (lbs.)	No. per missile
W76/Mk-4	90-100	363	8
W88/Mk-5	475	<800	8-10

SLBMs patrol both US coasts, playing the primary deterrent role. Their locations depend on targeting policy. Recently, balance has shifted to the Pacific due to the increased targeting in places such as China, and decreased attention on Russia. With this purpose in mind, there is a substantial dependence on these particular warheads. Unfortunately, technical experts have publicly raised concerns for each type.

The W76, a 30-year old weapon, has generated an impetus for nuclear scientists to refurbish or replace it completely. Among its various weaknesses, its thin uranium casing is prone to hydrodynamic, or more specifically Raleigh-Taylor, instabilities, in which a lighter density fluid flows into a higher density fluid at a constant rate. (11) The resulting ripple effect has the potential to prevent intended detonation of the lithium-6 deuteride fuel. (12) While this problem is highly debated within the scientific community, the age of the weapon is assumed to decrease reliability and safety.

The newer W88 entered the stockpile with concerns already present. One such concern pinpoints a lack of safety features. First, the high explosive (HE) used as opposed to the insensitive high explosive (IHE) does not account for accidental detonation. Second, the W88 contains a non-fire resistant pit. A probabilistic risk assessment proves that a fire resistant pit is a necessary measure to protect against “the accident scenarios...in which nuclear weapons are involved in a hydrocarbon fuel fire of such intensity and duration as to breach the pit and thereby disperse the plutonium due to combustion followed by the entrainment of the plutonium oxide particles into the fire plume.” (13) This called for a pit production capability in order to replace the existing pits. A new W88 was developed by Los Alamos National Laboratory and approved by NNSA in June 2007. (14)

2.3 STRATEGIC BOMBS

Strategic bombs are employed on aircraft that have long-range capabilities, in parallel the strategic force criteria. Two aircraft, the B-2A Spirit and B-52H

Stratofortress, carry the B61-7, B61-11, and B83. The delivery system of the W80 is either the advanced cruise missile (ACM) or air-launched cruise missile (ALCM), which arm the B52.

Table 3: Characteristics of Strategic Bombs

Bomb	Yield (kilotons)	Weight (lbs.)
B61-7,11	10-350	695-716
B83	Up to 1200	2400
W80-1,3	Up to 150	290

Table 3, as shown above, provides the characteristics of each weapon. The B61-7 is an upgrade from the Mod 1 and is sometimes referred to as the “dial-a-yield” weapon for its multiple yield choices. The B61-11, the “bunker-buster” is an upgrade of the B61-7 due to its ability to penetrate 3-6 meters underground. The B83 has the advantage of a very large yield, which corresponds to a large weight of 2400 pounds. Its advantage is the ability to deliver the weapon at high speeds and low altitudes. (15)

3. NONSTRATEGIC NUCLEAR WEAPONS

Nonstrategic nuclear weapons, which include certain modifications of the B61 bomber and W80 warhead, represent only a small portion of the nuclear arsenal. Their characteristics are outlined in Table 4:

Table 4: Nonstrategic Nuclear Weapons

Bomb	Yield (kilotons)	Weight (lbs.)
B61-3,4,10	10-350	695-716
W80-0	290	5; 170-200

In addition to their short-range capabilities, nonstrategic weapons are generally smaller and lighter in weight than their strategic counterparts. As a result, their use is limited to operations in the battlefield, hence the alternative name of a tactical nuclear weapon.

3.1 *SEA-LAUNCHED CRUISE MISSILE*

The W80-0 warhead is carried by a BGM-109A-I missile on a Tomahawk Land Attack Missile-Nuclear (TLAM-N) weapon system. This weapon system is aboard a submarine or an airplane. Figure 9 this warhead:



Figure 9: W80-0 Warhead [16]

3.2 *NONSTRATEGIC BOMBS*

Nonstrategic bombs consist of Mod 3, Mod 4, and Mod 10 within the B61 class of bombs. They all have variable yield options, and can be carried aboard aircraft such as F15, F16, and F18s. (1) A dismantled B61 bomb is shown below in Figure 10:

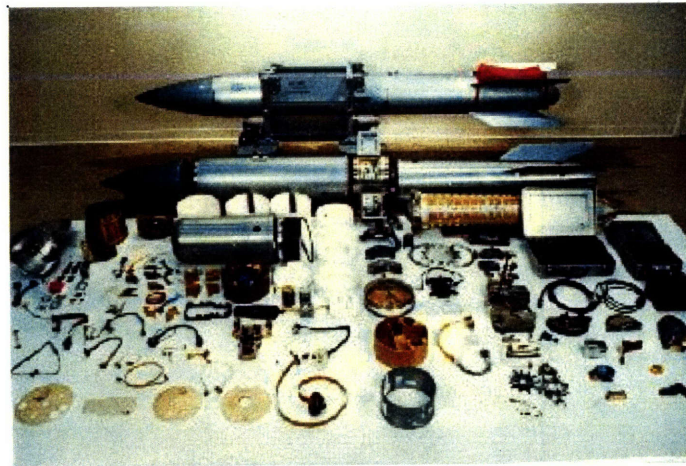


Figure 10: A Dismantled B61 [17]

