AIR WAR COLLEGE

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"HEADS, NOT TAILS"

HOW BEST TO ENGAGE

THEATER BALLISTIC MISSILES?

by

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ABSTRACT

Defending against theater and intercontinental ballistic missiles, potentially carrying nuclear, biological or chemical weapons, requires 100% effectiveness—anything less continues to afford our enemies weapons of mass effect. If the U.S. is to be successful in answering this threat, a re-evaluation of boost phase intercept (BPI) options is in order. This paper highlights the ballistic missile threat and joint defense systems; provides an assessment of those systems; re-evaluates BPI merits; and proposes a kinetic boost phase solution (with concept of operations) to bridge the potential fielding of space-base weapons. Early engagement provides better, faster, cheaper and less destabilizing missile defense capability. "Heads, not tails" sounds a call to the Missile Defense Agency, Strategic Command and all Services to commit to producing BPI capability (first kinetic, then directed energy), ahead of other systems and upgrades.

Chapter 1

Introduction

9/11 refocused the United States on defense. President Bush's "axis of evil" description accurately drew a line between those states that would use or support the use of terrorism and Weapons of Mass Destruction (WMD), and those states that will not allow that threat to remain unanswered. History and future threat assessments all point to delivery of WMD by ballistic missiles. Defending against theater and intercontinental ballistic missiles (TBM/ICBM), potentially carrying nuclear, biological or chemical weapons, requires 100% effectiveness—anything less continues to afford our enemies weapons of mass effect—where panic and uncertainty magnify any destructive capability. If the U.S. is to be successful in answering this threat, a re-evaluation of boost phase intercept (BPI) options is in order.

In 2003, the US officially withdrew from the 1972 Anti Ballistic Missile Treaty in pursuit of a National Missile Defense (NMD). The architecture is based primarily on Army/Navy terminal and midcourse defense systems, augmented by Air Force BPI directed energy weapons, e.g., the Airborne Laser (ABL). Migration to space-based weapons and ground-based BPI kinetic energy weapons are planned. Although this approach is logical programmatically, it demands hundreds of billions of dollars, runs counter to Air Force global power force posture, and delivers too little defense, too late

(2020 and beyond). Current acquisition strategies are attacking this combat deficiency from the tail rather than head-on, and recently, seem more focused on the easier and less likely threat of ICBMs. The TBM threat is global. It is the more compelling ballistic missile threat to the U.S., its allies, and its national interests. It is technically more difficult to counter due to: compressed engagement timelines inherent to shorter range missiles, and detection and tracking problems associated with the large numbers of tactically mobile weapons available to both nation states and terrorist groups. The Missile Defense Agency (MDA) must completely address the theater challenges if it ever hopes to have a truly effective national missile defense.

Although, America and our allies can applaud the technical progress of the last decade, the ballistic missile threat remains largely unanswered. It appears the 2005 Quadrennial Defense Review will slowly deliver the death knell to the airborne laser. The Air Force's ability to fulfill its assigned boost phase mission is again in jeopardy. The gap between capability and national strategy just got more pronounced. President Bush introduces the National Security Strategy with this statement,

> The gravest danger our Nation faces lies at the crossroads of radicalism and technology. Our enemies have openly declared that they are seeking weapons of mass destruction, and evidence indicates that they are doing so with determination. The United States will not allow these efforts to succeed. We will build defenses against ballistic missiles and other means of delivery.[1]

A critical capability to effectively counter this growing "crossroad" threat describes boost phase intercept.

This paper advocates a re-evaluation of BPI options to secure an air-launched kinetic energy weapon capability within five years. Specifically, it sounds a call to MDA, Strategic Command (STRATCOM) and all Services to commit to producing BPI capability (first kinetic, then directed energy), ahead of other systems and upgrades. This paper will highlight the ballistic missile threat and joint defense systems; provide an assessment of current NMD systems and deficiencies; re-evaluate BPI merits; and propose a kinetic boost phase solution with concept of operations (CONOPS) to bridge the potential fielding of space-base weapons. The compulsory tasks to achieve BPI will require national determination analogous to our pursuit to walk on the moon, where Yankee ingenuity and drive prevailed. Negating the effects of this global TBM threat is a constitutional imperative, for it forms the foundation for an effective national missile defense.

Chapter 2

Background—Threats and Joint Systems

The Scud was a clumsy, obsolete Soviet missile…in the grand scheme of warfare, a mosquito. However, the Scud was effective as a terror weapon against civilian populations. General Norman H. Schwarzkopf, *It Doesn't Take a Hero*

The U.S. and Coalition forces were far from effective in neutralizing the first Gulf War TBM threat. More accurate performance, saturation attacks, or even a single WMD impact would have tainted and delayed our victory, or even "made it virtually impossible for us to resist an enemy offensive or mount an effective counterattack." [2] Appendix A highlights our Gulf War Scud experiences. That was nearly fifteen years ago, and yet it came as a surprise—despite the fact that tens of thousands of V-1 "buzz bombs" and V-2 ballistic missiles were launched against the allies by the Germans over 60 years ago.

The more pertinent questions now are how has the threat evolved since the Gulf War and how is it likely to be employed? The majority of the world's TBMs are in the 300-600 km range class. North Korea, China, and the former Soviet states are the largest exporters. Non-democratic clientele such as Iran, Syria, Libya, Pakistan, and the potential for Venezuela to emerge as a rogue state, reflect national security concerns. There are four tendencies in TBM development: greater range (in excess of 1000 km), much greater accuracy, multiple warheads/decoys, and proliferation of WMD. According to the Central Intelligence Agency, 25 countries have, or may have, TBMs with mass destruction capability,[3] and the Rumsfield report states 15 nations have ICBMs.[4] Appendix B provides a depiction of this growing ballistic missile threat. The imminent threat is not so much the missiles themselves, but rather, the proliferation of WMD warheads and those that fractionate (split into multiple sub-munitions) prior to apogee.

The Ballistic Missile Defense Organization (BMDO), predecessor to the MDA, was established to manage and integrate the individual Service's active defense programs into an effective missile defense capability.[5] Figure 1 provides an excellent overview of the entire theater engagement envelope and common active missile defense terms (also listed in Appendix C).

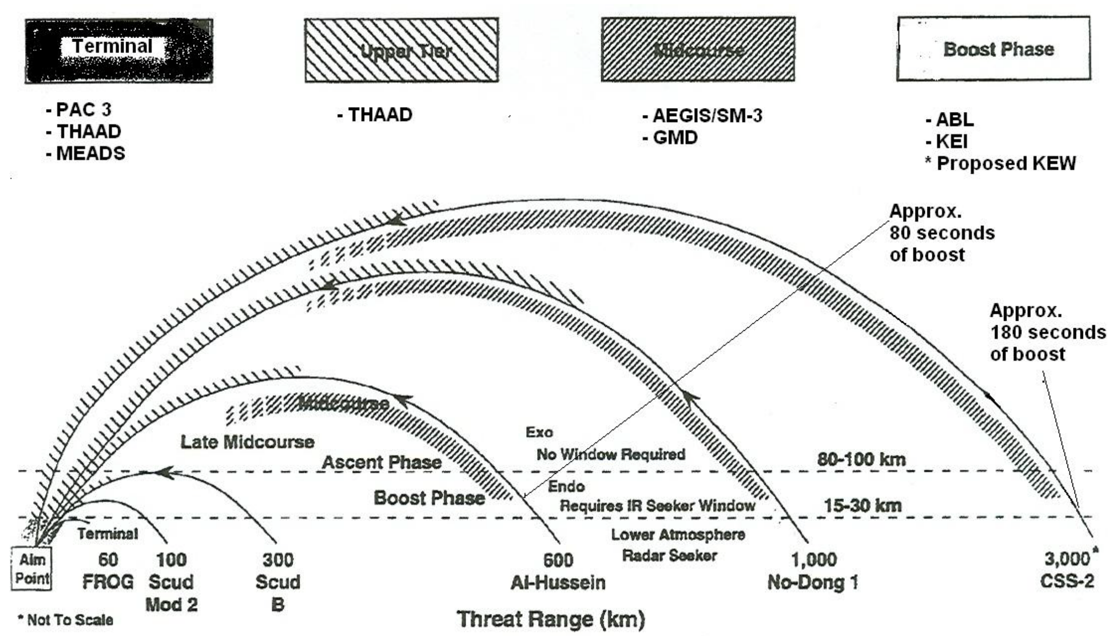


Figure 1.[6] **MDA TMD Program Candidates and Engagement Envelope**

This chapter will review each phase of intercept (terminal—"the tail", midcourse, and boost phase—"the head") and the associated weapon systems—some of which are fielded and others of which are in various stages of development—and , lastly sound a renewed call for a kinetic solution.

The emerging, and often asymmetric, world powers are gaining ICBM technologies in the "econo" version. The defense investment strategies of these countries are not slanted to the glamour of fighters, rather to the practicality of TBMs and cruise missiles. Additionally, transnational terrorist organizations are openly pursuing this same TBM and WMD capability. In today's plausible scenarios, the terminal defense approach can be easily overwhelmed with saturation, decoys, and countermeasures, and thus is woefully inadequate—it kills too few, too late. Our National Security Strategy reflects a belief that our national interests are more likely to be threatened by regional conflicts and terrorism, than by a direct military conflict with one of the major world powers. How to prevent and/or respond to regional TBM escalation is a prerequisite building block to a viable missile defense at home and abroad.

