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Accomplishing the mission of National Missile Defense with current technology

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ACCOMPLISHING THE MISSION OF NATIONAL MISSILE DEFENSE WITH CURRENT TECHNOLOGY

by

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The Purpose of this thesis is to evaluate the Ballistic Missile Defense Organization's proposals for a National Missile Defense (NMD). This thesis compares the costs of missile systems that will provide a NMD, such as Patriot Advanced Capability - 3 (PAC-3), Navy Area (SM-2 Block IVA), Theater High Altitude Area Defense (THAAD), Navy Theater-Wide (SM-3), and the Ground-Based Interceptor (GBI). The data gathered for this thesis included unclassified performance data and the gross cost data relevant to the above systems. Interviews were conducted with personnel that are expert in US Navy SPY radar and Aegis combat systems, and have knowledge of SM-2 Block IVA and SM-3 missile systems.

This thesis concludes that there is redundancy in the development paths to creating a single, centrally located Ground-Based Interceptor and radar (GBI/GBR) site. By eliminating or amending the 1972 ABM Treaty to allow a multi-site NMD, a Coastal NMD could be constructed in the near future, using technology that is available today and missiles that will be placed on ships starting in 2002. As development of SM-3 and THAAD missile technology continues, these systems could be used to implement a multi-site NMD far sooner than a GBI could.

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ACCOMPLISHING THE MISSION OF NATIONAL MISSILE DEFENSE WITH CURRENT TECHNOLOGY

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March 2000

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The Purpose of this thesis is to evaluate the Ballistic Missile Defense Organization's proposals for a National Missile Defense (NMD). This thesis compares the costs of missile systems that will provide a NMD, such as Patriot Advanced Capability - 3 (PAC-3), Navy Area (SM-2 Block IVA), Theater High Altitude Area Defense (THAAD), Navy Theater-Wide (SM-3), and the Ground-Based Interceptor (GBI). The data gathered for this thesis included unclassified performance data and the gross cost data relevant to the above systems. Interviews were conducted with personnel that are expert in US Navy SPY radar and Aegis combat systems, and have knowledge of SM-2 Block IVA and SM-3 missile systems.

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I. INTRODUCTION

A. WORLD EVENTS

In 1991 Sadam Hussein launched an Iraqi Scud missile at a pier in the Northern Persian Gulf where US Navy Cargo Ships were offloading equipment and supplies in support of the Operation Desert Shield military build-up. The equipment on that pier was worth billions of dollars. US Navy Aegis/SPY Radar equipped Ticonderoga Class Cruisers were patrolling nearby to protect the pier and the personnel unloading equipment, supplies, and cargo. The Cruisers detected the ascent of an Iraqi Scud missile shortly after it was launched from Iraq [Ref. 14].

They tracked the Scud through its ascent as it closed the distance to the pier. Even though the Cruisers had the ability to detect and track the missile they had no weapon to intercept it. Luckily, the scud widely missed the pier, impacting in an unpopulated area [Ref. 14]. If the Iraqi Scud had struck its intended target, many lives would have been lost, billions of dollars of equipment would have been destroyed, the Gulf War campaign against Sadam Hussein would have been delayed months, if not years. Sadam's forces would have had more time to entrench themselves in Kuwait and the opportunity to continue their invasion into the oil fields of Saudi Arabia. At the very least, there would have been many more American and allied casualties. At the worst, the outcome of Desert Storm could have been very different.

On 31 August 1998, North Korea launched a Taepo Dong-1, multi-stage ballistic missile, which flew directly over Japan and continued for two-thirds of the distance to Hawaii [Ref. 8]. Japanese Navy Congo Class Destroyers with exported American SPY-1 Radars detected the missiles shortly after launch, tracked them as they ascended and flew over Japan, continued to track them as they descended, and were even able to detect where they splashed into the Pacific [Ref. 14].

The North Korean Taepo Dong-1 test confirms the validity of the 1998 Rumsfeld Commission Report, which stated that the U.S. might be within five years of being threatened by ballistic missiles. For years, North Korea has been known as a major exporter of missile technology. A North Korean representative made no attempt to hide this, telling Capitol Hill staffers that the motivation for their sales is to obtain precious hard currency for the famine-ridden nation. One of North Korea's major customers, Iran, reportedly had technicians observing the missile test. It is speculated that Iran's next missile, the Shahab-4, will come on line in the near future with help from North Korea, China, and Russia [Ref. 23].

The missile test put North Korea in company with India, as one of few developing nations to master multiple stage ICBM rockets. Pakistan and Iraq are not far behind. That brings North Korea closer to building an intercontinental missile, with a range above 3,400 miles. The Taepo Dong-2 is estimated to have range of nearly 4,000 miles. The 1998 Rumsfeld Report also said that North Korea was "working hard on the Taepo Dong-2" and that a lightweight version could reach most areas of the US [Ref. 8].

In 1999, the SM-2 Block IV Standard Missile is capable of achieving very high altitude. The SPY-1 Radar and Aegis fire control system are capable of tracking and engaging missiles at very high altitudes. The SM-2 Block IV missile has already been developed, acquired, and produced. The Aegis system is installed on all Cruisers and most Destroyers in the US Navy. Did the design specifications of Aegis and SM-2 Block IV require these systems to have the capability to perform Theater Ballistic Missile Defense (TBMD)? How much testing and evaluation has been done in this area to investigate the effectiveness of TBMD by Aegis ships carrying SM-2 Block IV missiles? If these ships are effective TBMD platforms, then what is required to modify these ships to perform National Missile Defense (NMD)?

B. AREA OF RESEARCH

This study investigates the background and foundation for the need for a National Missile Defense. There is current debate in Congress concerning what new technology should be developed and produced to achieve NMD. This thesis examines what our capabilities are today in achieving TBMD and NMD and, if current capabilities are sufficient, what is the most effective way to utilize in-place technology to achieve NMD. This thesis compares and contrasts the various proposals made by the Ballistic Missile Defense Organization (BMDO).

The thesis research consisted of an evaluation of the most likely threat in NMD; our current capability to meet that threat; comparison of cost of acquisition of new technology to achieve NMD versus the cost of modification and/or integration of current technology to achieve NMD; and conclusions on the most cost effective way to achieve NMD.

C. BENEFITS OF STUDY

If this thesis shows that the US Navy is currently capable of performing NMD, then a great deal of acquisition costs can be avoided by not developing new systems to perform NMD. This will save Congress and the taxpayers money. It will also make the US Navy the primary service for NMD and likely secure further funding for current programs such as DD-21, Smartship, Aegis, SM-2 Block X, etc.

If redundancies are found in program proposals and RDT&E, this thesis will recommend changes to eliminate redundancies for cost avoidance. If there are areas where a Department of Defense joint solution would be more efficient, this thesis will make a recommendation for action or change.

This thesis attempts to point out where development is being done in an area or technology that has already been developed. By eliminating redundancy with pre-existing military or civilian technology, great cost avoidance can be achieved.

This study examines the Navy's current capabilities to perform NMD and explains what further development is necessary to improve it. It describes the most efficient way to achieve NMD.

D. RESEARCH QUESTIONS

Primary:

- Is the SM-2/Aegis combination a low-cost way the achieve effective NMD?

Secondary:

- What is the potential threat to the US that must be countered to accomplish the mission of NMD?
- Is the SM-2 Block IV missile controlled by the Aegis fire control system able to meet that threat?
- Are multiple Aegis ship platforms able to defeat multiple threats?
- What composition and position of ships is required for effective NMD?
- Is the DD-21 in its current configuration an effective platform for NMD?
- How effective are forward-deployed ships in the Persian Gulf in achieving TBMD at point of launch?

- How much will the acquisition of NMD technology cost?

E. SCOPE OF THESIS

This thesis investigated the following:

- Aegis / SPY-1 Radar capabilities
- Area and Theater BMD missile capabilities.
- The programs of the BMDO.
- Estimated requirements for cost effective NMD
- Estimated cost of acquiring new technology to perform NMD.
- NMD missile capabilities.
- Threat missile capabilities.
- Redeployment of current assets versus acquisition of new technology.
- Efficient use (placement/configuration) of current assets in performing effective NMD.
- Conclude the most efficient way to achieve effective NMD.

F. METHODOLOGY

This is a comparative thesis. The methodology required for this thesis research can be divided into the following steps:

- Review pertinent literature, including books, technical manuals, National Military Strategy Doctrine, Acquisition estimates, and other NMD information resources.

- Determine the most likely threat to NMD.

- Contrast threat missile capability with US defensive systems capability.

- Determine the integration capabilities of Aegis ships in a multiple threat scenario.

- Determine the most cost-effective way to deploy US Navy cruisers and destroyers to perform TBMD and NMD.

- Contrast current estimates of the cost of acquiring new technology to perform NMD.

- Conclude with analysis to determine the most efficient way to achieve effective NMD.

II. BACKGROUND

"The proliferation of weapons of mass destruction and the ballistic missiles that deliver them pose a major threat and must remain a major focus of US defense policy and budget allocations. The National Missile Defense program positions the United States to deploy the most effective possible system to defend US territory when the threat warrants such a deployment."

—William S. Cohen, SecDef, February 12, 1997

"The proliferation of short-range ballistic missiles in the world today poses a direct, immediate threat to many of our allies and to some US forces deployed abroad in defense of our national interests. Over time, the proliferation of longer-range missiles could pose a greater threat to the US itself."

—Paul G. Kaminski, USD for A&T, March 6, 1997

A. HISTORY OF NMD

In September 1967, US Secretary of Defense Robert McNamara announced President Lyndon Johnson's decision to deploy a limited anti-ballistic missile (ABM) system that would be capable of protecting virtually the entire US population against small-scale ballistic missile strikes. Five years later, the United States reversed course and signed the ABM Treaty, which placed severe restrictions on superpower anti-missile deployments [Ref. 1].

For nearly twenty years, the ABM Treaty and its underlying rationale enjoyed widespread support among both US policymakers and members of the defense establishment. In November 1991 the consensus supporting America's "no defense" force posture had been severely shaken by world events that led Congress to demand the deployment of a limited ballistic missile defense (BMD) system [Ref. 21].

The Iraqi ballistic missiles strikes of the Gulf War demonstrated that deterrence cannot be relied upon to protect US forces or the US homeland from future missile attacks, or from attacks with nuclear, biological, and chemical weapons (NBC). The Gulf War showed further that other means of protection - the global non-proliferation regime, diplomacy, intelligence-gathering, and counterforce operations - are inadequate and must be reinforced with an active defense capability such as NMD.

The need for BMD takes into consideration the post-Desert Storm consensus that a threat to the US homeland is gradually emerging. It further considers the deployment guidelines established by the 1991 Missile Defense Act, which were reaffirmed by the 1996 Ballistic Missile Defense Act. These considerations point to a phased BMD production that begins with an NMD site at Grand Forks, North Dakota. Such a site could be comprised of one hundred ground-based interceptors (GBIs) supported by sensors capable of providing over-the-horizon track data on inbound missiles. The benefit of this plan is that it will provide an effective NMD and also be compliant with the ABM treaty because the Grand Forks deployment would be in protection of an ICBM silo launcher fields [Ref. 12].

The Defense Department asserts to Congress that a Grand Forks deployment could defend the entire Continental US (CONUS) against twenty to thirty reentry vehicles coming from a generally northerly direction. Outside analysts concur with the Pentagon's assessment. To protect the entire country against a wider range of threats, America's phased BMD deployment could be completed with six additional GBI sites: three more in CONUS, two in Alaska, and one in Hawaii. The BMD system would be supported by space-based missile tracking sensors and be capable of shooting down about two hundred NBC warheads [Ref. 40]. With space sensor support and a total of four hundred GBIs deployed in CONUS, non-government studies indicate that in a two-hundred-warhead attack, more than 95 percent of the inbound reentry vehicles could be successfully engaged, thus saving millions of American lives [Ref. 17].

The ability to defend against two hundred warheads is proposed because this is the largest number controlled by a single person— the commander of a Russian Typhoon class submarine, which carries twenty strategic missiles, each armed with ten nuclear warheads. The Central Intelligence Agency has determined that submarine and other commanders of Russia's strategic forces could possibly defeat safety devices and launch their weapons without civilian authorization [Ref. 25]. Moreover, some regional nuclear powers, such as China and Russia, have already deployed nuclear arsenals comprising between seventy and two hundred warheads [Ref. 5].

1. Strategic Defense Initiative (SDI)

President Ronald Reagan first proposed SDI in March 1983 as a military research program for developing an anti-BMD system. The Reagan administration thereafter vigorously sought acceptance of SDI by the US and our NATO allies. As initially described, the system would have provided total US protection against nuclear attack. Reagan said it would render nuclear weapons "impotent and obsolete." The conception of SDI marked a break from the nuclear strategy that had been followed since the inception of the arms race. With the dissolution of the Soviet Union, the signing of the Strategic Arms Reduction Treaties (START I and II), and the election in 1992 of Bill Clinton, the SDI, like many other weapons programs, was given a lower budgetary priority. In 1993, SecDef Les Aspin announced the abandonment of SDI and the establishment of the Ballistic Missile Defense Organization, a less costly program that would create a ground-based antimissile system [Ref. 34].

The SDI system was originally planned to provide a layered defense by means of futuristic weapons technologies, several of which were only in a preliminary research stage. The goal was to be able to intercept incoming missiles in midcourse, high above the earth. Among the weapons required for the program were space and ground-based nuclear X-ray lasers, subatomic particle beams, and computer-guided projectiles fired by electromagnetic rail guns - all under the central control of a supercomputer system. (The space-based weapons and laser aspects of the system gained it the media name "Star Wars," after the popular 1977 science-fiction film.)

SDI was originally projected to cost anywhere from $100 billion to $1 trillion. Actual expenditures amounted to about $30 billion. The initial annual budget for BMDO was $3.8 billion. To date over $49 billion has been spent on NMD (Table 1).