4. INFRASTRUCTURE

4.1 *DOMESTIC*

The nuclear weapons complex describes the eight locations where experiments on nonnuclear components and analysis of inactive or reserve warheads are conducted. The operational warheads are on bases associated with either the Air Force or Navy. The Air Force is in control of approximately 62% of the operational warheads. (18) The civilian locations and military bases are shown in Figure 11:

Locations of U.S. nuclear weapons, 2006

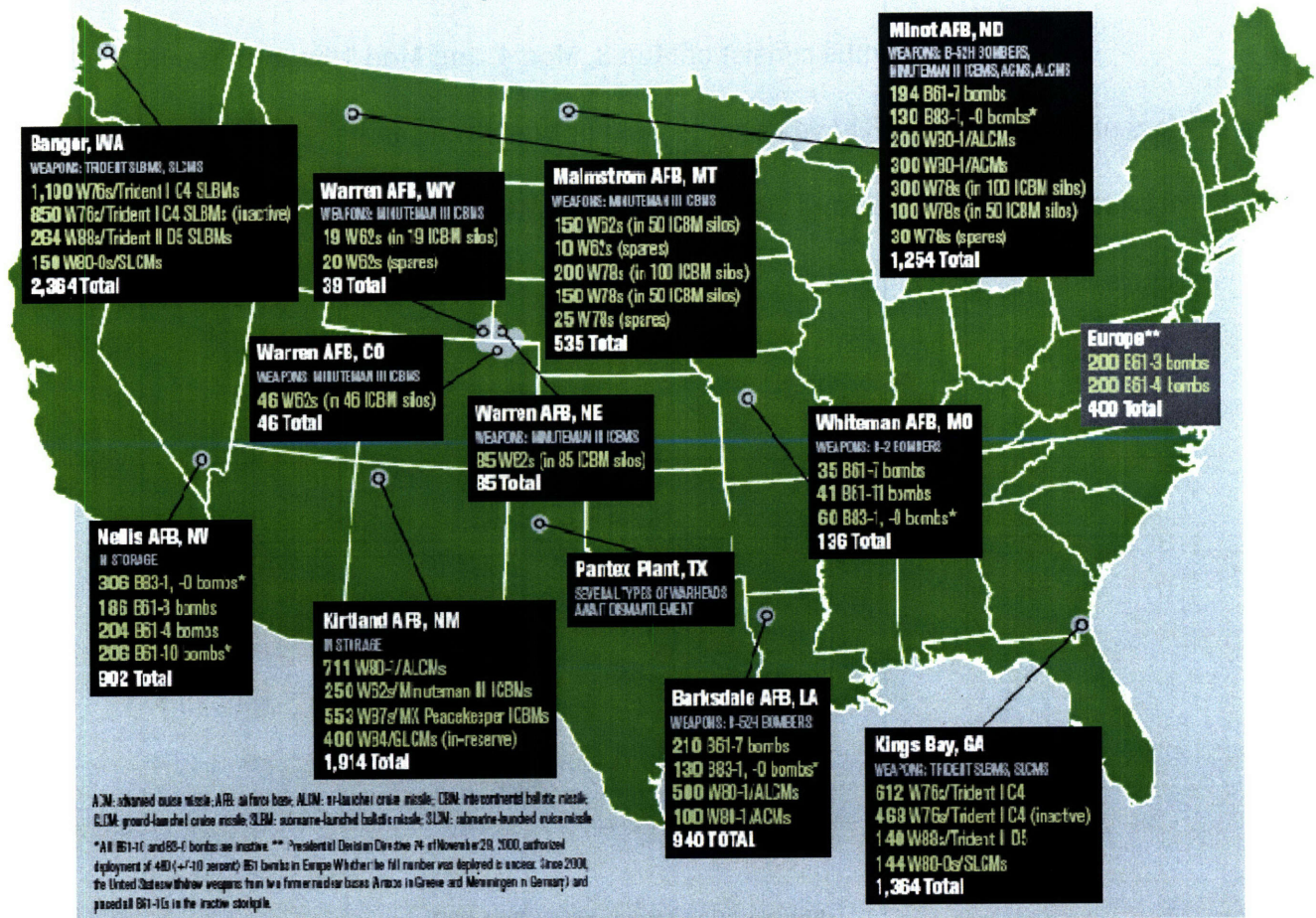


Figure 11: Locations of US nuclear weapons, 2006 [18]

Two naval bases on either coast, one in Bangor, WA and the other in Kings Bay, GA, are the locations of the SLBM force. Due to increased targeting against countries such as China, the Pacific coast base now holds about 2,364 warheads while that of the Atlantic has 1,364. All 3,728 warheads are split between 14 Trident III submarines in total. The Minot Air Force Base in North Dakota has the largest number of active weapons, with over 800 bombers and cruise missiles and 400 Minuteman III missiles. (18) The civilian location with nuclear weapons is the Pantex Plant in Amarillo, TX. Civilian locations without whole nuclear weapons

include: Y-12 National Security Complex in Oak Ridge, TN; Kansas City Plant in Kansas City, MO; Savannah River Site in Aiken, SC; Sandia National Laboratories in Albuquerque, NM, Livermore, CA, Kauai, HI, and Tonopah, NV; Lawrence Livermore National Laboratory in Livermore, CA; Los Alamos National Laboratory in Los Alamos, NM; and the Nevada Test Site in Las Vegas, NV. Two underground sites hold about 2,800 weapons that are mostly inactive. One site in New Mexico has about 1,900 in close proximity to the Pantex Plant. The other is in Nevada and holds about 900 warheads. (18)