The only success in halting ballistic missile launches in WW II and the Gulf War was to overrun the launch site on the ground with ground forces—air attack proved completely ineffective. Since occupying territory at the initial phase of conflict is unrealistic, ballistic missiles have to be dealt with in flight. The correct means to counter a TBM attack that attempts to overwhelm a defensive architecture is defense in depth. "The 1999 Defend America Act requires a missile defense deployment to be augmented over time to provide a layered defense against larger and more sophisticated threats."[7] Commonly referred to as "shoot-look-shoot," defense in depth provides multiple opportunities to negate the TBM, thereby statistically increasing the probability of kill (P_k), and forces the enemy to develop multiple countermeasures. "TBMs should be engaged by all means available throughout their entire flight profile."[8] All TBM launches must be detected, each missile tracked, identified as a hostile threat, successfully engaged, and this information shared with all Command and Control (C2) and Intelligence, Surveillance, Reconnaissance (ISR) assets to determine battle damage assessment and the need for subsequent engagements.

Building multi-layered missile defense capability is a joint endeavor and paramount to victory. Ballistic Missile Defense Organization (BMDO) took the approach to begin acquisition of systems with low-to-moderate development risk (Army terminal and Navy midcourse systems), versus perceived higher technical risk (Air Force BPI systems).[9] BMDO's FY1994-99 investment resulted in $12-14 billion for terminal defense and less than $100 million for boost phase.[10] In July 2001, Lt Gen Kadish, MDA Director, introduced the Bush administration's missile defense plan, which requested significant funding increases, announced withdrawal from the 1972 Anti-Ballistic Missile Treaty, eliminated the distinction between national and theater missile defense focused on development of a "layered" capability, and introduced an evolutionary untried open-ended acquisition process to "deal with unprecedented technical challenges" that will "deploy over time different combinations of sensors and weapons consistent with our national strategic objectives."[11] Starting in 2002, much of the program performance specifics became classified; therefore, the following discussions only draw data from open sources. The FY2003 MDA budget increased to $7.6 billion; FY2004 to $9.1 billion; FY2005 to $9.95 billion; and most recently, the House approved $8.58 billion for FY2006.[12] The following provides a brief description of where the money was invested and the resulting fielded capability. Chapter 3 will provide an analysis of this "evolving" missile defense architecture. The official **www.mda.mil** web site provides an excellent unclassified source of systems, progress, and issues.

In the words of former Air Force Chief of Staff, General Fogleman, **terminal defense** uses "the catcher's mitt approach"—the enemy pitches, we catch. The window of terminal engagement of warheads and decoys falling back into the atmosphere is 30 to 60 seconds. The kill mechanism is a kinetic hit to kill—a "bullet hitting a bullet." MDA terminal defense systems currently include the following systems.

1. Patriot Advanced Capability (PAC-3) is an improvement to the Patriot radar and missile system. It provides improved acquisition, identification, lethality, and an expanded engagement envelope. It is predominantly a point defense capability, i.e., defends a city, base or limited operating area. By May 2002, PAC-3 had successfully intercepted and destroyed 12 of 13 targets.[13] Initial operational capability occurred in late FY2002 and was fully operational in Operation IRAQI FREEDOM. The Netherlands, Germany, Japan, Israel, and Taiwan are in various stages of upgrading their Patriot missiles. South Korea and Italy are considering pursuing a similar capability. Much of the PAC-3 technical success was built on a joint U.S. and Israel venture, which resulted in fielding of the Israeli Arrow missile defense system in 2000.
2. Theater High Altitude Air Defense (THAAD) uses large ground-based phased array radar to short and medium range ballistic missiles both inside and just outside of the atmosphere. The first successful tests occurred in the summer of 1999; fielding is planned for FY2007-08.[14] It is air transportable, has a 40-missile capability, and provides for greater area defense than the PAC-3.
3. The proposed Medium Extended Air-Defense System (MEADS) is a cooperative effort with Germany and Italy to provide limited and mobile area

defense for an Army corps or vital assets. It will eventually replace the aging HAWK air defense system and leverages the PAC-3 missile. Initial planned deployment dates were FY2009, but will likely slip or be replaced by PAC-3 outright.

4. In December 2001, DOD cancelled the Navy Area Defense program, citing poor performance, significant overruns, and development delays.[15]

Midcourse is designed to extend the engagement envelope to intercept ballistic missiles during their ascent and exo-atmospheric descent. Midcourse provides the longest engagement window, up to 20 minutes for some ICBMs. Ascent engagement is preferred over terminal defense due to engagement prior to deployment of countermeasures or multiple warheads.

1. The AEGIS/Standard Missile (SM-3) combination is a surveillance improvement to the SPY-1 radar and tailors the SM-3 to support mid-course intercept of short and medium range ballistic missiles. The first successful test occurred in 2002 and is slated to have a contingency capability in FY2005-06.[16] Missile speed enhancements (from the current 3 kilometers per second (km/s) capability, to 4.5 km/s and eventually 6.5 km/s) are being explored to support engagement of ICBMs.[17]

2. The Ground Based Midcourse Defense (GMD) will use ground-based interceptors to defend the U.S. from a limited ICBM attack. It uses the AEGIS SPY-1 radar, a new X-Band phased array radar and leverages future space sensor capability. In FY2004 deployment began of the Pacific Missile Defense Testbed, consisting of GMD interceptors at Ft. Greeley, Alaska and Vandenberg Air Force

Base, California; up to 20 AEGIS/SM-3; X-Band radar at Shemya, Alaska; and dedicated Pacific Command PAC-3 systems.[18] As of October 2005, nine GMD interceptors are deployed. Recent test failures have curtailed further deployments.

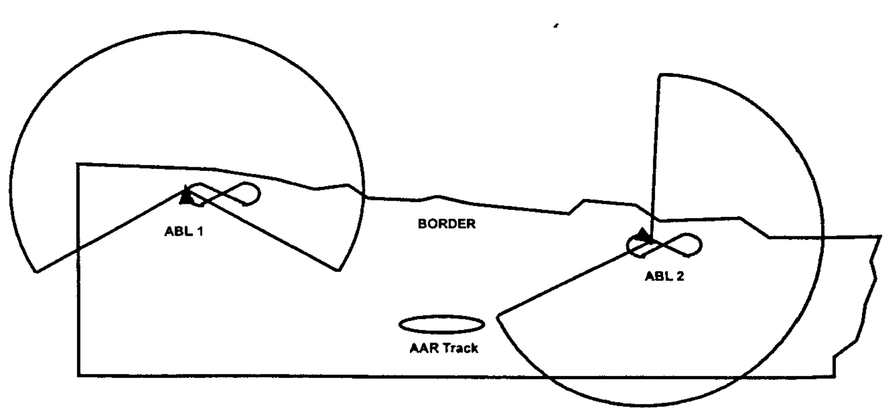
The **boost phase** is defined from ballistic missile launch until it stops accelerating under its own power. It is the most forward-based defense. The engagement window varies proportionately based on the ballistic missile range, anywhere from 20 seconds up to 5 minutes. General Fogleman stated, "Developing the capability to destroy a ballistic missile in the boost phase is vital…TBMs are best targeted in the boost phase when they are large (intact missile with a very large infrared signature), vulnerable, and highly stressed targets."[19] Intercepting a missile in boost phase is the "ideal" solution; a large area can be defended and negates most countermeasures.[20] It is also the most technically challenging mission. MDA is currently pursuing two parallel development courses (directed and kinetic energy).

1. ABL is a potentially lethal directed energy BPI system—our country's first airborne "death ray." It also provides risk mitigation for MDA's long-term vision of space based lasers with relay mirrors. ABL's infrared sensor suite will track theater missiles from launch (after clearing the cloud deck) until booster cutoff, with a full 360 degrees of coverage.[21] It will use a high-energy chemical oxygen iodine laser mounted on a modified 747-400 freighter. After extensive distributed simulation studies, the laser turret was determined to be best placed on the nose of the 747 to afford the greatest weapons engagement zone and minimize airflow distortions while lazing. The ABL will fire a 5-10 second burst of its megawatt laser to impart enough energy on the booster to heat, deform, or create structural

failure of a vulnerable component.[22] In engineering terms, the laser must place sufficient fluence (joules/cm^2) or irradiance (watts/ cm^2) on a one centimeter to more than ten centimeter area (target dependent) to inflict lethal damage.[23]

ABL (YAL-1A) testing was originally to culminate in 2003, with initial capability by 2009, and a fleet of seven by 2011.[24] Although this program continues to make substantial strides, its history is replete with delays. Chapter 3 will cover persistent challenges to this schedule. Of the seven modified aircraft, five will be available for operational duty at any given time. This will support only one major regional conflict at a time. During a normal 12- to 18-hour mission, the ABL will carry sufficient laser fuel for 30-40 engagements.[25] Effective ranges vary from 200-400 km, depending on the source quoted. Designed operating altitude requirement is 40,000 to 45,000 ft to provide 90% probability of having clear line-of-sight. Employment is expected to be that typical of other high value airborne assets—orbiting around 100 km from enemy lines; however, excursions into enemy territory have not been ruled out since it packs its own weapon. Below are two figures depicting two orbit employments:

Figure 2. Large Theater with Geographically Separated ABL Orbits[26]



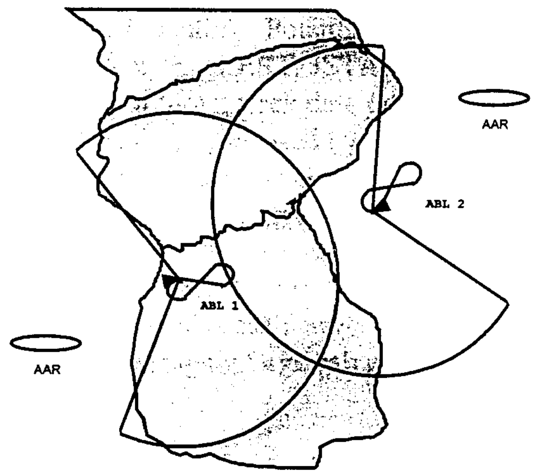


Figure 3. Small Theater with Overlapping ABL Coverage [27]

The Missile Defense Agency's newest system is the Kinetic Energy Interceptors (KEI). It will be worldwide transportable via C-17s and fired from mobile launchers, with full testing scheduled in FY2010-12.[28] Additionally, MDA plans to integrate the missile into a sea-based capability. The $4 billion program (over eight years) is aimed at ICBM boost phase capability, with objective aims at also providing some ascent mid-course capability. Technological advances in developing 6 km/s propulsion capability are showing promise.