Table 1 - NMD Historical Funding		
Year	**Total Funding (in millions)**	
1985	$	1,397
1986	$	2,676
1987	$	3,280
1988	$	3,553
1989	$	3,627
1990	$	3,571
1991	$	3,088
1992	$	3,932
1993	$	3,707
1994	$	2,728
1995	$	2,739
1996	$	3,405
1997	$	3,628
1998	$	3,800
1999	$	3,904
Total	$	49,035
		[Ref. 38]

2. The Ballistic Missile Defense Organization (BMDO)

At present, only a few countries, including Russia and China, possess missiles that can strike the US, but the potential for this number to increase cannot be ignored. Technology is spreading around the world at an astonishing rate, including technology dealing with ballistic missile development and weapons of mass destruction. Accelerating this growing technological trend is the continuing intent among some regimes whose objective is to harm the international system, especially the US and our allies. It is impossible to predict whether traditional methods of deterrence will operate under future conditions. Estimates are that a hostile regime could develop a long-range ballistic missile within fifteen years or less, or buy or receive one even sooner [Ref. 55].

These trends establish an uncertain but very significant threat to national security. As a result, the BMDO was formed to attempt to integrate technological development, affordability, a counter to the potential threat, international treaty considerations, and competing national defense priorities in order to establish the National Missile Defense program. The NMD Joint Program Office was established to manage the multiple-service components of a NMD system and oversee their integration into an effective architecture.

The NMD program is a Deployment Readiness Program and a Major Defense Acquisition Program intended to develop and maintain the capability to deploy an NMD system. The goal of the BMDO is to reduce the lead-time required to deploy an NMD system as a hedge against an uncertain threat. This will enable the United States to respond quickly to an identified threat, with a defense system designed to counter that specific threat. If deployment is required, the currently proposed NMD system could protect the US against limited attack by long range missiles. However, it would not be capable of repelling large massed attacks or attacks by short-range missiles from near US shores. Development of an NMD system also may reduce the strategic value of long-range ballistic missiles before they become commonly viewed as an essential component of international power and prestige, and thereby present a strong incentive against acquiring these missiles.

B. CURRENT NMD PROPOSAL OVERVIEW

From now until the year 2000, flight tests will continue at the national test range in the Pacific [Ref. 31]. If eventually successful, these tests will indicate that an effective and affordable NMD system can be built. The NMD program schedule is intended to allow flexibility according to the global threat, offering several increasingly capable deployment options as the Baseline NMD Program progresses.

The initial '3+3 option' is intended to enable the US to develop, within three years, the ability to deploy elements of a NMD system within another three years. Increasingly-capable deployment options after the initial option will add further capability with additional elements of the NMD system. [Ref. 32]

Although no deployment has yet been authorized, the NMD Deployment Readiness Program is continuing technology development and initial system integration with the goal of maturing the key components enough to field as a system. The key NMD components include a ground-based interceptor (GBI), a ground-based radar (GBR), Upgraded Early Warning Radars (UEWR), Battle Management / Command, Control, and Communications (BM/C^3), and space sensor technology [Ref. 20].

The GBI program is developing the technology and components for a state-of-the-art, cost-effective, lightweight, non-nuclear, hit-to-kill missile, to intercept and destroy inter-continental ballistic missiles targeted against the United States. Developing the GBI is the highest priority in the NMD program. This program consists of two efforts: the Exo-Atmospheric (outside the atmosphere) Kill Vehicle (EKV) and its booster. The EKV efforts are currently concentrating on the technical issues of the interceptor seeker. The EKV design began intercept flight testing in FY98 [Ref. 20].

The NMD GBR is designed to provide target identification, tracking, and discrimination. NMD program developers have constructed a test bed radar to resolve several technical issues and to participate in system testing. Upgrades to America's Early Warning Radar network will provide existing forward-based attack warning systems with the capability to augment the operations of a NMD system. These radars can be modified on a very short schedule, with a significantly lower cost than the alternative of building new radars. The BM/C^3 project is focused on integrating the NMD interceptor and sensor operations in support of informed decision-making. At present, the BM/C^3 element is primarily intended to help find the best NMD command and control structure, develop communications architecture for the entire NMD system, and facilitate NMD program integration [Ref. 20].

Another system vital to NMD is the Space Based Infrared System (SBIR). Although not funded by BMDO, this system may be critical to theater and national missile defense by providing surveillance, warning, and tracking data to overall missile defense operations.

The BMDO has designed its United States NMD as the "3+3" program [Ref. 27]. It is intended to be both evolutionary and flexible. RDT&E was originally scheduled to be completed by FY2000, after which the US would be able to quickly produce and deploy a NMD system in response to changing world situations. Alternately, if production and deployment are not funded, the 3+3 program calls for continuing development and improvement of the system designs, while keeping it ready for production and deployment on relatively short notice. Because of delays and shortfalls in funding, this is what we are seeing today. This degree of program flexibility is essential in the present world situation [Ref. 32].

The need for this kind of defense program flexibility is not new. Since the 1970s, changes in defense missions and in the systems designed to implement them have occurred every few years. NMD/TBMD missions have evolved from a deterrence-enhancing role against a massive threat, requiring large numbers of defense interceptors, to a protection role against regional or littoral aggression.

C. CURRENT CONGRESSIONAL OPINION

As Desert Storm subsided, a storm of a different type erupted on Capitol Hill. The war's lessons forced members of Congress to question our national defense security framework. The resulting debate broke years of deadlock over strategic defense policies and programs. Congressional passage of the 1991 Missile Defense Act demonstrated a bipartisan consensus desiring strategic BMD [Ref. 9].

Ballistic missile strikes might be carried out if another strategic power loses control of the forces on its soil. This contingency was considered a real possibility during the 1989 Tiananmen Square crisis in China and during 1991 and 1993 political upheavals in Russia [Ref. 34]. Purposeful attacks on the US are conceivable. A rogue nation or regime might be highly motivated to attack US interests or forward-deployed forces in order to disrupt a pending or on-going military campaign such as the NATO campaign against Kosovo, to claim revenge for a US attack, or for other reasons. Long-range ballistic missiles could be an attacker's delivery system of choice. America's current vulnerability to ballistic missile attacks could invite such scenarios.

Political and social upheaval can strike strategic powers like China and the former Soviet Union, thus threatening accidental or unauthorized missile launches. The global non-proliferation regime may slow, but not stop, third world powers determined to acquire NBC weapons and long-range ballistic missiles. New ballistic missile powers could threaten the US in the next ten years or sooner. The United States must make NMD force structure decisions on the basis of global strategic capabilities, not perceived intentions, because today's friends could be tomorrow's enemies.

The United States cannot count on deterrence to protect our interests. Rational and irrational enemies alike could threaten or carry out a missile strike on our forces. In principle, the US can mount credible defenses at both the strategic and tactical levels against terrorist NBC strikes such as suitcase bombs, as well as aircraft and cruise missiles. Because the US has not committed to protecting its allies and military forces by upgrading its defenses against theater ballistic missiles, the vulnerability of America invites attack. Missile defense deployment timelines must be aggressive in their anticipation of emerging threats. Deployments must be shortened to permit extensive BMD training and exercises to ensure optimum performance of procured systems when potential threats mature.

Given these assertions, congressional recommendations are [Ref. 9]:

1. BMD research and development and subsequent procurement programs to meet current and potential ballistic missile threats.

2. ABM Treaty revisions that permit BMD R&D and procurement.

3. Cooperation with Russia and other countries to ensure that future BMD development is compatible with strategic arms reduction efforts, world peace, and stability.

We do not currently have the capability to destroy long-range ballistic missiles launched against America. Officials and analysts have spent more than 30 years debating whether and how the United States should defend itself against such threats. This debate has been neither academic nor inexpensive. Since President Reagan's 1983 vision of a global defense shield, Congress has appropriated almost $40 billion directly to the BMD program in the hopes of fielding a system or systems capable of countering ballistic missiles armed with mass destruction warheads. Many more billions of defense dollars have contributed indirectly to the BMD effort; Congress does not see an end to such spending. [Ref. 32]

In March 1996, the House and Senate Republican leadership introduced the Defend America Act of 1996 [Ref. 29]. The outcome of this legislation set the course for BMD into the next century. A change in the White House in November of 2000 might alter this calculus. The current NMD debate describes the two major competing visions of how NMD should be pursued and explores the key substantive differences between those visions.

The vote over NMD hinges on ideological and partisan grounds. Conservatives and some moderates view the deployment of ballistic missile defenses to defend the US as a significant difference between Democrats and Republicans. Such a difference demonstrates the degree to which the parties will commit scarce budget resources to a key national security concern. Many conservatives' point out that most Americans believe they are defended against ballistic missile attack. When told otherwise, the public expresses support for NMD because rogue states may be able to attack the nation with ballistic missiles. In contrast, liberals and other moderates note that NMD is not needed now because the United States faces no current long-range ballistic missile threats [Ref. 56]. Because NMD demonstrates a key difference between the parties, many conservatives believe the outcome of the current debate will play an important role in the year 2000 presidential and congressional races.

Another aspect of this ideological debate is the degree to which decision-makers and analysts stress NMD in an overall national strategy to counter the proliferation of ballistic missiles and weapons of mass destruction. This overall strategy includes a broad range of arms control agreements and negotiations, export control laws, and military deterrence. The strongest NMD advocates place less credibility on these other "counterproliferation" tools. Others, including the Clinton Administration, seek a compromise, including an ABM Treaty-compliant BMD development program, coupled with strong advocacy of each of these tools.

1. Defend America Act of 1996

The stated purpose of the Defend America Act of 1996 [Ref. 29] is to seek to establish a US policy for the deployment of an NMD system. The act asserts that the ballistic missile proliferation threat to the US is significant and growing. It asserts that the deployment of an effective NMD system will reduce the incentives for countries to develop or otherwise acquire intercontinental ballistic missiles, thus serving to inhibit and counter the proliferation of missiles and weapons of mass destruction. It also finds that it is in the interest of all nations to pursue a form of strategic deterrence based on defensive capabilities and strategies, rather than deterrence based on offensive means.

The Defend America Act establishes, as US policy, the deployment of an NMD system with an Initial Operational Capability (IOC) by the end of 2003 as a transition step away from an offense-only form of deterrence. The Act requires that this NMD system be capable of providing a highly-effective defense of the US against limited, unauthorized, or accidental ballistic missile attacks. The NMD system would also have to be augmented over time to provide a layered defense against larger and more sophisticated threats as they emerge. The Act requires that the NMD interceptor system provide defensive coverage of the entire US and include one or more of the following programs: ground-based interceptors, sea-based interceptors, space-based kinetic energy interceptors, and space-based directed energy weapons [Ref. 29]. The overall system would include fixed ground-based radars, space-based sensors (including the Space and Missile Tracking System), and battle management, command, control, and communications elements.

The Act would urge the President to reach an agreement with Russia to amend the ABM Treaty to allow the deployment of the NMD system envisioned in the Act. If agreement is reached, the Act requires the President to submit the agreement to the Senate for its advice and consent. Absent such agreement within one year after enactment of the Act, the Act calls for the President and Congress to consider exercising the option of withdrawing from the ABM Treaty in accordance with the provisions of Article XV of that treaty [Ref. 29].

2. Clinton Administration's NMD Program

The Clinton Administration will make its final decision whether to budget procurement funds in 2001 for the proposed National Missile Defense. The program's stated mission requirement is the defense of all 50 states against a limited missile attack by a rogue nation; it would also provide some capability to defend the United States against a small accidental or unauthorized missile attack from more nuclear-capable states. Although the Administration has stated it plans to decide in June 2000 whether to deploy a NMD, its budgetary proposals include about $4 billion for that purpose over the 2001-2005 period. Combined funding for RDT&E and procurement of all theater and national missile defense programs would average about $4.4 billion annually over the 2000-2005 period compared with $4.0 billion appropriated for 1999 [Ref. 30].

The Clinton Administration proposes to hold the funding level for all DoD RDT&E to about $34 billion a year with little year-to-year variation over the 2000-2005 period. The current request is not much different from that of June 1998. But in 1999, appropriations for RDT&E totaled about $36.6 billion [Ref. 30]; thus, the current request produces a real reduction in funding for that category that would total about 17 percent in 2005. Activities in the Army and Navy would fall by about 20 percent and 17 percent, respectively, in real terms. Air Force funding would fall below the CBO baseline by about 13 percent in 2005, and RDT&E in defense-wide activities would be about 22 percent lower in that year.

DoD has long stressed the importance of a qualitative "edge" over potential adversaries, and funding for RDT&E has been a key part of maintaining that superiority. As in weapons procurement, a steady-state approach to RDT&E funding might appear to be useful. However, the aging of weapons would have less effect on the edge that US forces now enjoy than would innovations developed by enemy forces. In 1990, budget authority for RDT&E totaled about $40 billion in 2000 dollars [Ref. 38]. By 2005, the Administration's plan would take the category's budget authority to about 70 percent of that level, suggesting an order of magnitude for the increases that might be needed in the future.

A key element in the Administration's plan is to finalize outstanding ABM Treaty understandings, such as formalizing the political commitment the United States and the Commonwealth of Independent States have made to the ABM Treaty. In October 1992, the Commonwealth states signed an agreement at Bishkek, Kyrgyzstan, wherein the parties agreed as a collective body to assume all the rights and obligations of the ABM Treaty [Ref. 34]. Although the United States and the key Commonwealth states agree on the formal need to expand the membership of the ABM Treaty, a final and detailed agreement has not been agreed upon. When signed, the rights and obligations of the

Treaty will be assumed by all that signed. Those who do not sign will not be bound by the agreement. The President's position, therefore, is to ensure as extensive participation in the Treaty as possible.