4.2 INTERNATIONAL

Although the actual number of nuclear weapons stored both in the US and internationally remains classified, estimates based on a robust gathering of information assert that a few hundred nonstrategic bombers, such as the B61-3 and B61-4, are held in six European countries. (18) These six countries include: Belgium, Germany, Italy, the Netherlands, Turkey, and Britain. (5)

III. FUTURE DIRECTIONS IN NUCLEAR WEAPONS FORCE STRUCTURE POLICY

1. DETERRENCE & REDUCTIONS

In the post-Cold War era, there have been two dominant themes in nuclear weapons policy. The first theme is reduction—both domestic and international. The second is based on the theory of nuclear deterrence, which “can be defined as the threat of using nuclear weapons to prevent the enemy from attacking vital

interests.” (4) Deterrence is categorized as either minimum or maximum, and in terms of force structure, reflects a corresponding small or large number of nuclear weapons respectively. Moreover, minimum deterrence maintains a clear distinction between nuclear and convention weapons while maximum deterrence does not. In an atmosphere that expresses a global interest in nuclear weapons reductions due to proliferation threats by “non-nuclear” states, follows a shift towards minimum deterrence.

The themes of deterrence and reductions are apparent in the various areas of nuclear weapons policy: declaratory, force structure, operational, nonproliferation, etc. Three main bodies, the US military—mainly the Navy and Air Force, the technical experts at national laboratories, and Congress are responsible for developing and enacting these policies. Thus, the policies that currently control nuclear force structure and its resulting effect on nonproliferation efforts are largely dependent on the dynamic between these three bodies, and how they can work together to achieve a balance between national security interests and minimum deterrence.

2. DETERMINANTS OF FORCE STRUCTURE POLICY

As mentioned in section 1.2, force structure policy describes the political decisions and consequent actions that determine the specific content, size, and location of the US nuclear arsenal. The current and future status of nuclear weapons depend on three key players that make, change, and implement force structure policy. A thorough analysis of the multifaceted roles of the entities in this complex

interaction reveals that each entity imposes limitations on the others. In an effort to simplify the dynamic, the military and technical experts can be assumed to work more or less together as a representative of the executive. In accordance with the US system of checks and balances, their decisions are offset by those of the legislative, or Congress. Ultimately, this results in a generally stagnant dynamic, in which changes to the force structure are best characterized as delayed if not completely inhibited.

2.1 THE MILITARY

Embedded in the organizational structure of the Department of Defense, the US military derives its role in nuclear force structure from national defense principles, strategic policies, and combative goals. The strategy specific to weapon of mass destruction “will focus military planning, posture, operations, and capabilities...on the active, forward and layered defense of our nation, our allies, partners and interests...with an emphasis on defeating threats as far from the United States as possible.” (19) In accordance with this ideology, the military’s Armed Forces, namely the Air Force (USAF) and Navy (USN), and the Commander of the US Strategic Command (USSTRATCOM) continue to concentrate on nuclear weapons as one layer of defense.

Although in-depth targeting and employment policy are beyond the scope of this paper, the assumption is for the military to maintain confidence in an updated and safe nuclear arsenal. Thus, the military’s active role, in addition to the

collaboration with the technical experts and responsiveness to Congress, is in large part responsible for the current stockpile and its future evolution.

The parts of the military in charge of nuclear weapons are the USAF, USN, and Commander of the US Strategic Command (USSTRATCOM) and in conjunction with various parts of the Department of Energy (DOE). They shape nuclear force structure by placing physical constraints on weapon designs and abilities in order to carry out effectively, safely, and hypothetically hit a specified target. For example, one determinant for a certain weapon type in the stockpile is the available delivery system.

The Navy and Air Force set technical parameters for all of the weapons in the nuclear arsenal through two sets of 'operational specifications': military characteristics (MCs) and stockpile-to-target sequences (STS). (Aloise, Gene letter) Following the theme of deterrence, their purpose is to ensure the success of a military effort using nuclear weapons. The MCs "[are] characteristics of a specific nuclear weapon upon which its ability to perform desired military functions...describe required weapons yield and fuzing options; weapons operational, physical, functional, environmental, vulnerability, safety, and reliability parameters; describe maintenance, monitoring, storage, and handling considerations; and set forth the priority of design compliance in the event of conflicting design requirements." (20) In short, MCs are the characteristics inherent in the design of the warhead. The stockpile-to-target sequence outlines "logistical and employment concepts and related physical environments, including

vulnerability criteria, involved in the delivery of a nuclear weapon from the stockpile to the target...[and] the logistical 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.” (20) Whereas the MCs are characteristics inherent in the design of the warhead, the stockpile-to-target sequence requires the ability of the warhead to move through different environments and conditions. Together, the MCs and STS documents provide criteria for the design and preservation of nuclear weapons.

As its name implies, USSTRATCOM is responsible for US strategic weapons. The commander works directly with and on the same level as the technical experts in analyzing the development of new weapons in addition to reviewing the old ones. Specifically, he evaluates weapon types, highlights compensatory measures if necessary, and admits to any missing or insufficient information. (21) This adds a necessary military perspective to reports that go through the Secretaries of Defense and Energy, on to the President and ultimately submitted to Congress.