To summarize MDA's first decade of investment and fielding, much progress was made in numerous areas. Essentially, PAC-3 is the most mature system and provides worldwide deployable limited point defense against TBMs. However, it cannot address ICBMs. AEGIS/SM-3 is on the brink of providing our first mid-course engagement capability. Declaration of initial operational capability for GMD, signaling the beginning of a national defense against the accidental or limited ICBM attack, is expected within the next couple of years. All other programs are at varying stages of developing or maturing the vast array of needed technologies. Kinetic energy weapons are faring better than directed energy or space-based solutions. It is a case of reaping ripe technological fruit versus genetically engineering the fruit of the future. Persistent research and development over time, combined with acquisition of the best, will produce an effective national missile defense architecture. The realist view is "despite the progress in ballistic missile defense since 1993, the U.S. is still years away from effective defenses against a robust threat in either national or theater defense."[29] The author's view is that the MDA's multi-layered and flexible acquisition approach is sound but could greatly benefit from a re-evaluation of boost phase options to produce a more effective, efficient defense against the more likely TBM threat. An assessment of current systems will lead us back to the BPI debate—its remaining challenges and significant benefits. "Heads, not tails" is where the focus should be. Early engagement provides better, faster, cheaper, and less destabilizing missile defense capability.

Chapter 3

Assessment of Current Missile Defense Systems

Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after they occur. Giulo Douhet

Currently funded programs are inadequate in addressing today's TBM/WMD threat. The three Army programs (Patriot, THAAD and MEADS) are greatly improving our terminal defenses. The Patriot PAC-3 upgrade improved the sensor, command and control, and missile. The fielded result is a larger engagement envelope and improved lethality, which sufficiently addresses shortfalls in Gulf War performance. Additionally, the Patriot system retains its ability to provide simultaneous point defense of enemy aircraft, cruise missiles, and TBMs, but full missile defense capability requires placing the weapons system in a TBM-only mode. Even with the marked improvements, the Patriot and its Israeli counterpart, the Arrow, have inherent limitations.

To be effective, terminal point defense systems must be pre-positioned to protect vital assets/areas in those regions of concern to U.S. national security interests. If not, they will be late to need. This constant presence on foreign soil has enormous political and fiscal costs, both to the U.S. and its allies. This issue also fuels al Qaeda's justification rhetoric of a "defensive jihad." Constant in-theater deployment also runs counter to long-term U.S. military strategy to lessen our "deployed footprint," while being able to project power globally. Additionally, there are an inadequate number of terminal defense systems available to protect the number of civil and military targets likely to be targeted by an enemy. A reliance on terminal defenses implies an “acceptable sacrifice” mentality—we can’t defend everything, therefore, we protect what we “think” is most important. Therein lies the very strength of a TBM—military significance has little bearing on effectiveness. The first TBM that is successful in threatening life represents a victory. CNN won’t portray the dead and wounded, nor will the populace view themselves as an “acceptable sacrifice.” Israeli missile defense expert Arieh Stav goes even further, to state,

> Arrow is a strategic failure, both conceptually and operationally… historical evidence indicates that it accelerated the regional TBM/WMD arms race, undermined Israeli Defense Forces pre-emptive deterrence doctrine and cannot achieve the theoretical 99.9% effectiveness rates…leakers are likely due to cheap and easy deception means available to the enemy.[30]

Terminal defense is a legitimate layer in aerospace defense. Its primary purpose was and should be to deal with the occasional “leaker,” not the foundation of our missile defense.

Theater High Altitude Air Defense (THAAD) addresses some of the limitations of Patriot, but still falls short of negating either the political or military threat of TBMs. It targets ballistic missiles exclusively; it can’t engage aircraft or cruise missiles. Its expanded engagement envelope will provide selective “area defense" and limited shoot-look-shoot capability. Imagine an umbrella over a city, with Patriot being a subset bubble over a specific high value asset. THAAD protects more but still requires pre-positioning and sufficient numbers and has a much larger logistic footprint than Patriot. It can be deployed two ways—over the high value area or forward deployed to extend engagement ranges. Forward deployment is doctrinally sound because it contributes to a multi-layered defense. While the Medium Extended Air Defense System (MEADS) will help share the burden of defending Europe and ensure interoperability, it remains caught in transatlantic politics, and if fielded, retains the same inherent operational limitations stated above. A terminal defense strategy alone cannot counter saturation attacks, fractionated warheads, decoys, and WMD. Our enemies' defense investment strategies prove they understand this weakness—TBM and countermeasure proliferation continue at an alarming pace. Appendix B depicts a 2004 global ballistic missile snapshot.[31]

Terminal defense against ICBMs is even more problematic.

> The first problem associated with (terminal defense) interception of nuclear missiles is the question of interception altitude. Less than 10 km would cause great damage on the ground, similar to that of a hit made by the nuclear warhead itself. Above 40 km would likely create an electro magnetic pulse (EMP)…paralyzing all the communications systems and electronic systems above ground…finally, an enemy may choose to overwhelm a defense by deploying large numbers of false targets.[32]

This fact leads us to MDA's ramped-up emphasis, since 2001, on midcourse phase capability. GMD fielding in Alaska and California is the benefactor of this focus. Despite the huge technological progress made to date, MDA would be the first to admit this represents an infant's step towards strategic missile defense. Withholding an initial operational capability declaration and calling it a Pacific Missile Defense Testbed speaks volumes of its not fully tested capability. The bottom line is that full deployment was necessary to conduct realistic testing of the entire system. The secondary benefit is the world sees some NMD capability, but of undeterminable quality. Only Russia and China have the ability to attack the U.S. with ICBMs, and current politics make that an unlikely scenario. So why the apparent full-court press on fielding Ground-based Missile Defense (GMD)?

There are three primary drivers. First, a 2001 Presidential mandate eliminating distinctions between theater and national missile defense called for a single integrated system, capable of intercepting missiles of any range at every stage of flight.[33] Prior to 2004, fielded capability was only terminal defense and only addressed the theater threat. GMD provided a new and very visible step towards midcourse and strategic defense. Second, is the potential deterrent value to those countries ascribing to join the "ICBM Club." However, even if time proves this strategy was effective in containing proliferation of the ICBM threat to U.S. territory, it will undoubtedly drive our enemies to greater regional TBM capability and thus threaten our national interests abroad. This is the paradox of attacking missile defense from the tail towards the head. Third, ground-based sensors, C2, interceptors, and kinetic kill vehicles (KKVs) provide the most fertile development and test environment to enable accelerated migration to sea, air and space. This last contribution will be the most valuable to all missile defense capabilities.

AEGIS Ballistic Missile Defense addresses the theater midcourse layer and will be a welcomed addition to the NMD architecture. It will provide a rapidly deployable and mobile defense for coastal areas and island/peninsula nations. In addition to the expanded protection area it provides over terminal defense systems, it offers a more palatable basing solution to our allies and our enemies and is well-suited to existing Navy missions. It shares the same limitations of terminal defense: possible warhead fall-out in friendly territory, and intercept after fractionation. Destroying one out of 10 sub-munitions or even destroying 30% isn't close to the requirement. To combat these deficiencies, AEGIS BMD and GMD should serve as the catalyst to developing: faster booster/interceptors which better address the range of threats and launch profiles; more discriminatory engagement of threat warheads through better sensors and battle management algorithms; and production of a multi- kill vehicle system.[34] All are needed, but technology maturation is conservatively 10 or more years, given what is already on MDA's plate.

"A successful BPI campaign eases the requirements placed on a terminal missile defense system and provides an answer to many of the measures an enemy can adopt in order to counter terminal defenses."[35] The Air Force signaled acceptance of the boost phase mission by making ABL a major acquisition program in 1996. At that time, airborne directed energy weapons were believed to be ten years in the making. At 20 years, lazing should be sized to support UAV concepts, and at 30 years a "Foto fighter" and realization of a space-based Global Precision Optical Weapon may be possible.[36] This vision is proving difficult to implement. Although the airborne laser program continues to make substantial strides, its history is replete with technical delays and cost overruns. In all fairness to ABL, the technology required is of unprecedented quantity, complexity and quality, and most freely acknowledged, the program was underbid. Those closest to the challenges always believed the initial capability would be $2 billion, not the $1 billion wickered into the DOD budget. Some early budget-driven design decisions, such as choosing the 747, which flies too fast and too low, have complicated the technical challenges exponentially. Consequently, ABL repeatedly draws the General Accounting Office (GAO) eye. In 2002 the GAO identified six critical technologies that remain immature.