3. Deterrence and the ABM Treaty

The issue of offensive nuclear deterrence remains central to the debate over BMD. To some of the supporters of the Defend America Act of 1996, the 1972 ABM Treaty embodies much of the immorality of guaranteeing the vulnerability of the US population in the strategic relationship (Mutual Assured Destruction) that existed between the United States and the Soviet Union throughout the Cold War. Many supporters believe that the ABM Treaty is a relic that not only stands in the way of deploying effective BMD, but stands in the way of moving toward strategic stability based on defensive deterrence. The Defend America Act and its supporters assert that effective BMD systems would serve to deter others from acquiring ballistic missiles armed with mass destruction warheads [Ref. 26]. These arguments, which began in earnest with the advent of Reagan's "Star Wars" vision, have aroused but not persuaded Capitol Hill.

Others, however, believe that offensive deterrence remains valid and critical to the strategic relationship between the United States and former Soviet Union. It is because the Defend America Act threatens this relationship, that the White House continues to defer funding of a NMD. For example, the Act requires an initial NMD deployment to be augmented over time to provide a layered defense against larger and more sophisticated threats. Second, the Act makes it US policy to seek a cooperative transition away from an offense-only form of deterrence as the basis for strategic stability. Third, the Act directs the Secretary of Defense to deploy an NMD that includes one or more of four ABM interceptor options, three of which would violate the ABM Treaty. The one treaty-compliant option is basically the Clinton Administration plan. Administration officials point out that supporters of the Act generally believe that a ground-based only system is a mistake and that they have argued for years the need to place weapons and interceptors in space. Finally, the Act requires amendment of the ABM Treaty within one year or formal withdrawal should be considered. Administration officials have said Russia would see this as tantamount to an "anticipatory breach" of the Treaty and that it would put the strategic nuclear arms reduction treaties (START-I and START-II) at risk. To the Administration, these elements of the Act are viewed negatively as Reagan Star Wars ideology that reflects disdain for the ABM Treaty and the strategic stability between the United States and Russia.

Major disagreements over NMD also include three related cost issues. The first concerns aggregate NMD system costs. They are noted here because key players in the current debate are using them. Some key committee staff supporters believe that it would cost about $3 to $7 billion (depending on which of the four interceptor options were pursued) to field an NMD system that meets the immediate requirements of the Act [Ref. 10]. They also point out that this money is part of the Republican balanced budget, and is not new money. The Missile Defense Study Team at the Heritage Foundation maintains that a sea-based ABM system could be achieved by employing AEGIS cruisers and their infrastructure. This system would cost about $6 billion and could be deployed by 2002 [Ref. 17].

There is wide disagreement as to how much it will cost to develop and produce a Ground Based Interceptor Missile and deploy 100 of those missiles to North Dakota. General Malcolm O'Neill, former Director of the BMDO, stated that a single ground-based treaty-compliant system might cost about $5 billion; more recently, he estimated the cost at $7 to $8 billion [Ref. 10]. Earlier this year Representative Livingston, Chairman of the House Appropriations Committee, quoted $13 to $16 billion for a NMD deployment. Robert Bell, Senior Director, National Security Council, cites a figure of $20 billion for a two-site, land-based ABM system - money that he says is not in the Future Year Defense Budget or the DoD outyear budgets. The CBO estimates the cost to develop and deploy a layered NMD system at $31 to $60 billion [Ref. 30]. It would include both ground and space based weapons. Finally, the Center for Strategic and Budgetary Assessments argues that, while limited NMD deployments are likely to cost as little as $5 billion, effective, layered NMD deployments envisioned in the Act could cost more than $50 billion, and those costs could be underestimated by 20 to 40 percent [Ref. 21].

The Clinton Administration maintains that its NMD plan will produce cost savings if the ballistic missile threat does not appear sooner than expected (i.e., in less than 10 years). The NMD program, therefore, could advance indefinitely at relatively low funding levels until it was necessary to deploy a system, thus saving large sums of money that would be used to build and deploy a near-term NMD required under the Defend America Act. Supporters of the Act admit that less money might be spent over the near term, but raise the question of how much risk we should assume [Ref. 53]. This leads to the third issue. A significant difference exists between NMD supporters who want to deploy an NMD system as soon as possible and others who believe that NMD can wait. The former believes that the risk simply is too great. Cost considerations should not be the determining factor; they are therefore willing to pay a higher insurance premium to insure against the risk of a ballistic missile attack on the United States. In contrast, opponents of this crash NMD deployment effort are satisfied with paying a lower insurance premium and believing that there will be sufficient time to deploy a system when required, thus saving money and allowing NMD technology to continue development.

The 1972 ABM Treaty limits the development, testing, and deployment of defensive systems capable of intercepting strategic ballistic missiles. The Treaty and its 1974 Protocol limit the participants to a system of no more than 100 ground-based interceptors deployed at a single site [Ref. 1]. Many consider this to be the "foundation of strategic stability" between the United States and the former Soviet Union because it ensures retaliatory capability without an offensive nuclear arms race.

As of March 1999, the Senate has voted to continue funding to develop a National Missile Defense. The next chapter will examine the current proposals that will be funded in the year 2000 defense budget, how much each will cost, and specific capabilities and details of each proposal.

III. CURRENT NMD MISSILE AND RADAR PROGRAMS

NMD is the term that the Ballistic Missile Defense Organization has given to the defense of America from ballistic missile attack. BMDO programs are divided into three separate and logically complementary groups. The groups are lower-tier area ballistic missile defense, upper tier theater ballistic missile defense, and Battle Management Command and Control Systems with Space-Based Infrared (SBIR) weapons and sensors.

The lower-tier, area BMD is the simplest and most developed of these technologies. Lower-tier missiles are endo-atmospheric missiles. They remain in the earth's atmosphere and intercept missiles at or below 33 km / 20.5 miles. Lower-tier BMD programs use existing radar technology and conventional missile designs, such as air fins, infrared seeker heads, and boosted, single-stage rocket motors [Ref. 19].

Upper-tier, theater-wide BMD is much more complex. This missile technology is exo-atmospheric. These intercept missiles must leave the earth's atmosphere and must guide themselves in space by using thruster technology found on satellites and spacecraft in order to hit their targets. Upper-tier missiles are designed to engage targets at altitudes up to 150 km / 93.2 miles. Both upper and lower tier BMD missiles use hit-to-kill (HTK) warheads. HTK warheads have much more energy than conventional fragmentation warheads. This additional energy is needed to destroy and incinerate very large ballistic missiles that may carry nuclear, biological, or chemical payloads. For example, an older Patriot-2 missile with a fragmentation warhead will hit a missile with 0.3 megajoules of energy because only a small percentage of the fragments hit their target. A lower-tier area BMD missile, such as the Patriot Advanced Capability Three (PAC-3), with a hit-to-kill warhead will impact its target with 310 megajoules of energy because all the energy of the PAC-3 missile, including the warhead guidance system and missile body, are impacting on the target [Ref. 4]. The difference between a fragmentation warhead and a hit-to-kill warhead is a 1000% increase in energy. The trade-off is that a much better guidance system is required to intercept the target with a HTK warhead because a miss has no effect on the target.

The Battle Management Command And Control Systems with Space-Based Infrared weapons and sensors includes both ground and space based radars and optical infrared sensors to detect and track ballistic missiles as they travel through the atmosphere, into space, and back into the atmosphere to their target. SBIR satellites will have the ability both to detect ballistic missiles and to engage them with a Space-Based Laser (SBL) [Ref. 22].

A. PATRIOT ADVANCED CAPABILITY (PAC-3)

The first BMD program this thesis will examine is the Patriot Advanced Capability 3 (PAC-3) missile. The PAC-3 is a lower-tier ballistic missile interceptor. The PAC-3 is the maturest of the BMDO NMD proposals. It is currently in the Engineering and Manufacturing Development (EMD) phase of the acquisition process. PAC-3 is being fielded in three phased configurations. The first two configurations provided the Army with improved operational performance. The third configuration will provide the final element in the form of the hit-to-kill interceptor missile, along with additional communications, a single phased array radar, and ground support system improvements (Figure 1). The first deliveries of the ground system hardware and software have already begun, and development and operational testing will start this year. All of these efforts support a First Unit Equipped (FUE) date of late FY 1999.

The PAC-3 design program began in 1983, but flight-testing was not funded until 1987, when the prime contractor, Lockheed Martin Vought Systems, was awarded a contract worth $80 million. The program is intended to provide intercept capability against both TBMs and air-breathing missiles. The PAC-3 uses hit-to-kill for its prime kill mechanism with a secondary ring-type warhead of small pellets as a lethality enhancement against air-breathing targets [Ref. 19].

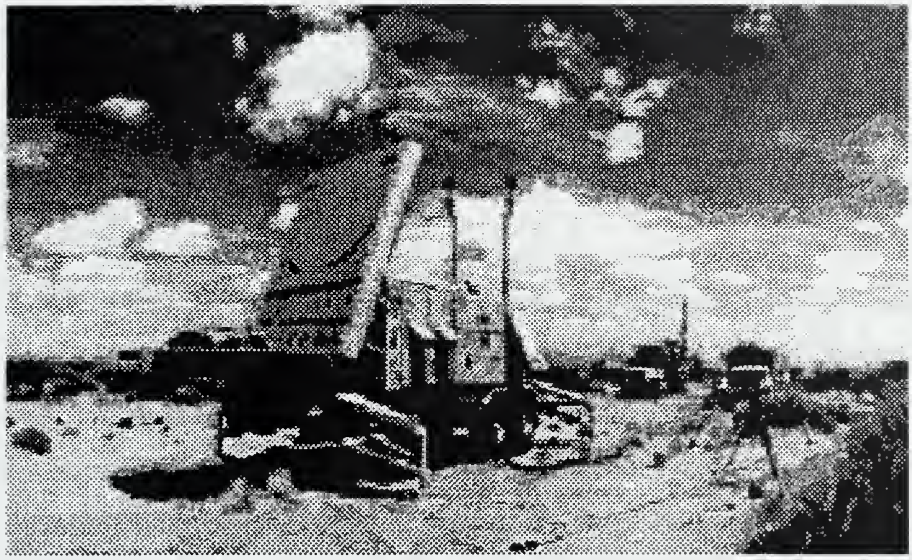

Figure 1 Ref. 44

To save cost, the PAC-3 is designed to utilize existing Patriot missile launcher units with some modifications. The missile uses inertial guidance for fly-out to the predicted intercept point. The weapons trajectory can be updated during flight using the Patriot fire control radar system. In the last two seconds of flight, a nose-mounted pulse Doppler radar seeker antenna is activated to terminally guide the missile to target. The Doppler radar also provides proximity fusing to activate the secondary kill system pellets [Ref. 46].

B. NAVY AREA BALLISTIC MISSILE DEFENSE

"In the business of theater missile defense, I really do believe that the Navy has a tremendous contribution to make with an AEGIS force already well-invested in... I'm excited about the potential of both lower-tier and upper-tier capabilities... I think it's relevant and a very, very potent capability for our country..."

- Admiral Jay Johnson, Chief of Naval Operations July, 1996

Ninety percent of the world population is within 200 miles of an ocean, sea, or gulf. The joint effort between the Navy and the BMDO to develop the Navy Area BMD and Navy Theater-Wide BMD programs will expand the Navy's mission with a real capability to defeat the growing ballistic missile threat. Capitalizing on rapid advancements in missile guidance, propulsion, and seeker technology, the Navy is on the verge of being able to protect U.S. and Allied forces ashore when threatened by ballistic missile attacks [Ref. 42].

The mission of the Navy Area BMD system is to provide U.S. and Allied forces, as well as areas of vital national interest, defense against theater ballistic missiles (TBMs). AEGIS cruisers and destroyers, equipped with a modified AEGIS combat system, will detect and track short to medium-range TBMs and engage them with the Standard Missile-2 (SM-2) Block IVA interceptor missile (Figure 2).

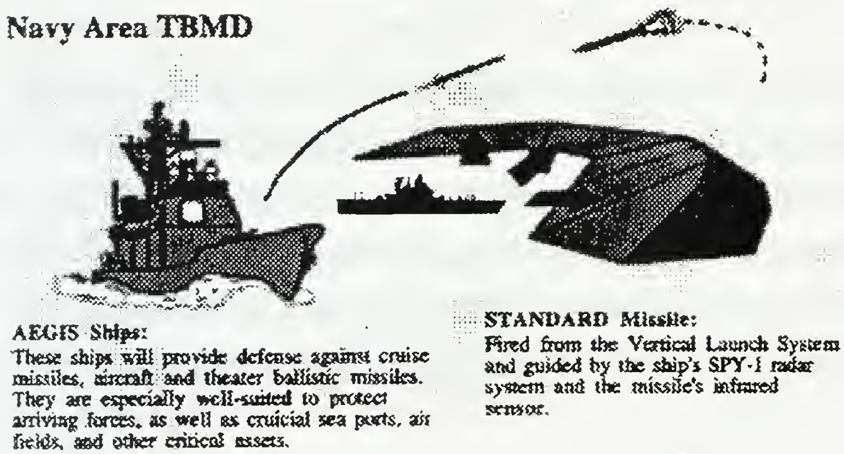

Figure 2 Ref. 27

The Navy has the flexibility to forward-deploy sea-based BMD forces to potential crisis spots in regions where land-based forces can not deploy. Since these sea-based forces will be deployed in international waters, no foreign governmental approval is needed. Thus, an effective defense capability can be put in place to provide Navy Area BMD before hostilities erupt or before land-based BMDs can be transported to the theater. If air and ground forces have to fight their way into a theater of operation, Navy ships can provide critical area defense coverage early in the conflict. Additionally, BMD provided by ships at sea will greatly reduce demand on our airlift and sealift assets. Desert Storm demonstrated the great time and resources required to move defense forces into a theater of operation with an active TBM threat. Deployed Naval forces with BMD capabilities could enable a theater commander to concentrate available lift on anti-armor systems, tanks, troops, ammunition, and other reinforcements needed to stop an enemy advance.