In general, the military focuses on four main aspects of nuclear weapons before all other design details. The first is yield. Yield is defined as a “measure of the amount of explosive energy it can produce.” (22) Its unit is in kilotons, which is equivalent to 1,000 tons of TNT. During the Cold War, nuclear competition resulted in the demand for high yield capabilities for both deterrent purposes and in the case of an attack. However, analogous to the changing nature of deterrence in the 21st century is the changing nature of yield to below 5kT. Although disregarded in the

FY2004 Congressional budget decision, a low-yield, earth penetrating weapon captured military interest due to its ability to destroy biological and buried sites reducing the otherwise collateral damage. (23) However, the current weapon systems, developed before or during the Cold War, still reflect the defense requirement for increased yield.

The second is compatibility with delivery vehicle. As mentioned previously, many of the specifications developed by the Navy and Air Force result from the specific delivery systems of the weapons. One major effect on weapons development resulted from the shift from internal to external transport of the weapon underneath a wing of modern aircraft, thereby escalating the necessity of reduced weight. Another example involves the B61 family of bombs. Beginning in 1960, the Air Force disclosed a need for a more versatile weapon that could be dropped at high and low altitudes while delivering a range of yields. (2)

The third is design safety. A weapon most noted for its safety features is the W80-0. Electronic components are armored such that critically high temperatures automatically activate response systems. It also contains both a strong and weak link in the coding device which prevents unauthorized detonation. Additionally, the missile is stored within an exterior audio-visual detection system on the ship. (16)

The fourth is reliability, or in other words, a confidence in their ability to hit the target. The importance of a successful military mission with respect to nuclear weapons is a national security issue. If a weapon were to fall and fail to detonate, it could be dismantled, used, and studied for use against the US. For this reason, the

weapon must be able to withstand extreme conditions or obstacles. Hypothetically, suppose the target is the Iran nuclear facility in Natanz. Satellite imagery in Figure 12 shows that this target and enrichment facility has undergone progressive burial.

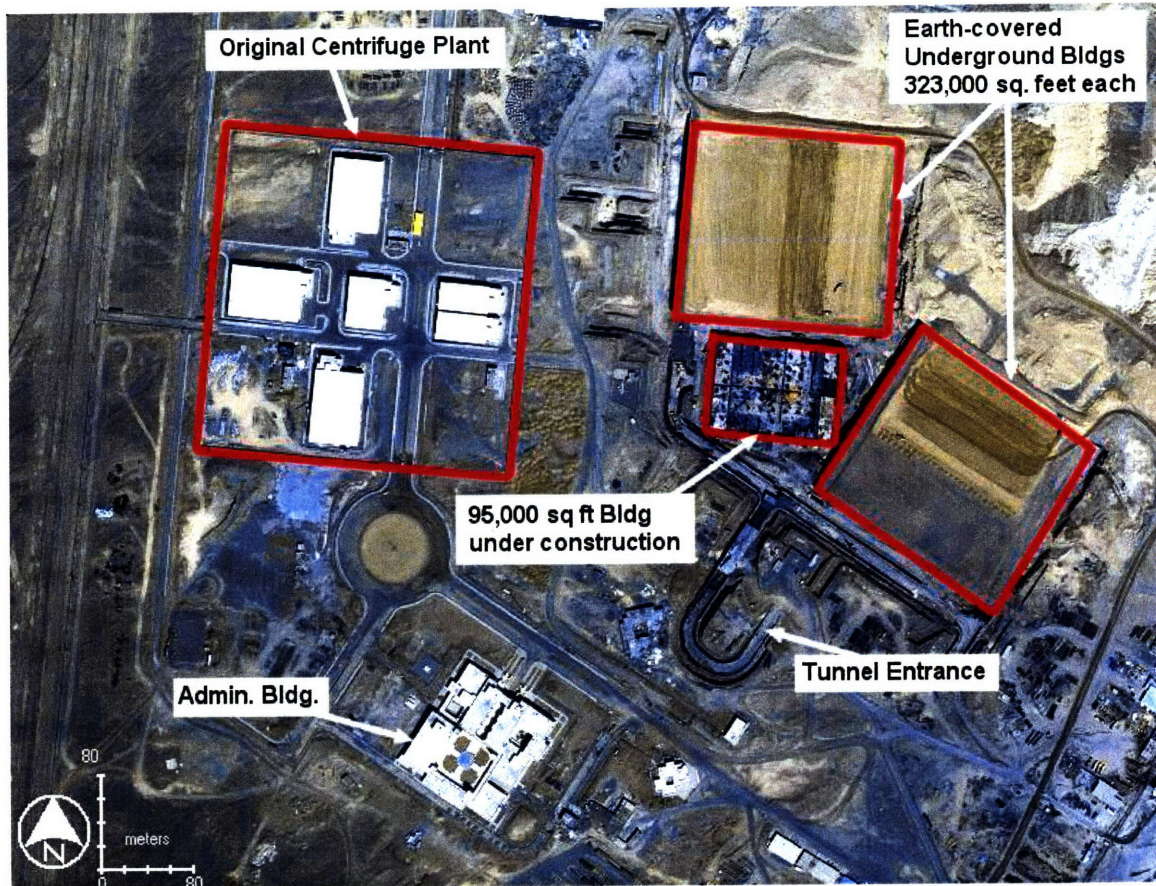


Figure 12: Progressive Burial of the Nuclear Facility in Natanz, Iran [11]

Thus, the nuclear weapon must be able to penetrate thousands of feet of rock and solid ground. This example substantiates the necessity for the B61-11 weapon system. Commonly referred to as the “bunker buster”, its upgraded delivery system from the Mod 7 allows this warhead to detonate underground.