1. Devices that stabilize the laser system aboard the aircraft (the removal of laser beam jitter, caused by vibration in flight).

2. Optics—mirrors and windows—that focus and control the laser beam inside the aircraft.

3. Optical coatings that enhance the optics' ability to pass and reflect laser energy.

4. Target tracking hardware and software that involves integrating and synchronizing three lasers (range finder, target acquisition, and directed energy weapon laser).

5. Measuring and compensating for atmospheric turbulence, which scatters and weakens the laser beam.

6. Emergency laser shut-off safety systems (toxic chemicals and plasma heat dissipation).[37]

The last couple of years narrowed the challenges down somewhat, but a few significant obstacles remain.

1. Target tracking—the beacon laser must not only track the ballistic missile, it must track the nose cone and maintain discrimination of all missile parts. Due to atmospheric disruption, it is equivalent to trying to "bird watch from underwater."

2. The 747 is a suboptimal platform, as previously stated. Compensating for the inherent shock wave off the nose turret continues to plague the laser performance. A compromise is to fly slower, but the cost is decreased altitude of 38,500 ft, and thus another atmospheric impact on laser power.

3. Integrating optics with the airframe is exceptionally challenging. The resonator must be developed for up to 11 inches of random flex from one end of the aircraft to the other.[38]

In 2004, the ABL program office deferred purchase of the second aircraft and pursued a more knowledge-based approach to development.[39]

The operational utility also is in question. The $11 billion program will only produce seven aircraft; it would take 14 ABLs to cover two major regional conflicts. Five airplanes constantly in theater make training and testing with other assets in the states impossible. One issue that cannot be minimized is the logistics tail and the unique complexities of supporting laser weapons/fuels in various overseas operating locations. At present, that is not covered in the bill or in the CONOPS.

Even if all the technology design specifications are reached, there remain the significant shortcomings of directed energy weapons, whether they are airborne or space-based. They do not necessarily kill the warhead and are susceptible to simple countermeasures. The ABL is not designed to kill the warhead due to lazing fuel conservation (platform weight limited). Rather, it targets a classified aim point on the booster to create the fastest killing fluence. The explosions caused from igniting fuel under pressure are certain to be spectacular, but the warhead is tossed down track in a random, distorted ballistic path. This is why the real engagement envelope and standoff ranges will be critical measurements of effectiveness. Additionally, responsive threats that use composite hardening, missile rotation (spinning bullet), or surface reflectivity enhancements will increase the fluence requirements two to tenfold, thereby decreasing ABL's engagement range and number of shots available in one sortie.[40] The only counter to these enemy tactics is more ABLs. As a high value asset, it will require dedicated fighter protection with tanker support and/or significant countermeasures to ensure freedom to operate. The lumbering 747 and huge heat signature when lazing make ABL a lucrative and easy target. Overall, ABL offers a legitimate BPI capability to engage some ballistic missiles over enemy territory. However, technology maturation and insufficient numbers hinder overall effectiveness of this boost phase solution. The 2005 Quadrennial Defense Review basically continues suspension of an Air Force production decision, and thus, MDA must make hard investment decisions. We are at a "tipping point" for boost phase solutions. Although this paper unequivocally advocates for kinetic boost phase solutions first, it is critical that we do not throw out the directed energy baby with the bath water. ABL and its team of experts are not easily reconstituted. Continued airborne research and development are essential to achieving directed energy migration to space and ground-based systems.

The newest MDA boost phase pursuit is Kinetic Energy Interceptor (KEI). It is promising, and combined with midcourse solutions, will accelerate development of kinetic boost phase capabilities. It is designed to counter the ICBM threat, and thus will require securing of basing rights from our allies and integrating this into a sea-based system. Ability to counter regional TBM threat will require modification of design and CONOPS. Any further assessment would be premature.

Assessments of the current NMD architecture range from sobering to steadily improving. In the 60 years since the V-2 first threatened our interests, we managed to field a limited point defense capability with its well-documented limitations. To its credit, MDA advanced many enabling technologies, and since 2001, more equally embraced all phases of ballistic missile threat. As a result, our missile defense potential is improving but still falls short in leveraging all that boost phase brings to the requirement and addressing the more likely threat—TBMs. Specifically, the hope of countering ICBMs with KEI and the uncertain, extended future of ABL leave the boost phase equation stagnated and our theater defenses hollow. <u>Our nation needed, and still needs, a true kinetic theater BPI capability</u>.

Chapter 4

Re-evaluation of BPI

The previous chapters provided background, system descriptions, and capability assessment of ballistic missile kill capabilities. This chapter will borrow from two studies, one done by the RAND Corporation in 1994 and another from the Congressional Budget Office (CBO) in 2004. The purpose is to convince MDA, Congress, and warfighters that the boost phase layer is the most critical and efficient layer of defense. Given the persistent challenges of directed energy, the subsequent chapters will propose air-launched kinetic BPIs be developed and fielded as the number one MDA acquisition priority.

The RAND study focused on determining the optimal allocation of resources for multi-layered TMD and addressed two critical elements for military and political strategists. First, it provided a valid methodology to assess theater candidate systems to determine the most cost-effective combination and where additional capability would produce the quickest increase in P_k of incoming TBMs. Second, it offered unequivocal proof of the boost phase layer's premium value. RAND's principal cost drivers should be applied to current MDA acquisition plans to prioritize investment towards kinetic BPI accordingly. Highlighted below are the simple, apolitical, non-parochial "missile defense economics" truths that point to the correct military solution both in dollars and lethality.

1. Figure 4 illustrates that a single layered strategy, i.e., present terminal defense, requires three times more interceptors than a two layer (add true midcourse), and four times more than a three layer (add boost phase) TMD architecture.[41]

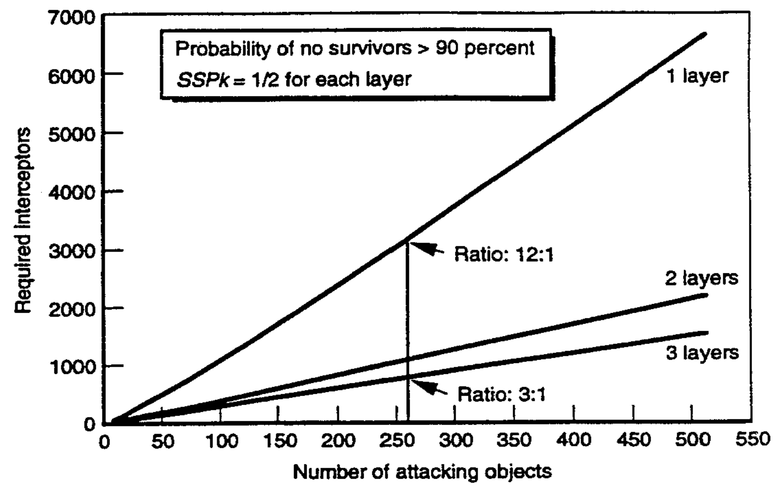


Figure 4. Layering Reduces Sensitivity to Attack Size[42]

2. The preceding ratio is quite insensitive to the total number of attacking TBMs for two- and three-layered TMD systems (Figure 5). Given a 50% P_k, it takes 15 friendly interceptors in a single-layered defense, whereas it takes 3 interceptors per attacking object for three-layered defenses. Two layers are 3.5 times more

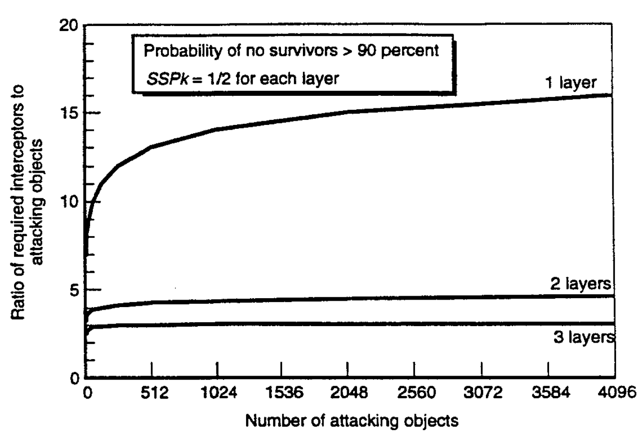


Figure 5. Ratio of Required Defender Inventory to Attack Sizes[43]

efficient. Three layers are 5 times more efficient.

3. The size of a TMD inventory necessary to achieve a demanded probability of no "leakers" is highly sensitive to the existence of multiple look-shoot opportunities or engagement layers (Figure 6). Current MDA core systems require a tactical C2&ISR choice to determine which system (Navy or Army) will engage each incoming target based on geography. Any subsequent engagements would be limited to PAC-3 batteries firing, if self-defense criteria were met. True shoot-look-shoot re-engagement options require engaging a ballistic missile in different parts of its flight profile. "Multiple layers can dramatically reduce the size of the inventory of interceptors required to achieve a stated level of outcome—and all other things being equal, the more layers, the greater the reduction in cost."[44] An architecture built upon terminal defense is impractical, while a boost phase foundation provides the greatest efficiency.