The Navy has many years of experience with Battle Force air defense and has developed the command and control systems necessary to conduct area defense from the sea. The ability to integrate satellite communications, the Joint Tactical Information Distribution System (JTIDS), Tactical Related Applications/Tactical Receive Equipment (TRAP/TRE), Naval Tactical Command System-Afloat (NTCS-A), and other vital intelligence, sensor, and tactical information makes the Navy a logical choice to have a role in BMD [Ref. 14].

The Navy successfully demonstrated BMD capability recently when a ballistic missile target was shot out of the sky for the first time using a Block IVA version of the proven SM-2 missile. With this intercept, the Navy moved into a new era where it will play an increasingly vital role in the defense of forces ashore.

C. SPY-1 RADAR AND AEGIS COMBAT SYSTEM

The AN/SPY-1 Radar is the electronically-scanned, fixed-array radar for the Navy Aegis fleet air defense missile system. It operates in the E/F Band with an output of several megawatts. The Raytheon transmitter serves several parallel channels simultaneously. The arrays are in four sections, each covering 90 degrees of azimuth. Each array has 4100 discrete element nodes and measures 3.65m octagonal. The Spy radar has no moving parts. The four radar elements are controlled by AN/UYK-7 computers to steer multiple radar beams for target search, detection, classification, and tracking [Ref. 24]. The Linebacker upgrade is a software patch, which enables the AN/UYK computers installed on all Aegis ships to compute the necessary intercept data to guide an intercept missile to hit and destroy a fast moving ballistic missile. The SPY Radar can track missiles at a distance of 300 km / 186 miles [Ref. 11].

The SPY-1 Radar first went to sea in 1974 and has undergone continuous improvement and upgrade over the last 25 years. The latest version is the SPY-1 B/D used on the Arleigh Burke Destroyers and the latest Tichonderoga Cruisers. The Patriot single-array radar and the THAAD ground-based radar are both based on the SPY-1 phased-array radar design [Ref. 19].

A major benefit of the SPY/Aegis combination is that, unlike a Patriot or THAAD control truck, a Navy Cruiser/Destroyer Combat Information Center (CIC) has room for more than a dozen operators, allowing multiple targets to be delegated to different trackers, thereby reducing information overload on the decision-makers [Ref. 15]. A Navy ship also has the ability to easily generate the very large amounts of power required for the radar. An Aegis cruiser or destroyer can track and engage 100+ targets by itself, and multiple Aegis ships can automatically coordinate with each other for cooperative intercept scenarios [Ref. 16].

The Navy Area BMD program includes modifications to the Aegis Combat System and SPY-1 Radar to enable detection, tracking, and engagement of TBMs using SM-2 Block IVA missiles, and minor changes to existing command and control systems. More than 50 Aegis cruisers and destroyers are at sea or under construction and the support, training, and logistics infrastructure is already in place and operating [Ref. 24]. A User Operational Evaluation System (UOES) called "Linebacker" is at sea today to provide feedback to the BMDO and to influence tactical design improvements [Ref. 14]. Linebacker could be quickly made available for contingency use by regional military commands such as Commander-in-Chief Europe.

Two Aegis cruisers, Lake Erie, and Port Royal, were the first to receive Linebacker upgrades in September 1998. Successful sea trials were completed in October 1998. The Linebacker ships have been conducting at-sea testing, developing core doctrine and tactics, and serving as models for getting our BMD capability to sea.

The Lake Erie and Port Royal are scheduled to complete 15 BMD intercept tests in the next 18 months [Ref. 14].

D. SM-2 BLOCK IVA STANDARD MISSILE

Development of the SM-2 missile for cruiser and destroyer use began in 1969 with a view to use the SM-2 with the Aegis /Spy Radar system, incorporating mid-course guidance correction. After extensive RDT&E, production of the SM-2 Block I began in 1977 and entered service in 1979. The Block II version upgrade integrated the New Threat Upgrade (NTU) package for the baseline Ticonderoga (CG-47) Cruisers. The Block IIIB missiles entered service in 1990, incorporating upgrades from the Missile Homing Improvement Program [Ref. 11].

Development of the SM-2 Block IV missiles began in July 1987. These are dedicated, vertically-launched, ER missiles for the Ticonderoga and Arleigh Burke class ships. They entered service in 1994 and remain the Navy's primary surface-to-air missile [Ref. 11].

SM2 Block IVA and the PAC-3 missiles are developmental counterparts and are both being produced in Tucson, Arizona, by Raytheon [Ref. 14]. SM-2 Block IVA missiles incorporate an Area BMD role by providing a lower-tier or endo-atmospheric system in support of near-shore, littoral-warfare operations. SM-2 Block IVA missiles conduct engagements against aircraft and anti-ship missiles in the same way as previous SM-2 Block IV and earlier missiles. Against ballistic missiles, the SM-2 IVA receives the usual mid-course guidance data, but in the terminal phase, as the missile approaches the target, the IR seeker fairing is ejected and the missile rotates to bring the seeker to bear. This puts the missile under internal IR guidance, and the image is resolved until the target comes within view of the forward-looking proximity fuse. The missile then guides itself to the intercept point where the warhead is detonated [Ref. 24].

The Block IVA has added the ballistic missile interception capability in the endo-atmospheric lower-tier to 33 km but is also able to intercept targets at sea level. This makes the Block IVA a very useful multi-purpose intercept missile. It is capable of destroying many types of conventional missiles, such as the Exocet sea skimming missile, aircraft of almost all types that fly at Mach 2.5 or less (most aircraft in existence, with exceptions like the US SR-71 and Russian MIG-29), and all lower tier ballistic missiles such as the Iraqi Scud [Ref. 11].

Following successful lethality testing at White Sands, New Mexico, the Navy Area BMD program was approved for entry into EMD on 22 February 1997 [Ref. 22]. The program commenced development flight testing in 1999, followed by an at-sea demonstration of the Aegis Linebacker upgrade. To date, the SM-2 IVA has successfully passed four seeker angle tests, six warhead sled tests, and eight TBM threat tests. On 24 January 97, SM2-IVA hit a Lance Missile simulated ballistic missile target. On 18-20 November 1999 at the Pacific Missile Test Range near Hawaii, the Lake Erie and Port Royal successfully conducted an at-sea ballistic missile tracking exercise where the SPY radar was able to detect the launch of a ballistic missile and track it throughout its flight until it splashed into the Ocean [Ref. 14].

To equip 57 Aegis destroyers and 22 Aegis cruisers with Navy Area BMD capability between fiscal year 1998 and 2011, the Navy plans to buy 1,500 SM-2 Block IVA missiles. The Navy also plans to field a prototype system, incorporating the Linebacker upgrade, beginning in September 1999. This will provide an interim BMD capability and allow fleet personnel to evaluate the system. The Navy plans to equip the two Linebacker cruisers with a total of 35 SM-2 IVA missiles for testing and/or use in a national emergency [Ref. 7].

E. NAVY THEATER-WIDE BMD (NTW)

For the Navy's Theater-Wide BMD, or upper-tier / exo-atmospheric defense, the BMDO has proposed the development of a next generation Standard Missile (SM-3).

The SM-3 will provide Ticonderoga cruisers and Arleigh Burke destroyers with a lightweight exo-Atmospheric Projectile (LEAP) Kinetic Warhead (KW) to intercept longer-range, higher-flying ballistic missile threats [Ref. 36].

Functional Technology Validation (FTV) tests call for the SM-3 missile to be launched from modified Navy Vertical Launch System canisters in the same way as current SM-2 missiles (Figure 3). After 111 seconds of fly-out, the nose cone covering the KW is ejected and the third stage of the missile ignites. The KW is ejected 46 seconds later and within 20 seconds, intercepts the ballistic missile target at a range of 425 km / 260 miles and at an altitude of 122 km [Ref. 43].

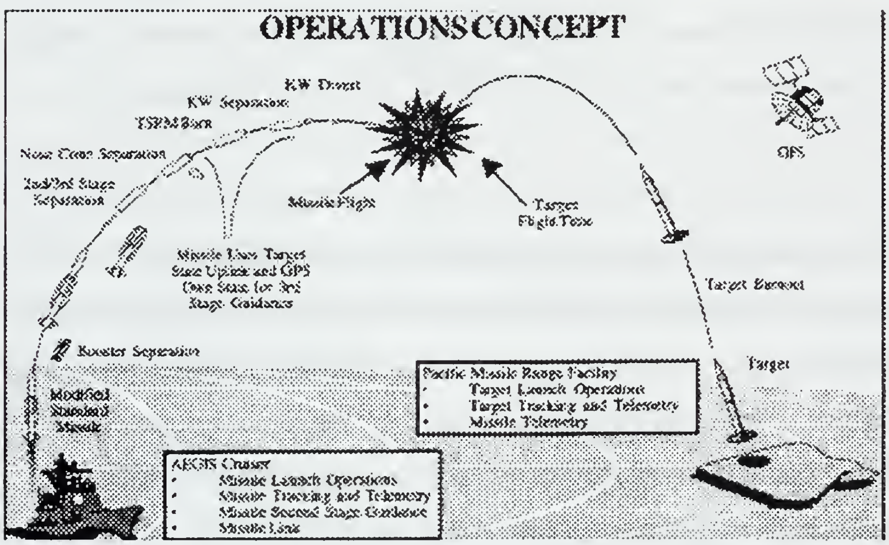

Figure 3 Ref. 43

SM-3 Block I will be the Engineering Manufacturing Development missiles and SM-3 Block II will be the initial operating capability missiles. Block I missile RDT&E is scheduled to be completed by 2002 and, if production is funded, it is anticipated that 650 SM-3 Block II will be produced. The SM-3 can reach an altitude of 76 miles while at a range of 260 miles [Ref. 30]. These are the unclassified capabilities of SM-3. Note that this data is a combination point on an ellipse. Neither the altitude nor range is an absolute maximum point.

F. THEATER HIGH ALTITUDE AREA DEFENSE

THAAD is a ground-based weapon system being developed by the Ballistic Missile Defense Organization and the Army to defeat theater ballistic missiles by intercepting them in flight. The system supports the national objective of NMD and TBMD.

The THAAD system is an easily-transportable battery of missiles capable of hit-to-kill interception of incoming tactical theater ballistic missiles at heights up to 150 times greater than the patriot missile used in Desert Storm, and at ranges of up to 125 miles [Ref. 19]. The THAAD proposal is intended to allow existing air defense systems to continue the role of anti-aircraft defense while THAAD performs TBMD and /or NMD.

The THAAD system includes missile launchers, radar, and fire control components integrated into truck beds or trailers that will fit into the cargo bay of C-130 military cargo aircraft (Figure 4). THAAD can receive tracking and targeting data from space-based sensor satellites such as Brilliant Eyes or its own Raytheon ground based radar (GBR), which is a $9.2m^2$ array-sized 25,344 Hz I/J band radar which performs the duties of surveillance, threat identification, and classification [Ref. 19]. The GBR is essentially similar to one of the four phased-array radars from the Aegis Cruiser / Destroyer SPY-1D radars.

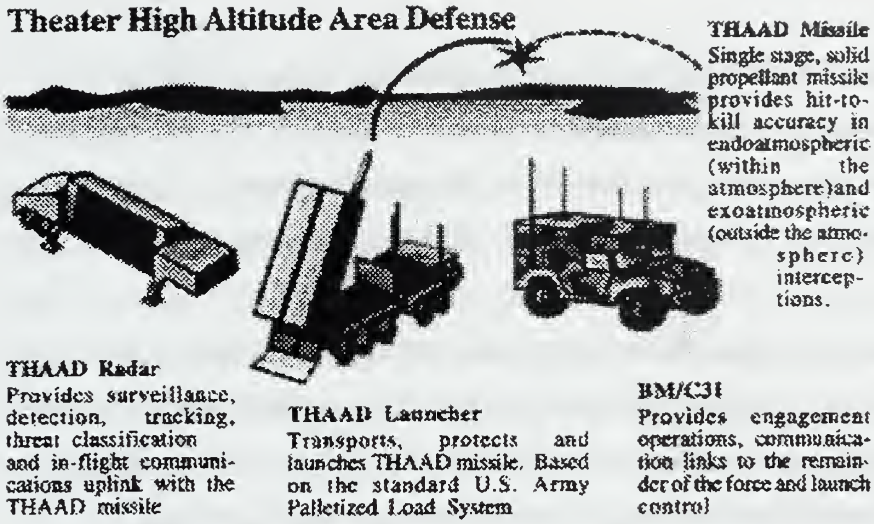

Figure 4 Ref. 36

The THAAD program is currently in the Program Definition and Risk Reduction (PD&RR) phase of development and is the maturest of our upper-tier TAMD systems. In 1997, as a result of failure to achieve an intercept in flight tests and the need to reduce technical and programmatic risk, the QDR endorsed a plan to restructure the program and to achieve a FUE in 2007 [Ref. 33].

After flight test seven, BMDO and the Army commissioned an Independent Review Team (IRT) to review the program's processes and the design of the THAAD missile. The IRT has had a direct impact on the way the THAAD program is conducting business [Ref. 48]. Ground-testing is where the most recent technical problems have been detected, and, consequently, the rigorousness of the ground-testing program has been increased [Ref. 4].

The 6.2m long, 900kg launch weight THAAD missile is a single-stage, solid-fueled missile capable of both endo and exo-atmospheric intercepts [Ref. 19]. A target object map and predicted intercept point is provided to the missile prior to launch; after which the missile receives in-flight updates. Terminal homing is an infrared nose-mounted unit with the seeker looking through an un-cooled side window with a shroud, which will separate prior to terminal homing. THAAD must hit to kill.

The extremely fast THAAD missiles are expected to engage targets out to 125(+) miles and intercept inbound missiles as high as 93 miles in altitude. The THAAD is a shoot-look-shoot missile, meaning that two THAAD missiles will be launched to engage one inbound missile. Each THAAD missile has a kill probability (Pk) of 0.9 [Ref. 19].