Currently, the military is engaged in nuclear weapons reductions, following the post-Cold War policy trend. In order to do this, however, Congress required the

military to explain the logic behind specific reductions. (10) As opposed to the design and maintenance requirements placed on the technical experts, the military must also respond to decisions by Congress and guidelines put forth by international treaties. Congress mainly limits the military programs to modernize and equip their missiles and defense systems through budgetary action. This requires a dialogue between the two entities in which Congress receives updates and reasoning for current programs.

2.2 TECHNICAL EXPERTS

Technical experts refer to those scientists and engineers that design, construct, and assess current nuclear weapons. Formally part of the executive branch of government, three laboratories are run by the National Nuclear Security Administration (NNSA), within the organizational structure of the Department of Energy. The NNSA aims to “assure the safety, security, and reliability of the US nuclear weapons stockpile while at the same time considering options for transforming the stockpile and the complex infrastructure that supports it.” (24) Of the three national laboratories, two conduct research and development on the nuclear warheads specifically, Lawrence Livermore and Los Alamos. The third, Sandia National Laboratory, is responsible for the nonnuclear weapon components. Additionally, the Pantex Plant actively supports the laboratories through “fabrication of chemical explosives...assembly, disassembly, testing, quality assurance, repair, retirement, and final disposition.” (9)

Technical experts at these civilian nuclear weapons facilities primarily affect force structure through the Stockpile Stewardship Program as mandated by the 1994 National Defense Authorization Act (Public Law 103-160). Most of the literature on this program undoubtedly quotes the current status of US nuclear weapons as “safe, secure, and reliable”. However, this assurance precedes a major concern within the scientific community—the aging nuclear stockpile. Addressing this concern, the technical experts have consequently embedded themselves, the military, and Congress in the debate over renewal or replacement of current weapon systems. In an effort to make these changes, assumed to be necessary to the US nuclear force structure, they have devised two main goals to protect not the present, but the future, reliability and safety of nuclear weapons. These goals are the Reliable Replacement Warhead and Complex 2030. (24) In doing so, the technical experts have encountered impediments that are physical, political, and fiscal in nature, due to the relationships with the military, other labs, and Congress.

First and foremost, the designs of nuclear weapons reflect the ability of the military to operationalize missions to safely and effectively hit specific targets. In other words, the military-imposed operational constraints discussed in the previous section, such as aerodynamic and safety properties must coincide with the engineering of the nuclear, electrical, and mechanical components. Thus, the relationship between the military and technical experts is best described as a partnership between the DOD and DOE. As an illustration, the military objective to maintain high yield with a simultaneous decrease in weight has resulted in the use of implosion and boosting principles. In the former, the fissile material is

compressed such that the heavy metals (uranium or plutonium) effectively liquefy under extreme pressures. This compression results in a supercritical mass, which is more efficient than a larger mass, which has more surface area from which neutrons are lost by escape rather than by fission. This effect is shown below in Figure 13.

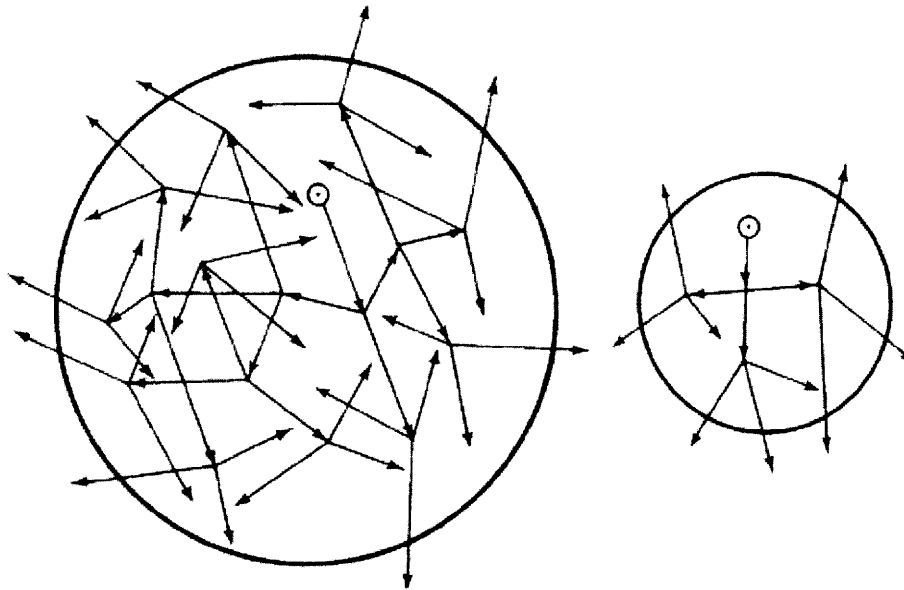


Figure 13: “Effect of increased mass of fissionable material in reducing the proportion of neutrons lost by escape” [22]

Analogous to principles in nuclear reactor theory, efficiency is lessened because loss of neutrons by escape decreases the percentage of nuclear material that undergoes fission.