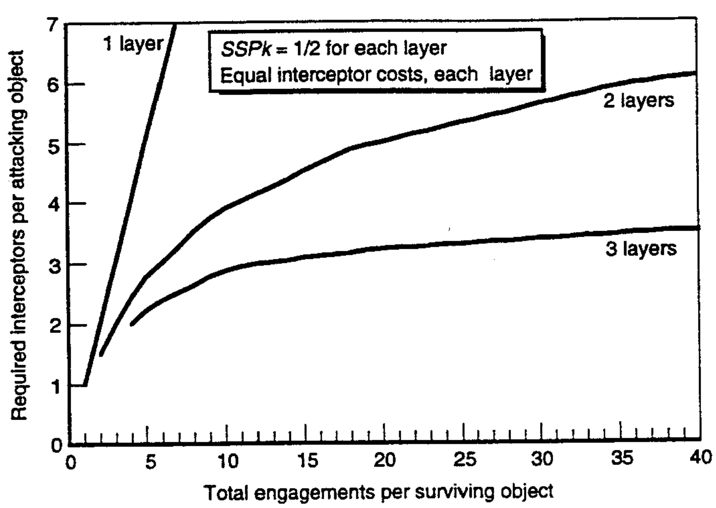


Figure 6. Layering Reduces Cost per Attacking Warhead[45]

4. In the case of WMD, the demand for no “leakers” increases. Effectiveness can be achieved at a relatively small increase in expected total system cost, if a complete three-layered architecture is pursued.[46] Figure 7 reveals two important things. First, it takes less than one additional interceptor per attacking object to raise the probability of no “leakers” from 18% to 94%.[47] This is critical justification for getting appropriate multi-layered interceptor strengths. There are two ways to buy this efficiency—buy more missiles or buy look-shoot-look-shoot opportunities. BPI provides both. Buying an 18% solution, when the 94% solution is within reach is analogous to “terminal” myopia. Current strategies reflect the “acceptable sacrifice” mentality. The U.S. need not sacrifice the protection of its people and interests when the solution is both possible and affordable. Second, fielding the most lethal interceptors is tactically smart, technically possible, and fiscally imperative. An interceptor P_k improvement of 50% to 75 % cuts the number of interceptors required by half.

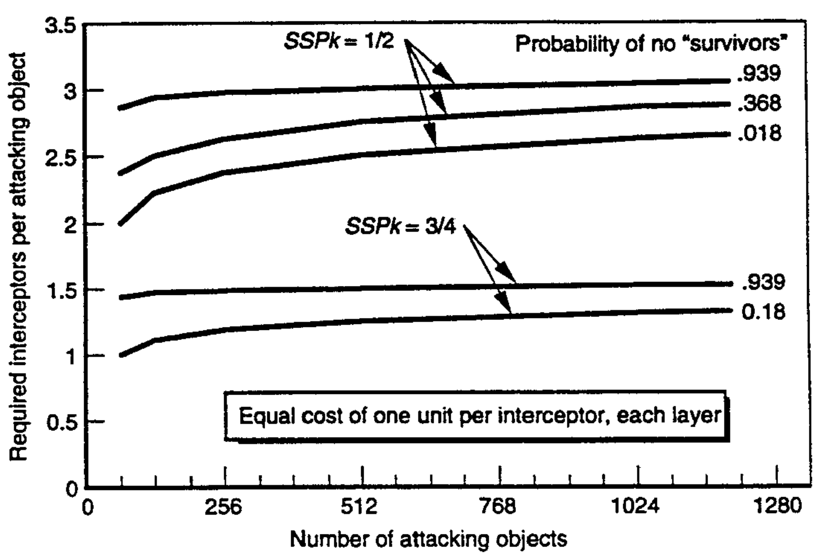


Figure 7. Cost per Attacking Object is Sensitive to Probability of Kill (P_k)[48]

5. Perfect kill assessment is desired because it saves money. Engagement deconfliction is required between all Service systems to prevent lingering debris and wasting interceptors on the same targets, or those that have already been neutralized. It is important to note that kill assessment requires time—shoot, interceptor fly out, impact, determine need to shoot again—and decide which TMD asset to commit next. In the current proposed architecture, this kill assessment time element will be extremely difficult to achieve (it requires an ascent or near apogee first intercept). Therefore, to achieve the desired P_k, these terminal defense systems will have to shoot salvos, thus driving up the costs. Figure 8 depicts this relationship.

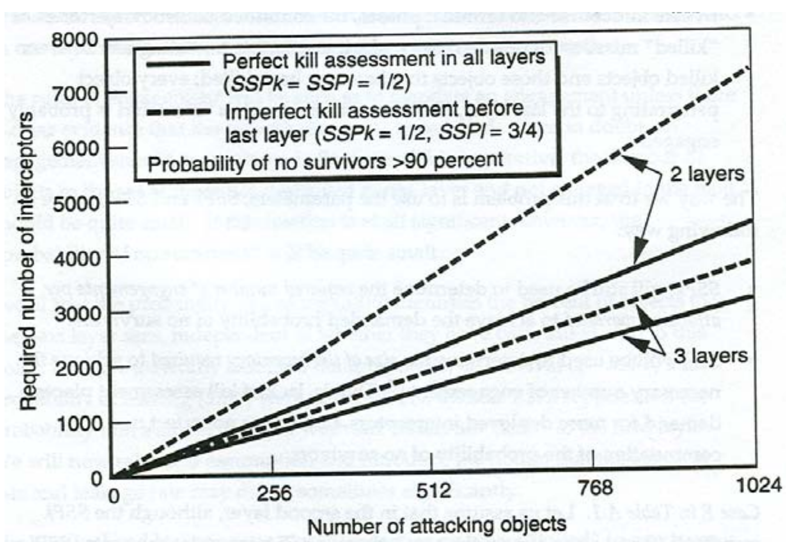


Figure 8. The Effects of Imperfect Kill Assessment[49]

6. Because fractionating warheads and the use of decoys complicate post-fractionation defenses, BPI provides the largest payoff. Figure 9 depicts the optimal allocation of TMD interceptors against a potential TBM threat capable of fractionated warheads.

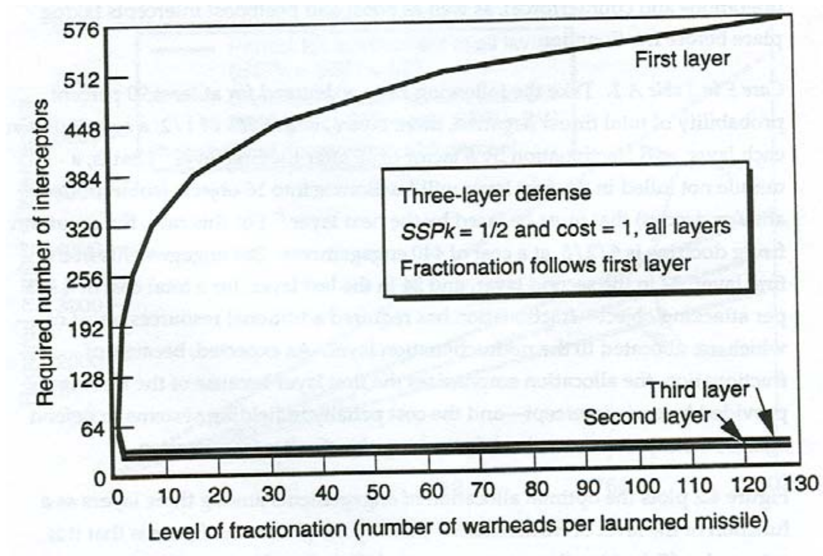


Figure 9. Effect of Fractionation on Interceptor Allocation to TMD Layers[50]

Understanding this paradigm is critical. Investment in responsive BPI can create exponential savings by reducing the numbers of terminal and midcourse defenses. Overseas pre-positioning of these defenses is thus minimized. The terminal defense and midcourse layers are crucial, but in the right number. Without BPI, the U.S. cannot afford the number of defenses required. With BPI, it won't have to place national interests in the "acceptable sacrifice" category.

7. All defenses have a saturation point. The key to a sound joint acquisition strategy is to field a system of the right composition and right numbers, so as to exceed the enemy's ability to overwhelm it. The number of variables is staggering, but the ultimate limitation is always money. The problem of saturation is always felt most in the last layer of defense. If the prior layers don't meet their P_k expectations, the subsequent layers may run out of interceptors or opportunities to engage every target.[51] Defending against saturation is always best done at the source of the threat, especially for ballistic missiles carrying sub-

munitions that will fractionate soon after booster engine cutoff. Additionally, during the boost phase, the TBM does not have much down range movement; thus, once successfully engaged by a BPI, any remaining debris falls on enemy terrain and does not pose follow-on targeting problems for midcourse or terminal defenses. Lastly, BPI provides the most effective defense against an electro magnetic pulse (EMP) attack. "An EMP attack is potentially the most devastating one against the U.S. or an ally, producing catastrophic effects for which there is no consequence management… It could render useless all non-hardened electronic components over the target area, reducing it to the equivalent of an early 19th century society."[52]

8. If terminal defense weapons engagement zone "footprints" don't overlap, it is equivalent to giving the enemy fractionated warheads.[53] Statistically, more interceptors have to be allocated to the previous layers. Overlapping coverage in each layer is essential, but most important for terminal defenses. Such coverage is mandatory for the system to be fully effective.