THAAD missiles are continuing development at the White Sands Missile Test Range and the Navy's Pacific Missile Test Range. On 10 June 1999, THAAD had its first successful missile intercept after eight failures [Ref. 57]. THAAD is continuing testing and development by the BMDO in conjunction with Lockheed Martin.

G. GROUND BASED INTERCEPTOR (GBI)

The GBI and its associated components provide the "weapon" of the NMD system. Its mission is to strike high-speed ballistic missile warheads in the midcourse or exo-atmospheric phase of their trajectories and destroy them by force of impact [Ref. 32]. The GBI consists of three components. The first component is the missile payload called the kill vehicle. The kill vehicle has its own sensors, propulsion, communications, guidance, and computing functions which all work together to complete the intercept.

The second component is a booster that will propel the EKV toward an approximate intercept location so that the EKV can perform terminal maneuvers to impact the incoming warhead.

The third component is the ground command and launch equipment that is needed to launch the interceptor. This consists of the hardware and software for interface with the BM/C^3 system control consoles, and missile silos required to accomplish daily maintenance and readiness functions and to launch the interceptor upon command.

NMD interceptor missile proposals will use existing off-the-shelf motors by United Technologies and Alliant Tech Systems, with a generic exo-atmospheric kill vehicle (EKV) cutaway at the top. No decision has been made to produce or deploy any element of the NMD system, including interceptor missiles. They, along with associated radars, command and control systems, and space and ground-based launch detection systems could be deployed by 2005 if it is determined that there is an emerging threat to the US of a limited ballistic missile attack [Ref. 30].

During flight, the GBI receives information from the NMD BM/C^3 system to update the location of the incoming ballistic missile, enabling the GBI on board sensor system to identify and home-in on the target [Ref. 36]. The GBI will consist of a multi-stage solid propellant booster and an exo-atmospheric kill vehicle. Each missile will contain 27,766 pounds of solid propellant fuel. The exo-atmospheric kill vehicle will contain approximately 30 pounds of liquid propellant [Ref. 39].

The deployed GBI will be a dormant missile that remains in its underground silo until launch. A launch will occur only in defense of the US from a ballistic missile attack. There will be no flight testing of the missiles at the NMD deployment site. The technical status of each missile will be monitored and any required maintenance conducted at a contractor's offsite production facility. Interceptors in storage at the GBI site will be used to replace missiles requiring repair or selectively removed for reliability testing [Ref. 39]. Developmental and operational testing of the GBI will be conducted at designated US missile test ranges.

The initial GBI site deployment will be 20 interceptor missiles. The GBI site will contain launch silos, missile receiving and processing buildings, missile storage facilities, and additional support facilities. Approximately 600 acres will be required to support the GBI missile field and associated technical facilities. When the GBI site and associated technical facilities become fully operational, total site-related employment will be approximately 150 to 200 personnel [Ref. 39].

GBI Characteristics are all classified, but in accordance with the directed requirements of the NMD proposal, the GBI missiles must be capable of defending all of CONUS from one central site in North Dakota. In order to do this, the GBI missile will need a range of greater than 1,000 miles / 1,600 km [Ref. 27]. In order to intercept an inbound ICBM, the GBI will also be required to reach any altitude and travel at high mach speed.

H. AIRBORNE LASER (ABL)

Operation Desert Storm demonstrated that US military forces have limited capability against theater ballistic missiles. US defensive capability is limited to weapons that defend against missiles nearing the end of their flight, such as the Patriot. No capability exists to destroy missiles in the boost phase shortly after launch. Consequently, DoD is expending considerable resources to develop the ABL's capability to intercept missiles in their boost phase. The ABL program involves placing various components, including a powerful multi-megawatt laser, a beam control system, and related equipment, in a Boeing 747-400 aircraft [Ref. 54], and ensuring that all the components work together to detect and destroy enemy ballistic missiles in their boost phase.

The ABL program is DoD's first attempt to design, develop, and install a multi-megawatt laser on an aircraft. The ABL is also expected to be DoD's first system to intercept missiles during the boost phase. To successfully destroy a missile in its boost phase, the ABL system would have to, within about 30 to 140 seconds, detect a missile shortly after it has been launched several hundred kilometers away, track the rising missile's path, and hold a concentrated laser beam on the missile until the beam's heat causes the missile's pressurized casing to fracture and then explode [Ref. 54]. This explosion would then cause a missile's warhead, along with any nuclear, chemical, or biological agents it may contain, to fall short of the intended target and possibly back on the aggressor's territory. The range of the ABL is specified to be 310 miles / 500 km [Ref. 54]. The obvious limitation of the ABL is that it must be at the right place at the right time. Being able to intercept an ICBM in its boost phase means flying an ABL 747 in the vicinity of the threat either continuously or as the situation dictates.

The ABL will operate from a central base in the US and be available for deployment worldwide. The program calls for a seven-aircraft fleet, with five aircraft to be available for operational duty at any given time. The other two aircraft are to be undergoing modifications or down for maintenance or repair. When the ABLs are deployed, two aircraft will fly, in figure-eight patterns, above the clouds at 40,000 feet. Through in-flight refueling, which is to occur between 25,000 and 35,000 feet, and rotation of aircraft, two ABLs will always be on patrol, ensuring 24-hour coverage of potential missile launch sites within the theater of operations. The ABLs are intended to operate about 90 kilometers behind the front line of friendly troops but could move forward once air superiority has been established in the theater of operations [Ref. 54]. When on patrol, the ABLs are to be provided the same sort of fighter and/or surface-to-air missile protection provided to other high-value air assets, such as the Airborne Warning and Control System and the Joint Surveillance Target Attack Radar System.

Unlike the PAC-3, SM-2 Block IVA, THAAD, and SM-3 missiles, the ABL is not part of the incremental development of the GBI missile. The ABL is part of the concurrent development of the space-based laser. The ABL is included here because it is a part of the NMD proposal.

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IV. THE BALLISTIC MISSILE THREAT

A. NATIONAL INTELLIGENCE ESTIMATE 95-19

A significant chasm exists in the NMD debate over estimates of the ballistic missile threat to the United States. In general, this has focused on a National Intelligence Estimate (NIE) 95-19, whose key findings were initially reported as free of contention. The NIE testified that the US will not face a new long-range ballistic missile threat prior to 2010 [Ref. 55]. The NIE further stated that the North Korean Taepo Dong II, which might have the range to reach Hawaii or Alaska, would not be operational within the next 5 years. Some cite recent Chinese threats to launch missiles against Los Angeles if the US interfered in any Chinese-Taiwan conflict as evidence that the US does face a current threat. Administration officials dismiss such threats as rhetoric and note that conflict with China is not new. The US has long included China in its nuclear deterrence strategies [Ref. 25].

The NIE energized the BMD debate. To the Administration, the assessment rendered its '3+3' NMD plan prudent. But critics pointed to serious flaws. The first is that the NIE was simply wrong; rogue states have the means and the desire to develop and field ballistic missiles that could threaten the US. The Intelligence Community (IC) response is that such efforts among rogue states are too technologically-challenging and any efforts would be detected years before deployment could be completed. Others add that efforts on the part of rogue states to acquire ballistic missiles and weapons of mass destruction derive from regional rivalries, rather than a desire to threaten the US [Ref. 5].

A second charge made is that the NIE focused primarily on indigenous capability and failed to analyze closely the strong likelihood of ballistic missile sales or technology transfers. The IC stated it allowed for the acquisition of some foreign technology and also concluded that no country with intercontinental missiles would sell them. A third charge made was that the NIE did not account for the possibility of a catastrophic failure of intelligence or analysis [Ref 55]. Some analysts have said we can never know the capabilities of rogue states, citing intelligence failures before and after World War II and Iraq's ballistic missile and weapons of mass destruction programs as examples. The IC said it recognizes this possibility but found it unlikely because ICBM programs progress slowly, and the technological base and economic resources of hostile states are limited. Others add that strategic technological surprise, such as ICBM programs, is very difficult to achieve. Tactical or small-scale technological surprise is more likely. As a precaution, the Administration is exploring emergency NMD concepts that could be deployed much sooner than the '3+3' plan. Some have charged that the NIE was politicized, that its outcome was skewed to favor the Clinton Administration's NMD plan. This charge has been denied by senior Administration and IC officials [Ref. 34].

B. WORLD DEVELOPMENTS

A large number and expanding variety of ballistic missile systems are found in the military arsenals of several nations. Most are imported, some are domestically developed, and a few are indigenously modified. The current threat includes more than 25 countries armed with ballistic missiles, hundreds of missile launchers and thousands of missiles with ranges up to 2,000 miles (Figure 5). In addition, Russia, China and North Korea either possess or are developing inter-continental ballistic missiles (ICBMs) that could strike targets as distant as 6,000 to 8,000 miles, including the US [Ref. 18].

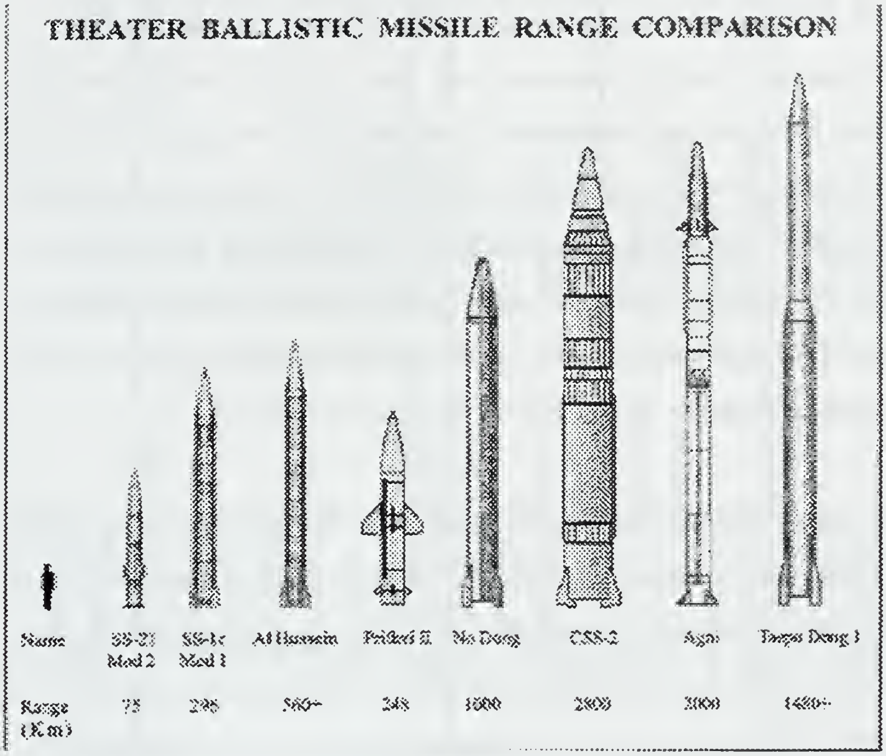

Figure 5 Ref. 35

Ballistic missiles are appealing weapons for developing nations and often serve as status symbols. Their long range, short flight time, relatively low cost and ability to carry a variety of warheads, provide unique political and military advantages. In addition, defenses against ballistic missiles are not as mature or widely deployed as defenses against aircraft or other delivery systems. The importance of BMD is underscored by the growing proliferation of nuclear, biological and chemical (NBC) weapons of mass destruction (WMD) [Ref. 26]. The nuclear club has grown in the past 20 years. Currently, nine nations possess nuclear weapons and several more nations either have the ability to develop nuclear weapons or have active nuclear weapons programs. Chemical weapons have been dubbed "the poor man's atomic bomb" and are viewed as a fast, attractive, and affordable alternative to nuclear weapons by many developing nations. More than 30 developing nations have chemical weapons programs. Over a dozen developing nations have biological weapons research programs, although they are somewhat harder to develop and maintain than chemical weapons [Ref. 34].

An example of the growing sophistication of Third World ballistic missile developments is the long-range missiles that have been developed in North Korea. The Nodong-1 was tested in 1994 and may be capable of carrying NBC weapons. The Taepo Dong-1 was tested in 1998 and can certainly carry NBC weapons. Currently, the North Koreans are developing the Taepo Dong-2 with a range of 3,000 miles, which will be able to hit the US [Ref. 14]. In July 1995, and again in March 1996, China conducted tests of its DF-15 and DF-21 short and medium range ballistic missiles off the coast of Taiwan, at times as close as 20 miles from the Taiwanese coast [Ref. 5].

Today, Russia and China possess missiles capable of directly threatening the US. While both countries continue to modernize their ballistic missile forces, the US intelligence community continues to assess a deliberate, accidental, or unauthorized attack by Russia or China on the US as unlikely. While no hostile nation currently possesses the capability to threaten the US with ballistic missiles, the possibility of a limited, long-range ballistic missile threat from a third world nation sometime in the not-too-distant future, is certain (Table 2).