The effect of the incorporation of military engagement with technical expertise highlights three methodological design and maintenance criteria: performance, reliability, and safety. Quantification of Margins and Uncertainties (QMU) provides a measure of performance by relating margins, uncertainties, and confidence. LANL and LLNL, responsible for the formalization of this method, define margins, uncertainties, and confidence as follows: (25)

“Margin is the amount by which the design parameter exceeds that [value required for a warhead to operate as indicated]—the excess performance built into the design...Uncertainty results from imprecise knowledge of design parameters and of the minimum value required to ensure performance....Confidence is the ratio of margin to uncertainty: if margin is high and uncertainties low, confidence is high; if both are high, confidence is low. Having margins greater than uncertainties provides confidence against potential failure modes.”

Reliability, as defined by SNL, reflects the probability of surviving different environments to reach a target. Formally, it is “the probability of achieving the specified yield, at the target, across the Stockpile-to-Target Sequence of environments, throughout the weapon’s lifetime, assuming proper inputs.” The third criterion refers to safety features preventing unwanted or uncontrollable detonation. Thus, the technical experts routinely test the weapons to ensure they are safe for military handling and storage as well as reliable for military use. As such, the collaboration between the DOD and DOE is a continuous process, for most of these safety parameters and design features, such as the yield-to-weight ratios, need to be maintained.

Currently, the main physical limitation to weapons’ assessments is the inability to conduct nuclear tests as mandated by various congressionally supported (although not necessarily ratified) arms control agreements, such as the Limited Test Ban Treaty (LTBT) in 1967 and the Comprehensive Test Ban Treaty (CTBT). In this way, foreign policy imposes a legislative constraint on technical analysis and predictability of the current and future stockpiles. Consequently, the nuclear test ban affects force structure, for in order to predict the reliability and safety of each weapon and its components, testing is done via computer simulations and

experiments. The modeling of specific aspects of the warheads and weapon systems serves to enlighten the scientists, engineers, and technicians of the complex physical processes that accompany nuclear explosions. However, due to the nature of, and inherent error associated with, experiments and simulations, the true complexity of the implosion must be broken into singular physical processes.

Although experimental methods and simulations allow for close inspection into the various electrical, mechanical, material, and nuclear components affected by aging and weapon detonation, these methods are also the only means by which technical experts can feasibly develop new parts or warheads. While assurance from the data proved sufficient for the building of new plutonium pits for the W88, they have not been deemed adequate for the development of a new warhead, as proposed by the Reliable Replacement Warhead. The latter program, in which a new warhead was designed for Minuteman III, introduces the financial dependency of the technical experts on Congress for program funding.

The NNSA receives appropriations as a part of the defense and energy budget for “weapons activities”. In FY2008, Congress appropriated a total of \$6.3 million, \$1.4 million of which is concentrated on the technical experts’ role in physical force and infrastructure, otherwise known as “directed stockpile work.” The NNSA, as the direct recipient of these funds, has requested increases in directed stockpile work from \$1.68 million in FY2009 to \$1.78 million in 2013. These funds are distributed as shown in Figure 14:

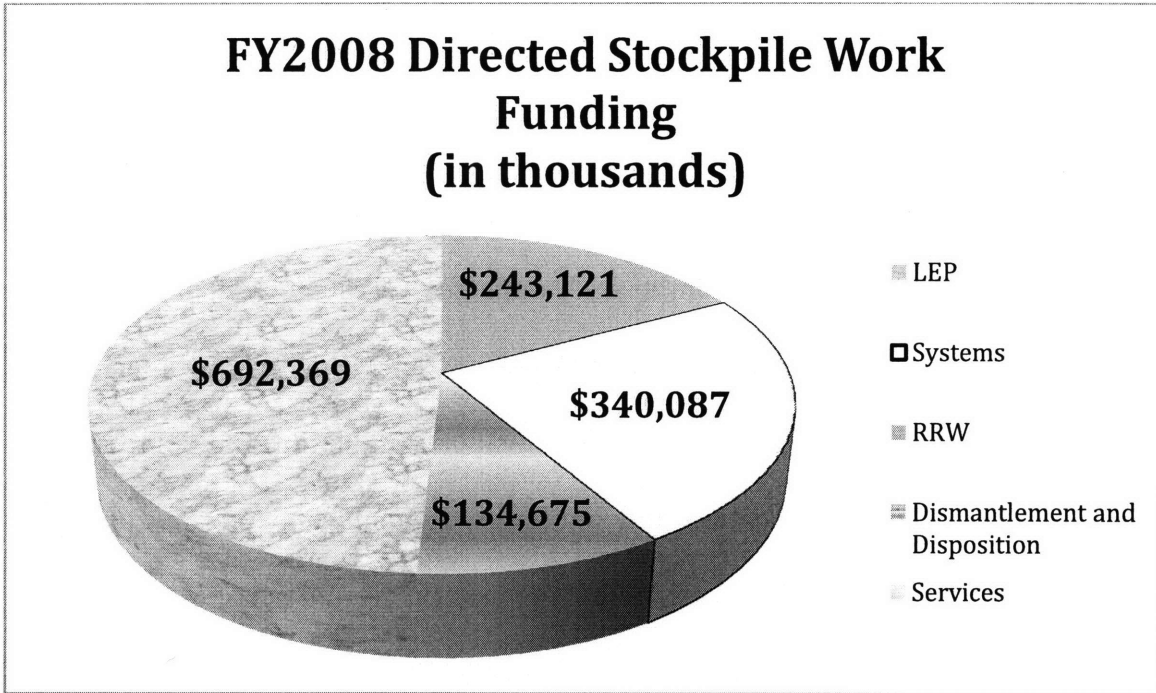


Figure 14: FY2008 Directed Stockpile Work Funding

The life extension program (LEP), which accounts for about 17% of total funding for directed stockpile work, involves replacing parts in the B61, W76, and W80.