9. Buy-in costs to different systems directly affect acquisition strategy, hence the ABL decision in the mid-90s. The actual hardware costs, the number of expected attacking objects, the availability of the technology, the overseas logistical footprint, and the number of people required are but a few of the factors to consider when comparing buy-in costs. MDA's charter is to negate the threat; therefore, this is the most significant consideration for determining buy-in costs. If we can't defend against fractionation and WMD, then our theater missile defenses are ineffective. "Accordingly, fielding the pre-fractionation boost phase

layer, even in the presence of a large buy-in cost, represents a large savings in expected total resources."[54] AEGIS BMD, KEI, and GMD advancements have outpaced ABL, and the investment equation now favors kinetic BPI.

To further illustrate the implications of these truths, consider a threat consisting of 51 TBMs, each with 10 sub-munitions, and a theater commander requirement of >90% P_k

Tradeoffs Between Prefractionation Defenses and Midcourse/Terminal Defenses

Units of Prefraction-ation Defenses	Percent Boosters Killed	Attack Objects Presented to Midcourse/ Terminal Defenses	Number of Engagements/ Surviv. Object	Optimal Firing Doctrine	Number of Engagements/ Attack Object	Cost of M/T Defenses	Cost of Prefraction. Defenses ($B)	Total Cost ($B)	Net Savings ($B)
0	0	512	13	4/9	6.85	24.6	0	24.6	0
2	18.1	419	12	4/8	6.53	19.2	4.0	23.2	1.4
4	33.0	343	12	4/8	6.53	15.7	5.0	20.7	3.9
6	45.1	281	12	4/8	6.53	12.8	6.0	18.8	5.8
8	55.1	230	12	4/8	6.53	10.5	7.0	17.5	7.1
10	63.2	188	11	4/7	6.21	8.2	8.0	16.2	8.4
12	69.9	154	11	4/7	6.21	6.7	9.0	15.7	8.9
14	75.3	126	11	4/7	6.21	5.5	10.0	15.5	9.1
16	**79.8**	**103**	**10**	**4/6**	**5.90**	**4.3**	**11.0**	**15.3**	**9.3** ←
18	83.5	85	10	4/6	5.90	3.5	12.0	15.5	9.1
20	86.5	69	10	4/6	5.90	2.8	13.0	15.8	8.8

Note: Optimal buy of prefractionation defenses in bold.

Table 1. Prefactionation Defenses versus Midcourse/terminal Defenses[55]

that no operational weapons impact on friendly soil. Midcourse and terminal defenses have a proven 50% probability of kill at $7 million for each engagement. Perfect kill assessment is possible but is not currently funded. Boost phase options exist but require further development. Table 1 depicts the tradeoffs. The maximum savings ($9.3 billion) for this case is achieved by investing heavily in the pre-fractionation (boost phase) defenses—kill more, sooner, and with less.

The CBO study concentrates on boost phase alternatives to counter ICBMs; however, it provides great insights into requirements for boost phase, MDA's FY2004-09 budget, and the challenges of space-based defenses. The analysis data is based on the Iran and North Korea securing ICBM capability. Countering the long-standing TBM threat would seem a more prudent approach to realizing anti-ICBM capability ahead of an enemy's potential fielding of ICBMs.

Boost phase is the most time compressed engagement problem. In the case of ICBMs, two factors drive the number of BPIs required to effectively provide area coverage. First is fuel type of the threat ICBM. Liquid-fuel boosters burn longer than solid fuel boosters. Second is the interceptor speed requirement as a function of commit time. Figure 10 depicts that solid fuel ICBMs will require roughly twice as many interceptor sites to cover Iran, and BPI speeds of 8-10 km/s will be required.

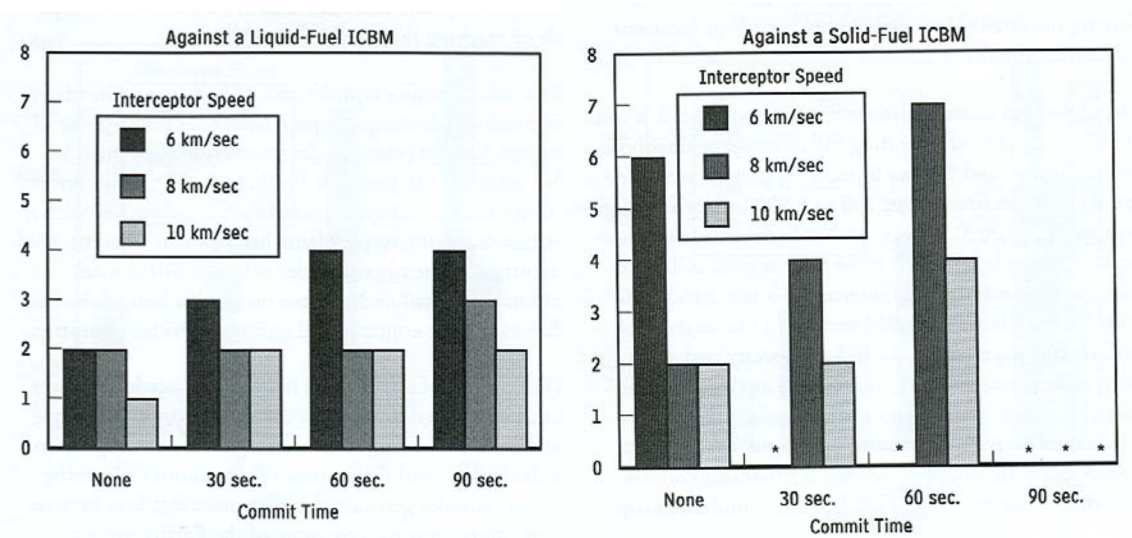


Figure 10. Number of Surface-based BPI Sites for Full Coverage of Iran[56]

TBMs are currently all liquid-fuel, but the trend will be towards solid fuel, so the problem isn't going to get easier over time. Combining other data covered in the next chapter, current air launched BPI speed requirements are 2-4 km/s minimum, with 4-6 km/s desired, and 6-8 km/s required in the future. Figure 11 provides a similar comparison for Space Based Interceptors (SBIs).

Liquid-Fuel **Solid-Fuel**

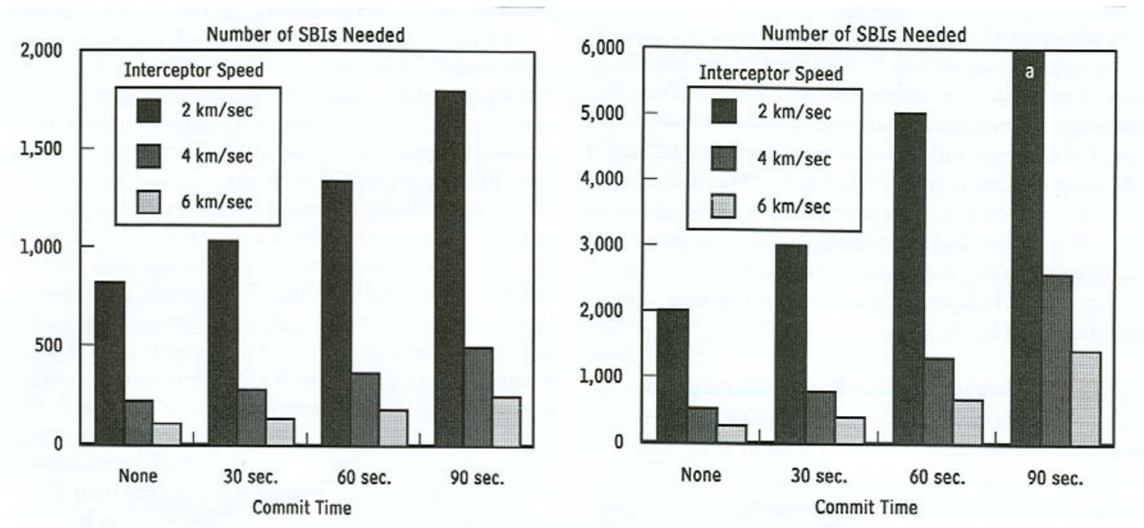


Figure 11. Characteristics of SBI systems Needed for Full Coverage of North Korea and Iran against a Single Liquid-fuel and a Single Solid-fuel ICBM[57]

Space basing can provide BPI access to any point on earth, including the interiors of very large countries that can't be reached by any ground and most air-launched BPI concepts. Moreover, the interceptor speed requirements decrease to the 2-6 km/s range. On the negative side, SBI constellations can only be tailored to a latitude band, not against individual countries.[58] The real issue is a budgetary show-stopper. CBO estimates that the cost of a BPI system which could counter liquid-fuel ICBMs launched from anywhere in both North Korea and Iran would be between $16-37 billion (2004 dollars) for surface-based, and between $27-78 billion for space-based. To counter solid-fuel ICBMs from space would raise the price tag an additional $30-146 billion![59] SPI is theoretically attractive, but until space lift can deliver capability for around $1000/lb and kinetic energy technologies mature to produce a "certified round" that fires and hits every time, it is not a realistic option.

MDA's pursuit of surface-basing also has limitations. Although basing is plausible in South Korea, it is problematic to U.S. and allied interests in most other scenarios. Sea-basing is a realistic alternative but adds significantly to the forementioned costs and supports only littoral enemy launches. Surface-based BPI suffers from the worst line of sight handicap, little mobility once pre-positioned, and the greatest demands on propulsion technology. Air-launched kinetic BPI minimizes these deficiencies, is more realistic than space-based, and offers a timelier alternative than directed energy.