TABLE 2

Ballistic Missile Threat Summary

Country	Missile	Type	Range (miles)	Warhead	Status	Year
China	CSS-2 (DF-3A)	MRBM	1,700	single HE / 1-3 mT	in service	1969
	CSS-3 (DF-4)	IRBM	4,300	single 2 mT	in service	1978
	CSS-4 (DF-5)	ICBM	8,000	single 5 mT	in service	1980
	CSS-N-3 (JL-1)	SLBM	1,700	single 250 mT	in service	1983
	CSS-5 (DF-21)	MRBM	1,100	single HE / 250 kT	in service	1987
	DF-31 / JL-2	ICBM/SLBM	5,000	single nuc	in development	2000
	DF-41	ICBM	7,500	single nuc	in development	1999
India	Agni	MRBM	1,500	single HE/nuc/chem	in development	2000
Iran	Nodong-1	SRBM	600	single HE/nuc/chem	in service	1994
	Taepo Dong 1	MRBM	1,200	single HE/nuc	in service	1999
	Shihab 3 (SS-4)	MRBM	840	single HE/chem/bio	in development	2000
	Shihab 4	MRBM	1,200	single HE/chem/bio	in development	2000
North Korea	Nodong-1	SRBM	600	single HE/chem/nuc	in service	1994
	Nodong-2	MRBM	900	single HE/chem/nuc	in development	1999
	Taepo Dong 1	MRBM	1,200	single HE/nuc	in service	2000
	Taepo Dong 2	ICBM	3,000	single HE/nuc	in development	2002
Russia	SS-19 Stilletto	ICBM	6,000	Mod 3, 6 MIRV 500 kT	in service	1975
	SS-25 Sickel	ICBM	6,500	single 550 kT	in service	1985
	SS-X-27 Topol-M	ICBM	6,500	single 550 kT	in development	1999
	SS-N-8 Sawfly	SLBM	4,800	Mod 1, single 1 mT	in service	1971
	SS-N-18 Stingray	SLBM	4,000	Mod 1, 3 MIRV 200 kT	in service	1977
	SS-N-20 Sturgeon	SLBM	5,100	10 MIRV 100 kT	in service	1982
	SS-N-23 Skiff	SLBM	5,100	4 MIRV 100kT	in service	1986

[Ref. 19]

C. CURRENT MISSILE STATUS

1. China

Since the end of WWII, the US has been to war three times: Korea, Vietnam and Iraq. The East has been the hot-spot of the world for the last 40 years, and recent developments are very troubling for vital US interests in the region.

China and Russia are the only two nations that currently posses long-range ICBM missiles. These missiles can target any state in America with a NBC warhead of mass destruction. Intelligence estimates China to have approximately 200 strategic ballistic missiles. China has been a nuclear-capable nation since 1964. It has an advanced chemical warfare program including extensive RDT&E, production, and weaponization. Although China has stated it would never develop biological weapons, it does possess an advanced biotechnology infrastructure and the bio-containment facilities to conduct R&D of lethal pathogens [Ref. 5].

In recent years, China has been modernizing its ballistic missile program. China is building more missiles and launchers for its stockpile and is replacing its liquid-propellant arsenal with two new classes of solid-propellant ballistic missiles. The DF-31 will have a range of 5,000 miles and the DF-41 will have a range of 7,500 miles. Both use solid propellant and have single re-entry vehicle warheads [Ref. 18].

Intelligence reports that China has at least one Xia-Class nuclear-powered ballistic missile submarine (SSBN) in service. It carries 12 JL-1 Ship-Launched Ballistic Missiles (SLBMs), each with a range of 1,056 miles. China is also developing a new TYPE 094 SSBN that will carry 12 or more of China's newest SLBM, the JL-2, which has an estimated range of 5,000 miles [Ref. 19].

2. North Korea

North Korea is considered a greater threat to US national security and defense than China. This is not because North Korea has superior missiles, but because North Korea has been selling its ballistic missile technology, including entire missile systems, to several countries known to be very anti-American, such as Iran, Syria, and Libya. North Korea's missile program is also known to rely heavily upon Iranian financing [Ref. 3].

Like China, North Korea has an active and mature chemical weapons program. Established in the late 1980's, North Korea has accumulated a large stockpile of nerve, blister, choking, and blood agents, all of which can be weaponized into ballistic missile warheads. Unlike China, North Korea has not signed the Chemical Weapons Convention (CWC), which allows international monitoring and inspections. North Korea also has a well-established bio-weapons and nuclear weapons infrastructure. Although North Korea is a signatory of both the Bio-Weapons Convention (BWC) and the Nuclear non-Proliferation Treaty (NPT), it is believed to have a secretive weapons program to continue development and weaponization of both [Ref. 3]. North Korea is known to be very active in both the development and export of ballistic missiles. This makes them our most dangerous neighbor.

3. India

India does not currently pose a known threat to the US. India has an active space program that uses multiple stage ballistic missiles and has recently performed nuclear testing, mostly in response to Pakistani nuclear testing. India has a full range of weapons of mass destruction, but it has not yet coupled WMD technology to long-range ballistic missiles for development or testing. It appears India has all the technology necessary to create NBC weapons. However, since India is on the opposite side of the world from the US, its does not pose a current threat [Ref. 34].

4. Iran

We have formed temporary alliances with Iran in the past, but religious differences have always created a rift between Iran and the US. Iran has never hidden its hatred of the "Great Satan." Iran first began development of chemical and biological warhead technology in response to Iraqi Scud attacks during the Iran-Iraq war. Iran is believed to have several hundred tons of blister, blood and choking agents which it has imported from China and India and stockpiled [Ref. 23]. Iran has signed both the BWC and the CWC, yet it continues to upgrade and expand its chemical and biological warfare production infrastructure and weapons arsenal.

In the same tradition, Iran has signed the NPT, but NIE authorities believe Iran is pursuing a secret nuclear weapons program. Iran's close proximity to several NBC countries such as China, India, and Pakistan has motivated it to pursue NBC weapons and ballistic missile technology. It is believed that Iran has acquired both North Korean ballistic missiles currently in service - the Nodong-1 and the Taepo Dong-1. Iran also has three domestic ballistic missile programs under development - the Shihab-3, Shihab-4, and another program to develop a ballistic missile with a range of 6,200 miles [Ref. 23].

5. Russia

Tensions between Russia and the US have greatly eased since the cold war, but the nuclear arsenals of both nations have not. Both nations still possess enough strategic nuclear missiles to destroy most of the earth. Moscow has the world's largest declared stockpile of chemical agents: 40,000 metric tons. As of January 1997, the Russian stockpile of tactical nuclear warheads was estimated at 25,000 warheads, as well as a missile arsenal of 3000 to 5000 missiles with over 1,200 operational ICBM and SLBM launch platforms [Ref. 34]. Russia has come under criticism for alleged transfers of WMD and ballistic missile technology to rogue states such as Iran, and has been implicated in aiding missile programs in China, the Middle East, and South Asia.

The threat of Russian missile and WMD technology is as great as or greater than that of North Korea and China. Russia has a much better developed and deeper stockpile of ballistic missiles, and Russia is having rougher financial problems than Asia. This is the primary reason why so much assistance money flows from the US to Russia. It is in the US's best interest to keep close tabs on Russia, and prevent Russia from selling it's stockpiles to the highest bidder.

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V. CAPABILITY AND COST COMPARISON

This chapter is a cost comparison of the various proposals of the BMDO. It will compare similar system costs, such as a comparison of PAC-3 to SM-2 Block IVA and THAAD to SM-3. This chapter will also summarize available data on GBI, ABL, and SBIRS. Most data presented in this chapter is summarized in Table 3.

A. PATRIOT ADVANCED CAPABILITY-3

The FY 1999 appropriation for PAC-3 is $322.3 million for RDT&E and $248.2 million for procurement. This funding supports deployment starting in 2000. An intercept test for the PAC-3 missile was completed in the fourth quarter of FY98. Operational testing began in March 1999 [Ref. 46].

The PAC-3 Missile Engineering and Manufacturing Development (EMD) program began in October 1994. Production plans are for 1,500 missiles, 180 modified Patriot launchers, and 74 modified Patriot radars. Total production costs are estimated at $3 billion. Production of PAC-3 configuration one began in 1999 for a FUE in 2000 [Ref. 6].

B. STANDARD MISSILE - 2 BLOCK IV A

The total cost of the Navy Area BMD program is projected to be $8.98 billion, including $2.05 billion for research and development, $4.18 billion for procurement, and $2.76 billion for operation and support. At of the end of FY98, more than $1.2 billion had been appropriated for system development [Ref. 30].

Low Rate Initial Production will begin in Fiscal Year 2000, with an FUE date in Fiscal Year 2002. The Navy plans to produce 185 Block IVA missiles, 12 percent of its total planned production quantity, during LRIP. The estimated cost for these 185 missiles is $568.2 million. Each Block IVA missile is expected to have an average unit cost of about $3 million [Ref. 50]. The BMDO Fiscal Year 1999 budget appropriation for the Navy Area BMD program is $246 million for RDT&E and $43 million in procurement funds. As part of a BMDO/Navy "shared approach" for the Navy Area BMD program, the DoN has requested a plus-up in the FY 2000/01 procurement budget of $111 million.

C. THEATER HIGH ALTITUDE AREA DEFENSE MISSILE

The DoD FY 1999 budget of $853 million fully supports deployment of the THAAD system in 2006. This level of funding is required for completion of the PD&RR flight test program, continuing risk reduction for EMD, and for acquiring missiles for a UOES capability. The budget is tied to three concurrent contractual requirements. $445.3 million is slated for the extension and completion of the PD&RR flight test program and completion of the Pre-EMD risk mitigation effort. This risk reduction effort is principally focused on the design of the EMD radar and battle management software, both of which are on the critical path to achieving the FUE in Fiscal Year 2006. Another $302.9 million will be used to initiate EMD and its associated start-up costs, such as materiel orders, Government-Furnished Equipment procurement, and "turning on" five major subcontractors. Substantial portions of the EMD start-up costs are associated with the THAAD radar development and not the interceptor missile. Finally, about $105 million will be used to execute the UOES missile purchase of 40 missiles [Ref. 47]. This will provide the warfighter in FY 2001/2002 with an interim capability until the objective system is fielded. The THAAD program finally completed its scheduled test missile intercept on 10 June 1999. This will allow exercise of the UOES contract option.

In September 1992, the US Army awarded the RDT&E contract for THAAD to Lockheed Martin Missiles and Space Company at an initial contract award cost of $689 million. The terms of the contract included three complete THAAD systems comprising three GBRs, three launchers, and 20 missiles. Total production plans are estimated to call for 1,422 missiles, 99 launchers, and 18 GBR units at an estimated cost of $11.3

billion for the THAAD missiles and launchers, and $5.4 billion for the Raytheon GBRs. FY 1997 RDT&E funding was $445.3 million [Ref. 47].

Program officials state that the hit-to-kill intercept technology is sound. They have had 7 of 22 successful tests during development of the warhead. They attribute the six missed targets to basic rocketry malfunctions, not the hit-to-kill guidance. The rocketry malfunctions were caused by problems such as dust in the infrared seeker eye, a guidance wiring short, and a cable crimped in the wrong place [Ref. 4].

THAAD's record of six hit-to-kill attempts and one success bodes badly for continued developmental testing. Lockheed Martin, the lead contractor, must have two successful hit-to-kill target intercepts by 30 June 1999, or it will pay for its failure with a $20 million penalty [Ref. 19]. As of 10 May 1999, $13.9 billion has been spent on THAAD research and development. The estimated total cost for THAAD Production is $16.7 billion [Ref. 28]. As yet, THAAD production remains unfunded.

D. STANDARD MISSILE - 3

The Navy Theater-Wide BMD program is currently in the Program Definition & Risk Reduction phase of development, and has passed an initial Milestone I Defense Acquisition Board (DAB) Review. As of 4 May 1999, NTW is approved for Baseline 0 [Ref. 14]. The Navy is following an evolutionary acquisition approach consisting of an initial Block I, system followed by a more-capable Block II system.

The Fiscal Year 1999 budget request for Navy Theater-Wide is $368 million.

E. GROUND-BASED INTERCEPTOR

Future NMD funding requirements depend on how the system is designed and when and where it will be deployed. The government and prime contractor have not yet agreed on a final system design, and the deployment schedule and location will not be definitive until, at least, the fiscal year 2000 deployment review. To provide a basis for estimating funding requirements, the BMDO prepared four different life-cycle cost estimates (Figure 6), based on two deployment locations - one at Grand Forks, North Dakota, and the other in Alaska, and two capability levels - one available in 2003 and the other in 2006. An initial operating capability would be established in 2006, and the full operating capability would be achieved in 2009 [Ref. 6]. The life-cycle cost estimates show the total costs to develop and produce system components, construct facilities, deploy the system, and operate it for 20 years.

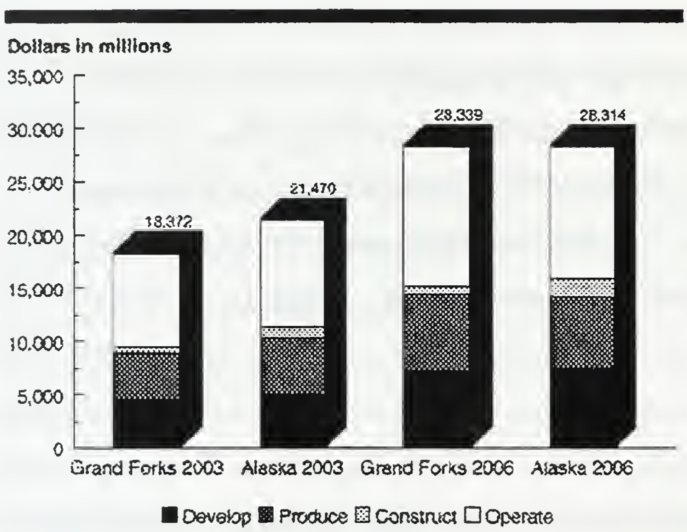

Figure 6 Ref. 6

F. AIRBORNE LASER (ABL)

The Air Force estimates the life-cycle cost of the ABL program to be about $11 billion. That estimate includes $1.3 billion for the program definition and risk reduction phase, $1.2 billion for the engineering and manufacturing development phase, $3.8 billion for the primary production phase, and $4.9 billion for 20 years of continuing production, operation, and support [Ref. 54].

G. SPACE-BASED INFRA-RED (SBIR)

DoD has estimated the SBIR research, production, and operation life cycle costs as $17.5 billion during FYs 1997-2020. Note that in Table 3 this cost total is included even though other program operation costs are not included. The SBIR program is scheduled for deployment in 2006, with 2007 through 2020 dollars being used for production [Ref. 52].