Funding for category “systems” refers to the activities such as assessments, replacements, and outputs of work done on all of the following stockpile systems: B61, W62, W78, W80, B83, W87, and W88. These activities require approximately 24% of the \$1.4 million. The Reliable Replacement Warhead (RRW) receives 0% of the funding. Dismantlement and disposition activities describe the actions by both the military and civilian workers at the Pantex Plant to make reductions in the number of weapons in the arsenal. Ironically, despite the major theme of reductions in nuclear weapons policy, this is the smallest category, receiving merely 9.6%. At the other extreme, the largest section, or 49% of total weapons funding, is

categorized as “services”. This pertains to R&D, production, infrastructure, and pit production.

The funding for “weapons activities” also includes that for experiments and simulations, represented by four of the six “campaigns” as categorized in the FY2009 budget request. These campaigns include: Science, Engineering, Inertial Confinement Fusion Ignition and High Yield, Advanced Simulation and Computing, Pit Manufacturing and Certification, and Readiness. Focusing only on conceptual and experimental scientific methods, the Pit Manufacturing and Certification Campaign and Readiness Campaign are not relevant. Each of the remaining four campaigns focuses on different aspects of a theoretical nuclear explosion, receiving a total of \$1.4 million in government funding. The breakdown of this funding is illustrated in Figure 15:

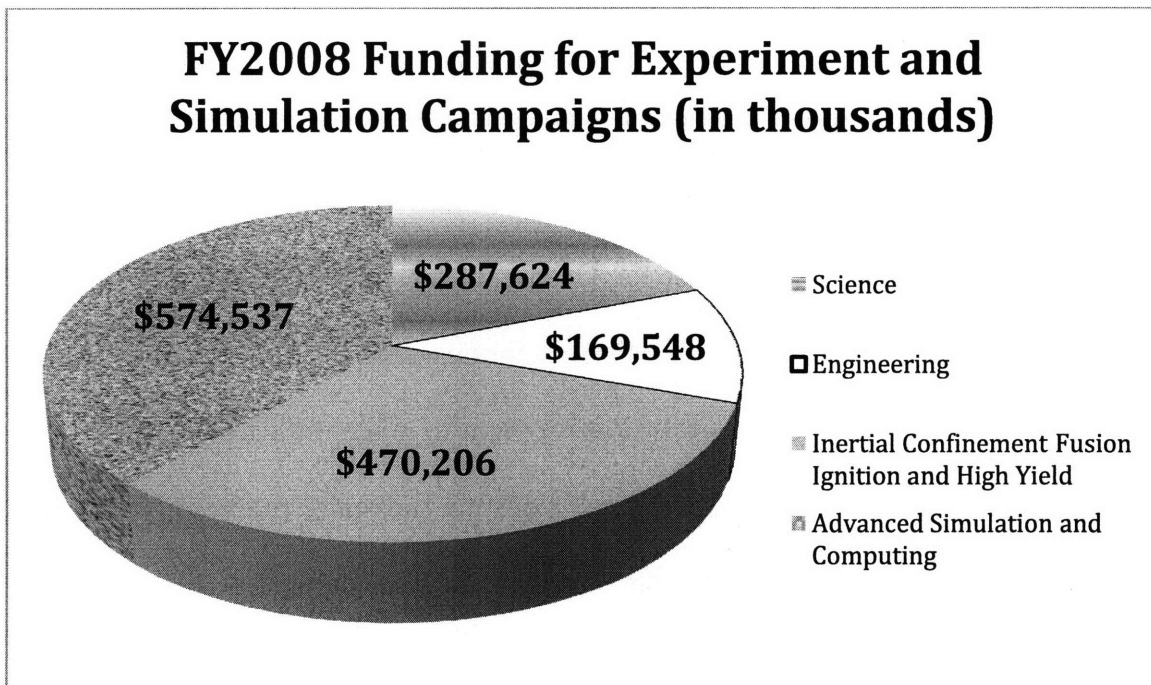


Figure 15: FY2008 Funding for Experiment and Simulation Campaigns

In regard to the weapon system itself, the Science Campaign studies the nuclear components while the Engineering Campaign investigates the engineering of the nonnuclear and nuclear parts. Taking into account external effects, the Inertial Confinement Fusion Ignition and High Yield Campaign induces realistic temperature, pressure, and radiation conditions. Lastly, these experiments supercomputers motivate these experiments in the Advanced Simulation and Computing Campaign. Table 5 outlines the title of each division listed under their respective campaigns as appears in the FY2009 budget request.