Table 2 below illuminates the boost phase budget compared to the total MDA budget. It is telling that the boost phase layer never comes close to 33%, and in fact, only averages 15% across FY2004-09. As a reminder, the $1-2 billion a year is directed increasingly at KEI and anti-ICBM.

	2004	2005	2006	2007	2008	2009	Total, 2004-2009
Budget for BMDS Interceptors Program	0.1	0.5	1.1	1.6	2.0	2.2	7.6
Total MDA Budget	7.6	9.0	8.3	9.6	7.9	7.9	50.3
Memorandum:							
BMDS Interceptors as a Percentage of MDA's Budget	1.5	5.6	12.9	16.8	25.5	27.8	15.2

Source: Congressional Budget Office based on a briefing by staff of the Missile Defense Agency, March 4, 2004.

Table 2. Funding for the Ballistic Missile Defense System Interceptor Program[60]

Instead of spending an indeterminate amount of time and national treasure on trial and error acquisition, MDA's acquisition emphasis needs to shift significantly (40-60%) towards boost phase and the theater threat, so as to accelerate a more effective and efficient NMD in the next five years.

Chapter 5

Proposed Air-Launched BPI System

The development of Air Power in its broadest sense, and including the development of all means of combating missiles that travel through the air, whether fired or dropped, is the first essential to our survival in war. Sir Hugh Trenchard, 1946

The idea of an air-launched BPI is not new. In 1994, the Air Force seriously explored and demonstrated through advanced simulation a concept of F-15Cs launching BPIs supported with off-board sensor tracking. The decision to pursue ABL instead was based on a belief that directed energy technologies would mature quicker and better support long-range plans to migrate this mission to space. For a brief moment, the kinetic BPI concept came back into vogue in 1996. BMDO sponsored a three-year study of fielding Tier-2 Global Hawk UAVs with six kinetic BPIs each, capable of loitering 40 hours at 65,000 feet.[61] Lawrence Livermore National Laboratory (LLNL) scientists believed the UAV, sensor, and kinetic boost phase technology was "ready to move forward to a demonstration."[62] Congressional interest perked when LLNL compared the estimated 20-year life-cycle costs of major BPI systems. The UAV/kinetic BPI price tag to support one major regional conflict was $1.5-2 billion compared to $5-6 billion for the ABL, or $23 billion for the space-based laser (1996 dollars). Additionally, the UAV-carrier concept could have been operational in FY03, five full years before ABL.[63] Air

Force concepts failed to gain funding priority because they didn't mass firepower and were perceived as bridled by technology. Those were missed opportunities, but current science and technology developments afford a second window of opportunity to close the critical boost phase gap and enable simultaneous strike of missile launchers.

By walking through the operational requirements, the desired BPI system can be described. Admittedly, some specifics must be extrapolated since most funded studies have been surface-based and space-based. This reality is a function of airborne BPI being synonymous only with ABL for a decade.

Launch Platform. It must exist in today's fleet and be on-station anywhere in the world within 24 hours. This assumption of some intelligence warning and potential launch zones is reasonable for state actors, but until space-based BPI is a reality, will require national vigilance of non-state threats. Because standoff ranges cannot be guaranteed in every theater, initial BPI may require closer than desired operating ranges; thus, the platform must have inherent offensive and/or defensive capability (armament and/or a proven electronic warfare suite). It must be able to loiter for 12 hours or more on its TBM defensive counter air orbit, preferably without refueling. The higher the operating altitude, the greater benefit to detection/commit timelines and engagement ranges. It must be able to carry twenty or more BPIs (up to 3000 lbs each--12 externally and 8 internally). For comparison: PAC-3 is 640 lbs, THAAD is 1220 lbs, and GMD is 22.5 tons.[64] The B-52 is the only platform that meets the criteria and can routinely operate up to 50,000 ft. Regardless of age and premature predictions about retiring the infamous workhorse, the B-52 is here indefinitely because it can carry most munitions in the Air Force inventory; some forecast service even out to 2050. The author recommends

28 of the remaining B-52s be converted to accept the TMD mission. Tier II and Tier III UAVs provide promising follow-on BPI platforms that can augment persistent and interior operations. The Israeli IBIS UAV and the Moab kinetic kill vehicle should provide many lessons learned. High-altitude airships may also prove valuable in the long-term equation and for indefinite threats, e.g., North Korea.

C2 & ISR. BPI and the B-52 are natural fits into the existing Theater Air Control System (TACS) architecture. BPI differs in having weapons free authority to engage any and all TBM tracks within its weapons engagement zone. In other words, ISR connectivity is the pre-requisite necessity, and C2 is done to share what is being engaged and by whom with the other missile defense layers. Authority to engage in the boost phase must be made in an advance, e.g., "stating that if a ballistic missile is launched from within a given area, it will be assumed to pose a threat and will be engaged."[65] The B-52 will require surveillance and intelligence data links (JTIDS and TIBS) to allow reception of cueing data and transmission of TBM tracks, weapons guidance, and engagement status to the other defense layers. Both of these datalink systems are off-the-shelf strap-on communication systems and already fit in MDA's integrated approach. If ABL achieves operational status, it could function as the primary BPI command and control (C2) to de-conflict BPI engagements by disparate systems.

Sensors. Because fighter sensors were inadequate, early Air Force BPI concepts relied entirely on off-board cueing of the ballistic missile launches and off-board in-flight target updates directly to the BPI. Modifications of the entire F-15 and F-14 fleets were price-prohibitive. With TIBS and JTIDS, the B-52 will be able to accept cueing from every overhead (space), airborne, and ground sensor. However, it is best for the launch platform to have its own ability to directly track TBMs and provide in-flight target updates. The TBM IR signature during boost phase, and even early ascent, is like a "Roman candle." There are two systems readily available that would require minor modification for installation in the B-52 and/or UAV. Cobra Ball recently added a medium wave infrared array, which can also fuse with satellite data.[66] The tracking results are more than adequate and logistically the easiest to support. The second system is a mature BMDO program called EAGLE IR. If it had been funded, it would have put IR sensors on all AWACS to provide cueing to the Patriot Information Control Center. Figure 12 provides the spectrum of IRSTS capabilities readily available.

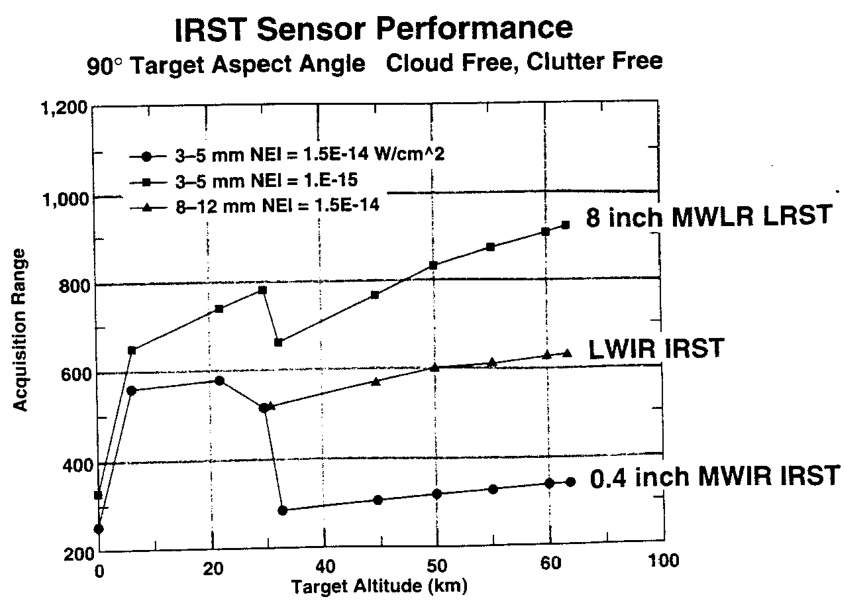


Figure 12. IRST Sensor Performance[67]

Most recently, Air Force Research Laboratories (AFRL) Sensors Directorate built a UAV-sized multi-spectral IR sensor using cross dispersion prism technologies. Any one of these IRSTs can be coupled with a laser radar (LADAR) to provide accurate ranging.

The limitation of electro-optical/IR sensors is degradation caused by weather (cloud decks) and IR interference (ground clutter, sun glint, IR countermeasures). In the BPI world, these equate to time delays. It would be extremely prudent to put phased array radar on the B-52/UAV to ensure earliest tracking and ability to simultaneously engage multiple targets. Technology for 350 km detection is readily available. Any and all boost phase solutions require a fusion all sensors. In the future the 1960's Defense Support Defense (DSP) constellation of infrared satellites will be augmented with the Space-Based Infrared System (SBIRS), a mix of four geosynchronous satellites, and the R&D Space Tracking and Surveillance System (STSS) will be restructured. Thus, detection and tracking of TBMs is doable now and full of greater capability in the near future.

BPI. The following table provides a summary of different interceptor concepts from a decade ago.