H. SUMMARY

The 1999 FYDP increased National Missile Defense System RDT&E funding by $1.4 billion, or 75 percent ($1.8 billion to $3.2 billion), from the 1998 FYDP. Despite the increase of $1.4 billion, considerable risk remains with the program's funding. For example, technical and schedule risks are very high. High technical risk is likely to cause increased costs and program delays and could cause program failure [Ref. 53]. The 1999 FYDP does not include funds to procure the missile system. If the decision were made in 2000 to deploy an initial system by 2003, billions of dollars of procurement funds would be required to augment the currently programmed research and development funds.

This chapter focuses on research, development, and production costs. There is very little data available on the operating cost these systems will require. This is because operating costs for a system not yet in operation are very hard to estimate. Table 3 is a comparison of the total costs of a BMDO proposed system to its capability. R&D and Production Costs are aggregate sums of all appropriations spent to date and an estimate of what further funding will be required for full development. The only operating cost data that were available was for the SM-2 block IVA and ABL. A comparison of capability to cost using Table 3 is problematic. The altitude, range and speed data on Table 3 are all unclassified. This means that this is not necessarily reality. A greater problem exists for this thesis in that, there is consistently significant error when calculating out-year data. An estimate for money that will be spent in 2009 has a great chance for error. At best, if all the data is estimated consistently, then comparing the estimated data will yield correct conclusions. For example, the exact maximum altitude that the PAC-3 and SM-2 Block IVA can reach is not known, but their unclassified data are similar. Therefore we can conclude that the capabilities of the missile are similar.

TABLE 3

BMDO Program Missile Capabilities and Costs

Missile ($ in billions)	Max Altitude (Miles)	Max Range (Miles)	Speed (Mach)	FUE	R&D	Production	Total
PAC-3	15	100	5	2000		$ 3.00	
SM-2 Block IVA	20.5	150	2.5+	2002	$ 2.05	$ 4.18	$ 6.23
THAAD	93	125+	7.5	2006	$ 13.90	$ 16.70	$ 30.60
SM-3	76+	260+	12	2007	$ 4.00		
GBI	76+	1000+	12+	2009	$ 7.50	$ 7.50	$ 28.30
ABL	~25	300	INF	2006	$ 2.50	$ 3.80	$ 6.30
SBIRS	Unlimited	300+	INF	2006	$ 3.30		$ 17.50

BMDO Budget Highlights

Appropriation ($ in millions)	FY 98 Appropriated	FY 99 Appropriated	FY 00 Requested	FY 01 Projected	FY 02 Projected	FY 03 Projected	Total
RDT&E							
PAC-3	$ 206.0	$ 322.3	$ 29.1	$ -	$ -	$ -	$ 557.4
SM-2 Block IVA	$ 290.0	$ 245.8	$ 268.4	$ 158.3	$ 52.4	$ 38.0	$ 1,052.9
THAAD	$ 406.0	$ 445.3	$ 611.6	$ 584.6	$ 413.9	$ 377.7	$ 2,839.1
SM-3	$ 410.0	$ 368.4	$ 329.8	$ 191.0	$ 145.0	$ 149.0	$ 1,593.2
NMD	$ 978.0	$ 1,550.5	$ 836.6	$ 1,718.0	$ 1,889.0	$ 1,714.0	$ 8,686.1
Other	$ 1,095.0	$ 972.2	$ 868.9				
Total	$ 3,385.0	$ 3,904.5	$ 2,944.4				
Procurement							
Pac-3	$ 349.0	$ 248.2	$ 300.9	$ 445.4	$ 433.1	$ 396.8	$ 2,173.4
SM-2 Block IVA	$ 15.0	$ 43.3	$ 55.0	$ 316.6	$ 412.5	$ 423.8	$ 1,266.2
BM/C3	$ 20.0	$ 22.8	$ -	$ -	$ -	$ -	$ 42.8
Total	$ 385.0	$ 314.3	$ 355.9				
MILCON							
Total	$ 3.0	$ 10.0	$ 1.4				
			[Ref. 47]				[Ref. 5]

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VI. CONCLUSIONS AND RECCOMENDATIONS

A. CONCLUSIONS

The intent of this thesis was to determine which, if any, missile technologies were needed to research, develop, and produce the components needed for a cost-effective NMD. The original hypothesis was that no technology was needed and a currently available SM-2 block IV missile could perform the mission of NMD. The SM-2 IV is a relatively slow, fragmentation warhead, that simply will not intercept and destroy ICBMs.

The SM-2 Block IVA is the lower-tier interceptor missile which is almost fully developed and is in Low Rate Initial Production for a FUE in 2002. The PAC-3 and SM-2 Block IVA were both developed and are being produced at Raytheon. This has allowed the DoD a significant cost avoidance and should be the model for the SM-3 and THAAD missiles.

The upper-tier missiles, SM-3 and THAAD, are continuing separate development, primarily because the Navy will not use a liquid propellant rocket motor for fire and safety reasons. The Army is not constrained to keep its THAAD missiles close together, as the Navy must do, and can produce a more capable rocket with liquid fuel. The kill-vehicle or warhead of the two missiles will share an 85% commonality, which will save over $150 million [Ref. 51].

The lower-tier and upper-tier missiles are intended to be developmental steps toward building a Ground-Based Interceptor missile. Most of the information on the capability of the GBI is classified.

A primary question in researching this thesis was: If ground-based exo-atmospheric defense missiles are necessary, why reinvent the wheel? Why not use an Aegis/SPY Radar system controlled by a Linebacker computer, and SM-2 block IVA (and later SM-3) missiles in an earthen VLS silo? The problem with this approach is the range of the interceptor missile. The SM-2 and SM-3 will, at best, be capable of protecting a 500 to 700 mile diameter circle of earth. It is intended that the North Dakota GBI site will protect all of the US from one central site. Consequently the GBI will be a very large missile that will likely have to be transported in segments by truck or train. The Ground-Based Radar will be five stories tall. In order to implement a multi-site NMD using Aegis and SM-2/3 technology, DoD would have to build a grid of sites spanning the US.

Is THAAD a necessary procurement? In most cases it is not. Since THAAD and SM-3 will have very similar capabilities, SM-3 can perform the role of Theater Missile Defense if it is in close enough proximity to the forces needing protection. In Korea, Vietnam, the Persian Gulf, and Kosovo, the SM-3 missile would have been in close enough proximity to provide theater missile defense. It is only in conflicts where the confrontation is significantly inland and out of the range of SM-3 and Aegis that THAAD would be required.

THAAD does have an obvious advantage over SM-3 in performing the role of NMD. THAAD can be deployed throughout the US until GBI missile development and production is complete. THAAD could protect the interior of America, while SM-3 could only provide a coastal NMD. If THAAD must be built, then why build a proprietary THAAD Ground-based radar? By using existing SPY/Aegis Radar technology, the THAAD program could convert an existing phased array radar into a portable THAAD GBR and avoid the cost of creating a compete new production line.

In the 1990s, the US seems to have taken on the role of the police force for the world. The current, worldwide US Navy infrastructure provides an opportunity for the US to control the ICBM threat to a large percentage of the world. The US Navy currently has Aegis ships in Everett, WA; San Diego, CA; Pascagula, MS; Mayport, FL; Norfolk, VA; Pearl Harbor, HI, and Yokosuka, Japan. They maintain a constant presence in the Persian Gulf and, recently, a presence in the Adriatic Sea. The US maintains Navy bases in Guam; Concord (SF), CA; Seal Beach (LA), CA; Grotton, CT; Charleston, NC; Key West, FL; New Jersey; Rota Spain; Naples, Italy; Sasebo, Japan and Bahrain. Just putting SM-3 missiles on Aegis ships and networking data with space assets will provide the US and its forces with a worldwide NMD and TBMD presence.

An analysis of TABLE 3 reveals that THAAD has greater altitude but less range than SM-3. This is an anomaly in that these are the manufacturers unclassified capabilities. In reality, SM-3 and THAAD will likely have similar capabilities, just as PAC-3 and SM-2 Block IVA have similar capabilities today. This thesis attempts to hypothesize cost avoidance by not procuring alternate missile systems. The incremental approach of developing and producing first an upper-tier BMD system and next an upper-tier BMD system to ultimately develop the Ground-Based Interceptor missile that can protect all of the US seems reasonable. In examining the development paths in this case the redundancy becomes immediately clear. PAC-3 and THAAD are very redundant of SM-2 block IVA and SM-3.

B. RECOMMENDATIONS

1. Overcome the ABM treaty and Create a Multi-Site NMD.

Under the proposals of the BMDO, a Ground-Based Interceptor single-site NMD can not be deployed until 2009. A SM-2 Block IVA multi-ship coastal NMD could be deployed by 2002 and upgraded to SM-3 by 2007. A THAAD based CONUS multi-site NMD could be deployed by 2007. Any multi-site ABM defense proposal is in violation of the 1972 ABM treaty [Ref. 1]. The US should eliminate the ABM Treaty or pursue negotiations to amend the ABM Treaty to permit:

- Multiple sea and ground-based interceptor sites.
- Unrestricted use of ABM sensors regardless of location.
- Unrestricted testing of ABM systems at observable test ranges.

By combining NMD with efforts to improve security at borders and ports of entry, the US will counter terrorist NBC strikes and significantly raise the expense and risks to potential NBC attackers. A few 'suitcase' bombs or a handful of strategic missiles will no longer be sufficient to guarantee strikes on the US [Ref. 25]. Arsenals that are substantial, sophisticated, and costly will be required. Some potential NBC aggressors might forgo pursuing a long-range strike option, while others might face significant delays in their ability to deploy significant arsenals. As for countries that do retain or acquire strategic arsenals, the US will have greater flexibility to deal with them if we are secured against limited threats. America's force projection capability, which is vital to implementing US global strategy, can only be maintained if the US is protected.

A far-reaching agenda with NMD as its centerpiece might seem unrealistic. But even a few steps in this direction would be worth the effort. In the early 1990s, Moscow and Washington began unprecedented talks on BMD cooperation, and Washington and Beijing took important steps toward initiating a strategic dialogue as well. Ballistic missile attacks during the 1991 Persian Gulf War prompted heightened global interest in tactical and strategic defenses, especially on the part of some US allies [Ref. 21]. The foundation is already in place and ready to support expanded, even global, BMD deployments.

The US faces a stark reality as it nears the twenty-first century. The country's vulnerability invites ballistic missile attack. In addition to putting the American people at risk, this threat might cripple the country's ability to join with its allies in leading the world toward a new international security framework. Failure in this mission will ensure that the world is an increasingly dangerous place in the future.

The decisions to invest in protection against future threats are not easy. Indeed, history records the plight of countless nations that pursued fragmented defense policies and failed to see disaster until it knocked on their door. The United States can avoid adding its name to this list by endorsing strategic defense and BMD in the nation's defense doctrine and force posture.

As development continues it is becoming apparent that the development costs of a single-site, Ground-based interceptor and missile system is going to be astronomical. The driver in this proposal is the 1972 ABM treaty. By eliminating this treaty the US can create a multiple-site NMD using nearly completed technology such as PAC-3, SM-2, THAAD, and SM-3, and avoid the great expenditures that will be required for GBI/GBR development and production.

2. Upgrade our Current NMD Defense Assets.

The Linebacker upgrade should be implemented on all Aegis ships. It is estimated that approximately $115 million dollars is required to bring all Aegis radar computers up to the minimum level for the 6.3 baseline prerequisite to integrate the Linebacker upgrade [Ref. 13]. The Linebacker upgrade requires the integration of millions of lines of software code into the Aegis AN/UYK-7 computers. The AN/UYK computers use early 1980's technology. They are essentially Intel 8088 10-Mhz computer processors. It is essential that all Aegis ships be capable of performing Area and Theater BMD. The only question is how to bring all Aegis ships up to the 6.3 baseline.

3. Linebacker Upgrade Should Integrate the COTS Program.

Current DDG-51 Arleigh Burke class destroyers cost about $1 billion each to build and about $9,000 each hour to operate [Ref. 7]. Yet the AN/UYK-7 computers onboard the DDG-51 use 8088 10-Mhz computer CPUs. A current Pentium III 550-Mhz Central Processing Unit is at least 55 times more powerful than the older 8088. Pentium III – 550 CPUs cost around $800 each, with prices dropping every day.

The Computer Off-The-Shelf (COTS) program is an effort to reduce production costs of all military computers by moving away from custom-built computer chips toward standard, commercially-available, competitively-priced computer hardware. This program will be part of the DD-21 and CG-21 programs, and it should be part of the Navy Area and Theater-Wide BMD programs as well.

4. Implement Coastal NMD.

SM-2 IVA can perform effective coastal NMD by intercepting ICBMs launched at the US. All inbound ICBMs must pass through the SM-2 block IVA missile's intercept envelope prior to hitting targets near the coast. THAAD will not be ready any earlier than 2006, while SM-2 IVA will be ready by 2002.

The current proposal is to place all of the LRIP SM-2 block IVA missiles on Lake Erie and Port Royal for continued testing and development of Navy Area TBMD technology [Ref. 50]. This will likely accelerate the full development of the SM-2 missile and assist with the development of the SM-3, but it will negate an early advantage of the SM-2 Block IVA missile. US Navy bases are evenly distributed to the corners of the US. There are naval bases in Everett, WA; San Diego, CA; Pascagula, MS; Mayport, FL; Norfolk, VA; and Grotton, CT. By distributing the LRIP SM-2 missiles to Aegis cruisers and destroyers already home-ported at these bases, and then linking those ships with ICBM threat data cueing from NORAD, the US will have a viable coastal NMD in the near future, four years earlier than either THAAD or GBI can deliver.

5. Cueing Threat-Axis Data to Aegis Ships.

Using existing technology there are sufficient assets for effective detection of ICBM launches and monitoring of space. NORAD already has the space surveillance technology, assets, and personnel in place to detect and track inbound ICBMs. This has been NORAD's primary mission for the last 20+ years [Ref. 12]. It would take little more than a high-speed, encrypted Internet connection to allow NORAD to pass target threat-axis data to Navy ships in port around the country. The Aegis cruisers and destroyers could then activate their radars, lock onto the ICBMs, and launch interceptor missiles.