Table 5: Activities within each Experiment and Simulation Campaign

<i>Science</i>	Advanced Certification Primary Assessment Technologies Dynamic Plutonium Experiments Dynamic Materials Properties Advanced Radiography Secondary Assessment Technologies Test Readiness
<i>Engineering</i>	Enhanced Surety Weapons Systems Engineering Assessment Technology Nuclear Survivability Enhanced Surveillance Microsystems and Engineering Sciences Applications Ion Beam Laboratory Refurbishment Construction
<i>Inertial Confinement Fusion Ignition and High Yield</i>	Ignition Support of Other Stockpile Programs NIF Diagnostics, Cryogenics, and Experimental Support Pulsed Power Inertial Confinement Fusion University Grants/Other ICF Support Joint Program in High Energy Density Laboratory

<i>Advanced Simulation and Computing</i>	Plasmas
	Facility Operations and Target Productions
	Inertial Fusion Technology
	NIF Assembly and Installation Program
	High-Energy Petawatt Laser Development
	96-D-111, National Ignition Facility
	Integrated Codes
	Physics and Engineering Models
	Verification and Validation
	Computational Systems and Software Environment
Facility Operations and User Support	

In regard to the RRW program, the congressional decision to eliminate funding for the 2008 fiscal year was in large part due to this diversification of function shown in Table 5. Due to the lack of technical expertise in Congress, decisions are made based on the reports and testimonies of various experts and leaders. The JASON report indicated a strong hesitation for implementing the RRW for two overwhelming reasons: better correlation between experiments and simulations in the absence of nuclear testing and peer scientific reviews. (26) A lack of consensus in the scientific community increases the probability of congressional debate and in effect, produces decreased or no funding. So, in spite of their overwhelming dependence on federal funding, the technical experts also affect their own goals by their ability to effectively present steadfast reasoning to legislators. Note that after the assurance of the design to abide by the critical military characteristics, the military's role is reduced in the remainder of this decision-making process.

2.3 CONGRESS

Unlike the military and the technical experts, Congress, a legislative part of government, has considerable control over the political and financial decisions regarding US nuclear weapons. Congress receives information and proposals from the military and technical experts in order to make decisions that are enforced through budgetary action. Legislators play a multifaceted role due to their motivations to protect the best interest of the US, to remain responsible to their constituency, and to make decisions that allow the US to remain a global leader and peacemaker.

Many of the ways in which Congress holds control over nuclear weapons policy have been addressed in previous sections. Both the military and technical experts both submit testimony and reports in front of the House and Senate committees and subcommittees. Congress also funds weapons programs, activities, and research. In addition to these functions, the role of Congress is also explained by pure politics. When control of both the House and the Senate went to the Democrats, who are traditionally anti-arms, the funding for the reliable replacement warhead disappeared.

Moreover, the main purpose of deterrence as an ability to induce large-scale societal fear suggests a reason behind a strong anti-nuclear sentiment in the US amidst a period of proliferation and increased national security threats. A February 20, 2007 poll conducted by the Democracy Corps indicated that 82% of

questioned people in the US feel that more governmental action should be taken to increase national security over the next decade. An argument could be made that deterrence is an effective security measure. However, others argue that it is not really that effective since there was still a catastrophic terrorist attack on 9/11. They further argue that it promotes the spread of nuclear weapons. Whether or not deterrence is an effective measure as perceived by the people reflects their attitude toward ownership of nuclear weapons. Another recent poll by Ipsos-Public Affairs indicates that 66% of another thousand people believe that no country, including the US, should have any nuclear weapons. In a system where all Congressional votes are public and legislators are elected by popular votes, public sentiment is one way they ascertain what determines the outcome of elections.

IV. CONCLUSION: THE EFFECT ON NONPROLIFERATION

Nuclear proliferation has been a concern since the end of the Cold War, especially as Russian and the U.S. began to dismantle thousands of weapons. 9/11, which served in part as an awakening to the reality of terrorist threats, brought this concern to the forefront of national security. Thus, nonproliferation is extensively studied and has developed into a separate policy area. While countless factors contribute to the complexities and problems associated with preventing the spread of nuclear weapons, force structure policy is one factor that determines the U.S. role in nonproliferation and resulting international reactions to this role. Without the trend towards reductions in nuclear policy, US efforts at nonproliferation are

effectively diminished in the international community. Proving to be a sort of domino effect, the creation of new warheads simultaneously counteracts nonproliferation efforts by the US, and consequently, nonproliferation efforts worldwide.

Despite efforts to cease nuclear proliferation, a counter-argument insists on the maintenance of the current stockpile in the effort to secure the country against attacks of biological, chemical, or nuclear weapons of mass destruction. Technical experts argue that the current nuclear arsenal is potentially weakened by the effects of aging. This has resulted in programs to improve current weapons, through production of new plutonium pits and the life extension programs, as well as incentives to replace weapons entirely through the reliable replacement warhead program. Working together with the DOD, the military supports any measure that increases reliability and safety in handling the current weapons. However, the scientific community argues over the absolute need for new weapons. This hesitation is backed by Congress, who responding to a generally anti-nuclear weapon American public and a proliferating international community, has halted funding for the reliable replacement warhead program. The stagnancy of US nuclear weapons policy is due to the controversy stemming from upholding deterrence for national security versus meeting the global expectation for nuclear arms reductions. The relationship between the three governmental groups in control of this policy area contributes to the controversy, and in turn, to the prevention of any significant changes to the current nuclear arsenal.

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