6. Upgrade Our Ally's Defense Technology.

The Japanese Navy should receive SM-2 Block IVA technology as soon as possible. Japanese Aegis destroyers are already in good positions to intercept and destroy ICBMs before they become a threat to the US. The Japanese Navy has long been a part of Aegis. They have several Congo Class destroyers, which are very similar to US Navy Arleigh Burke class destroyers. These destroyers integrate the latest Aegis technology and upgrades. The Japanese have given the US DoD $100 million to participate in development and production of the SM-2 Block IVA [Ref. 14]. It is logical to place these missiles (and eventually SM-3 missiles) on Japanese destroyers. Japan is in an excellent position to intercept ICBM missiles bound for the US.

7. DD-21 and CG-21 Program Integration of SPY/Aegis Technology.

The US Navy DD-21 land attack destroyer program is scheduled to begin replacing today's aging DD-963 class destroyers and FFG-7 class frigates, starting in 2010 [Ref. 41]. The plan is to buy thirty-two DD-21 destroyers at a total cost of $25 billion. The price-per-ship cost cap of $750 million for each destroyer would apply after the fifth destroyer. Because the DD-21 is designated as a land attack destroyer and because the two ship classes it is replacing do not have Aegis, the Aegis / SPY radar system is not a current requirement for the DD-21 program. Because integration of the Aegis combat system into DD-21 is cost-prohibitive and will likely exceed the $750 million cost cap, it is estimated that there is only a 50% chance that Aegis will be part of DD-21 [Ref. 7].

If the Navy is going to conduct the missions of Area BMD, Theater-Wide BMD, and Coastal NMD, then it is imperative that the DD-21 integrate the Aegis combat system. As TBMs proliferate, there is a greater chance they will be used in regional and littoral warfare against our own troops. The DD-21 land attack destroyer will play a major role in the defense of US Marines going ashore. If the DD-21 is to provide a credible defense, it needs to have the ability to intercept area and theater ballistic missiles.

APPENDIX A: SUMMARY OF ABM TREATY RESTRICTIONS

Signed at Moscow on 26 May 1972

Entered into force on 3 October 1972

Treaty is specifically between Russia and the US. No other countries have signed or were involved in the ABM treaty.

Article I

Neither the US nor Russia will deploy ABM systems for defense of the territory of its country or defense of an individual region except in specific defense of a national capital or an ICBM silo installation.

Article III

An ABM system in defense of a national capital or ICBM silo installation shall be no larger than a 150 km deployment area, with no more than one hundred ABM missile launchers, and no more than two large phased-array radar.

Article V

Neither Russia nor the US will develop, test, or deploy ABM systems or components which are sea-based, air-based, space-based, or mobile land-based. And no ABM system will be capable of launching more than one ABM interceptor at a time.

Article VI

Not to deploy radar for early warning of strategic ballistic missile attack except along the periphery of its national territory.

Article IX

Not to deploy ABM systems or components outside national territory.

Article XV

This treaty shall be of unlimited duration unless parties choose to withdraw.

Signed by Richard Nixon, President of the US and L.I. Brezhnev, General Secretary of the Central Committee of the CPSU. [Ref. 1]

List of References

1. Arms Control and Disarmament Agency, "Official Text: Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems." 26 May 1972. Washington D.C.: US Arms Control and Disarmament Agency, Office of Public Information.

2. Berstein, Richard and Ross, H. Munroe. 1997. *The Coming Conflict with China.* New York: Alfred A. Knopf.

3. Blanche, Bruce. "Scud Development in North Korea." *Jane's Intelligence Review and Sentinel Pointer*, (December 1996): 9.

4. David, Mulholland, "THAAD Failure Worth $20 Million," *Defense News*, v. 14 no. 18, pp.2, 10 May 1999

5. Defense Monitor. "Concern About "Star Wars" Missile Defense." *The Defense Monitor* v. 28 no. 1, Center for Defense Information, Washington, DC.: 1999.

6. Emery, Curtis H., Brig Gen., USAF, Deputy For Theater Air And Missile Defense (Acting) BMDO. BMDO Advance Planning Briefing. *Theater Air and Missile Defense "Progress To Deployment"*. Presented To The BMDO's Advance Planning Briefing For Industry. 1 May 1997.

7. Erwin, Sandra I. "New Combatant Reinforces Navy Role in Land Warfare." *National Defense*. January 1999.

8. High Frontier. "North Korea Fires Missile Over Japan: Rumsfeld Report Vindicated." *High Frontier Magazine*. Strategic Issues Policy Brief No. 16, 4 September 1998.

9. Hildreth, S.A., National Missile Defense: The Current Debate. Library of Congress Research Service. 7 June 1996.

10. Holzer, Robert. "Pentagon, Navy Pins Down Costs of TMD Program." *Defense News*, v.14 no.5, pp.4, 19 April 1999.

11. Hootoon, E.R., ed. 1998. *Jane's Naval Weapon Systems.* Alexandria: Jane's Information Group.

12. Interview between Alan A. Ross, Dr, TENCAP Visiting Chair Professor at the Naval Postgraduate School, Monterey, CA., and the author, 28 May 1999.

13. Interview between Chris Atkinson, LT, SWO, USN, former Navigator / Air Warfare Commander on USS Sanusinto (CG-56) Ticonderoga Class Aegis Cruiser, Monterey, CA., and the author, 28 May 1999.

14. Interview between Hamilton, G., CAPT, SWO, USN, Deputy Assistant Secretary of the Navy's Office. Guest Speaker at Surface Navy Association Annual Symposium. *TBMD on the Horizon*. Monterey, CA., and the author, 6 May 1999.

15. Interview between James Lee Jr., LT, SWO, USN, former Fire Control Officer / Tactical Action Officer of USS Bunker Hill (CG-52) Ticonderoga Class Aegis Cruiser, Monterey, CA., and the author, 20 May 1999.

16. Interview between Scott Scieretta, LT, SWO, USN, former FCO/TAO of USS Cowpens (CG 63) Ticonderoga Class Aegis Cruiser, Monterey, CA., and the author, 11 May 1999.

17. Keenan, J.M., *Overcoming the ABM Treaty: Paths to National Missile Defense,* Master Thesis, Naval Postgraduate School Monterey, California, June 1998.

18. Lamson and Bowen, "One Arrow, Three Stars: China's MIRV Programme, Part Two." *Jane's Intelligence Review*. v. 9 no. 6, pp. 266-269, June 1997.

19. Lennox, Duncan, ed. 1998. *Jane's Strategic Weapon Systems*. Alexandria: Jane's Information Group.

20. Lyles, L.L., General, USA, "National Missile Defense." Statement before Subcommittee on Defense Appropriations, U.S. Senate. 22 April 1998.

21. McMahon, S., "Pursuit of the Shield – The US Quest for Limited BMD. *Pacific-Sierra Research Magazine*, April 97.

22. Pike, John. "National Missile Defense." *Special Weapons Monitor*. FAS – Space Policy Project. 14 July 1998.

23. Rathmell, "Iran's Missiles Come Under Fire." *Jane's Intelligence Review and Sentinel Pointer*. pp. 5, December 1997.

24. Sharpe, R. CAPT, ed. 1998. *Jane's Fighting Ships*. Alexandria: Jane's Information Group.

25. Spector, L.S. "Strategic Warning and New Nuclear States." *Defense Intelligence Journal*, v.7 no.2, Fall 1998.

26. Starr, Barbara "USA Moves to Block Weapons Danger." *Jane's Defense Weekly*, Vol. 28, No. 19, (12 November 1997): 40.

27. U.S. Department of Defense. Ballistic Missile Defense Office. *National Missile Defense (NMD) Deployment Concept*. BMDO Fact Sheet NMD Objectives, November 1998. Washington D.C.: BMDO.

28. U.S. General Accounting Office. *Ballistic Missile Defense: Improvements Needed In THAAD Acquisition Planning*. Report to the Secretary of Defense, GAO/NSIAD-97-188. Washington D.C.: September 1997.

29. U.S. Congress. House. *Defend America Act of 1996.* 104th Congress, 2nd Session. 21 March 1996.

30. U.S. Congressional Budget Office., "CBO Analysis of the President's Budgetary Proposals for Fiscal Year 2000." Congressional Budget Office. April 1999.

31. U.S. Department of Defense. Ballistic Missile Defense Office. *History of the BMDO.* BMDO Fact Sheet SR-99-01, April 1999. Washington D.C.: BMDO.

32. U.S. Department of Defense. Ballistic Missile Defense Office. *National Missile Defense Program Evolution.* BMDO Fact Sheet JN-98-04, March 1998. Washington D.C.: BMDO.

33. U.S. Department of Defense. Ballistic Missile Defense Organization. *Theater High Altitude Area Defense System.* BMDO Fact Sheet AQ-99-05, March 1999. Washington D.C.: BMDO.

34. U.S. Department of Defense. Office of the Secretary of Defense. *Proliferation: Threat and Response*. Washington. D.C.: GPO, November 1997.

35. U.S. Department of Defense. Ballistic Missile Defense Office. *Ballistic Missiles and the World Security Environment.* BMDO Fact Sheet DSI-98-01, June 1998. Washington D.C.: BMDO

36. U.S. Department of Defense. Ballistic Missile Defense Office. *Ballistic Missile Defense – The Core Programs.* BMDO Fact Sheet AQ-99-01, February 1999. Washington D.C.: BMDO.

37. U.S. Department of Defense. Ballistic Missile Defense Office. *Ballistic Missile Defense Organization Budgetary History.* BMDO Fact Sheet PO-99-02, April 1999. Washington D.C.: BMDO.

38. U.S. Department of Defense. Ballistic Missile Defense Office. *Ballistic Missile Defense Organization Budgetary History.* BMDO Fact Sheet PO-99-02, April 1999. Washington D.C.: BMDO.

39. U.S. Department of Defense. Ballistic Missile Defense Office. *Ground Based Interceptor.* BMDO Fact Sheet, November 1998. Washington D.C.: BMDO.

40. U.S. Department of Defense. Ballistic Missile Defense Office. *National Missile Defense Program Architecture.* BMDO Fact Sheet JN-99-06, March 1999. Washington D.C.: BMDO.

41. U.S. Department of Defense. Ballistic Missile Defense Office. *Missile Defense Investment.* BMDO Fact Sheet PO-99-03, April 1999. Washington D.C.: BMDO.

42. U.S. Department of Defense. Ballistic Missile Defense Office. *Navy Area Ballistic Missile Defense.* BMDO Fact Sheet AQ-98-01, September 1998. Washington D.C.: BMDO.

43. U.S. Department of Defense. Ballistic Missile Defense Office. *Navy Theater Wide Ballistic Missile Defense.* BMDO Fact Sheet AQ-99-03, February 1999. Washington D.C.: BMDO.

44. U.S. Department of Defense. Ballistic Missile Defense Office. *Patriot Advanced Capability – 3.* BMDO Fact Sheet AQ-99-04, February 1999. Washington D.C.: BMDO.

45. U.S. Department of Defense. Ballistic Missile Defense Office. *Patriot Advances Capabilities –3: Missile Defense Program.* BMDO Fact Sheet AQ-98-04, March 1998. Washington D.C.: BMDO.

46. U.S. Department of Defense. Ballistic Missile Defense Office. *Patriot Advanced Capability – 3: System Flight Test Program.* BMDO Fact Sheet AQ-99-09, February 1999. Washington D.C.: BMDO.

47. U.S. Department of Defense. Ballistic Missile Defense Office. *The Ballistic Missile Defense Fiscal Year 1999 Budget.* BMDO Fact Sheet PO-99-01, April 1999. Washington D.C.: BMDO.

48. U.S. Department of Defense. Ballistic Missile Defense Office. *Theater High Altitude Area Defense System Flight Test Program.* BMDO Fact Sheet AQ-99-08, February 1999. Washington D.C.: BMDO.

49. U.S. General Accounting Office. *Ballistic Missile Defense: Issues Concerning Acquisition of THAAD Prototype System.* Report to the Congressional Committees, GAO/NSIAD-96-136. Washington D.C.: July 1996.

50. U.S. General Accounting Office. *Ballistic Missile Defense: Improvements Needed in Navy Area Acquisition Planning.* Report to the Secretary of Defense, GAO/NSIAD 98-34. Washington D.C.: November 1997.

51. U.S. General Accounting Office. *Ballistic Missile Defense: More Common Systems and Components Could Result in Cost Savings.* Report to the Secretary of Defense, GAO/NSIAD-99-101. Washington D.C.: May 1999.

52. U.S. General Accounting Office. *National Missile Defense: Risk and Funding Implications for the Space-Based Infrared Low Component.* Report to Congressional Committees, GAO/NSIAD-97-16. Washington D.C.: February 1997.

53. U.S. General Accounting Office. *National Missile Defense: Schedule and Technical Risks Represent Significant Developmental Challenges.* Report to Congressional Committees, GAO/NSIAD-98-28. Washington D.C.: December 1997.

54. U.S. General Accounting Office. *Theater Missile Defense: Significant Technical Challenges Face the Airborne Laser Program.* Report to the Ranking Minority Member, Committee on National Security, House of Representatives, GAO/NSIAD-98-37. Washington D.C.: October 1997.

55. U.S. General Accounting Office. *Foreign Missile Threats: Analytic Soundness of National Intelligence Estimate 95-19.* Testimony before the Select Committee on Intelligence, U.S. Senate, GAO/T-NSIAD-97-53. Washington D.C.: December 1996.

56. Central Intelligence Agency. NIE 95-19: Independent Panel Review of "Emerging Missile Threats to North America During the Next 15 Years" (Unclassified Version). OCA 96-1908, 23 December 1996.

57. Wired. "Target goes boom." *Wired Magazine Online.* [http://www.wired.com/news/news/business/story/20132.html]. 11 June 1999.

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