Maximum Kinematic Range Capabilities of BPI/API Options

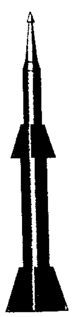
Interceptor, KKV, Ideal Velocity	Limited Operational Capability (years)	Minimum Intercept Altitude (km)	150-km Class Target	300-km Class Target	600-km Class Target	1,200-km Class Target
SRAM-ASAS, exo KKV, ~3 km/s	~3	~90	N/A	N/A	API at 385 km	API at 540 km
SRAM-ASAS, endo KKV, ~3 km/s	~4	40	API at 45 km	API at 220 km	BPI at 80 km API at 385 km	BPI at 120 km API at 540 km
AMRAAM-Hellfire, endo KKV, 2.1 km/s	~4	25	API at 65 km	BPI at 70 km API at 165 km	BPI at 95 km API at 155km	BPI at 125 km API at 45 km
Peregrine I, entry-level KKV, 3.0 km/s	~5	25	API at 95km	BPI at 95 km API at 220 km	BPI at 135 km API at 320 km	BPI at 180 km API at 255 km
Peregrine II, entry-level KKV, 5.6 km/s	>5	~40	N/A	API at 515 km[a]	BPI at 240 km API at 750 km	BPI at 325 km API at 1,020 km

NOTES: Ranges are referenced to the ground projection of the intercept point. Launch delays are 15 and 50 seconds for BPI and API, respectively. Target-acquisition sensor range or limitations in interceptor functions may reduce some of these ranges.
[a]171-km BPI range with preplanned product improvement KKV.

Table 3. Maximum Kinematic Range Capabilities of BPI/API Options[68]

To achieve a 240 km engagement zone against the 600 km TBM and a 325 km WEZ against the 1200 km TBM, the interceptor must attain speeds in excess of 5 km/s.

Additionally, it is important to note, that as long as tracking can be maintained, BPI provides some ascent midcourse capability. This accentuates the value of boost phase and MDA's integrated approach to maximize look-shoot opportunities. "All of the technology to deliver this missile system exists today; solid rocket propulsion technology just needs to be sized correctly for the mission."[69] Figure 13 lays out early design requirements.



Design description	Nominal booster performance
• Weights (kg): — Total missile 623.1 – AIT KKV and shroud 25 – First stage with interstage 442.9 – Second stage with interstage 155.2 • Missile dimensions: — Length = 427 cm (≈14 ft) — Max. body diameter = 45 cm (≈1.5 ft) • KKV specifications: — Length with shroud 135 cm — Length without shroud 93 cm — Propulsive divert 600 m/sec — Divert acceleration 15 g's	• First stage performance — Stored Delta-V (Ideal Vbo) = 2.4 km/sec — Burn time = 6 sec — Total impulse = 983 kN-sec — Specific impulse = 270 sec — Two segment motor • Second stage performance — Stored Delta-V (Ideal Vbo) = 3.1 km/sec — Burn time = 9 sec — Total impulse = 337 kN-sec — Specific impulse = 283 sec • Total booster performance — Stored Delta-V (Ideal Vbo) = 5.5 km/sec — Burn time = 15 sec

Figure 13. BPI Missile Design Description[70]

It's time to build it, not study it. The Air Force's C4ISR Visualization Center (Pentagon) and Distributed Mission Operations Center (Kirtland AFB, New Mexico) have resident virtual simulation capability to optimize and validate any BPI kinetic design.

The laws of physics haven't changed, but the recent options in satisfying the propulsion requirements have. One is born out of MDA's relationship with industry and one out of AFRL. In December 2003, MDA awarded an eight year $4 billion KEI contract for Orbital to design the booster and ATK to provide the engine for the 36 ft interceptor.[71] KEI will deliver a quantum leap in rocket propulsion to 6 km/s and closing velocities of 37 km/s.[72] Additionally, Raytheon offers a fighter or UAV capability by proposing a two-stage AMRAAM that will reach 2.65 km/s and is coupled with an AIM-9X seeker head. AFRL's Propulsion Directorate affords another option, well-suited for air delivery. Its scramjet research is focused on enabling the development of hypersonic cruise missiles with conventional jet fuels (JP-7). Initial flight test of the AFRL-DARPA X-51A Scramjet Engine Demonstrator will validate HyTech scramjet technology in a missile size (168 inches). This $170 million program will deliver 2-3+ km/s in FY2009.[73] On the surface, this is far below the desired 4-6 km/s, but does provide an initial capability correctly sized for an air-launched missile. Ongoing AFRL research will advance the HyTech scramjet performance into the 3-5 km/s range with different fuels, states hypersonic technology planner, Mr. Glenn Liston.[74] Indeed, NASA's X-43A Hyper-X vehicles recently demonstrated the ability of scramjet engines to operate at greater than 3 km/s (Machs 7 & 10). Scramjets can theoretically be four times as efficient as rocket engines by using atmospheric oxygen as the oxidizer, instead of heavy solid propellant, thereby reducing vehicle weight and dramatically increasing the speed.[75] The net result is that the missile loadout for a given range-speed capability can generally be doubled over what could be accomplished with an all-rocket approach. Scramjets can operate up to an altitude of 40-45 km, making them capable of TBM intercept. Above that altitude, a rocket powered kinetic kill vehicle (KKV—final stage) becomes essential. The current MDA approach for ground-based BPI is a two-staged rocket with a KKV. However, a rocket-scramjet hybrid missile can reasonably provide a 3-4 km/s BPI in the near future, with growth to 5 km/s—possibly precluding the need for a KKV stage.[76] The combined benefit of air launched and rocket-scramjet is two fold: greater range, plus the ability to get closer to the threat than ground variants, resulting in a larger defended area.

The X-51A is scheduled to fly five times in FY2009-10. This schedule is funding driven, not technology; better funding profiles could accelerate capabilities into FY2007.

The added benefit of a scramjet approach is a single propulsion system (indeed, a single missile design) for multiple functions, thus allowing a single B-52 to engage ballistic missiles with BPI and their launcher with hypersonic cruise missiles simultaneously (reaching up to 600 nautical miles under 10 minutes). This one-two punch can drastically reduce the number of TBMs our defenses would ultimately have to engage. With intelligence of the scripted events associated with ballistic mission launches and appropriate ROE in-place, a pre-launch hypersonic attack may even be possible. Scramjet BPI options are in the direct MDA interest and represent low-hanging technological fruit due to ongoing investments by AFRL and the Defense Advanced Research Projects Agency (DARPA). Lastly, with advances in detection and identification of enemy cruise missiles, the common scramjet approach will also support WMD cruise missile engagement over enemy territory.

Kinetic Kill Vehicle (KKV). BPI weapons guidance/KKV technology exists today. The U.S. has repeatedly proven it can hit a bullet with a bullet. The Homing Overlay Experiment successfully demonstrated the intercept of an ICBM re-entry vehicle at closures of 10 km/s; additionally, PAC-3 missile tests produced similar successes.[77] The latest success was on November 19, 2005 by an AEGIS BMD midcourse intercept. The largest technological hurdle to be countered is the extreme heating experienced by the IR sensor window during low altitude (below 25 km) engagements. Specifically, KKVs require a protective IR dome, which blinds the missile along most of its trajectory, hence the datalink requirement between the tracking sensor and the BPI. Once the eyes open, the IR window will still need cooling through ablative material coating.[78] This technology is maturing smartly due to aggressive testing across all layers. KEI is bringing bold advances in its Divert and Attitude Control System (DACS) as well as in areas of miniaturization and fine end-game control.[79] Multi-engagement enhancements will bring even greater capability against salvo launches. KKVs are designed to hit the actual warhead, not the booster, as with ABL. Boost phase can leverage either or both destruction mechanisms. MDA should also explore a marriage of nanotechnologies in the area of advanced energetics. AFRL's Munitions Directorate recently produced nanodimensional explosive composites that enhance explosive performance and improve handling safety.[80] The concept of lightweight explosives integrated into a KKV could potentially add proximity kill capability and a corresponding higher $P_{k,}$ translating into additional benefits for the remaining layers of defense.

Simulation Validation. Every piece of the architecture is already modeled in Air Force and joint operator-in-the-loop simulation facilities—the B-52 aircraft performance, any TBM threat, the same approved TBM scenario used to validate ABL, any BPI performance (missile fly out, sensor, guidance, and KKV), AEGIS, Patriot, THAAD, JTIDS, TIBS, air and ground threats, Cobra Ball, distributed connectivity to overhead satellites, and operators to evaluate the combat utility. Within months, a comprehensive test could be accomplished to refine operational requirements and CONOPS on the B-52/UAV BPI weapons system. MDA's simulation budget would be well spent towards this effort. Air Combat Command's 505 Distributed Warfare Group, located at Kirtland Air Force Base, New Mexico, is a proven entity in supporting such tests.

MDA Acquisition. Lastly, the B-52 BPI weapons system is a bridge to the future. Its presence provides long-term ABL augmentation to effect a true multi-layered defense. Enabling technologies will soon allow our C2&ISR to target the most appropriate weapons system because the type warhead may be known. The growth into the UAV platform is natural and should be accelerated. Both the B-52 and UAV should eventually carry BPI and air-to-surface missiles to simultaneously target the TBM and the launcher—the proverbial one-two punch. Both Army and Navy midcourse systems will have less area to defend and thus be able to concentrate their firepower, have earlier cueing, and avoid the saturation scenarios associated with fractionated warheads, resulting in higher P_ks.

Fielding theater kinetic boost phase capability must not just be our focus, but our NMD acquisition priority—one that moves our nation to unparalleled action and fields air-launched BPI and a tailored multi-layered active defense structure. The time is now.

Chapter 6

Proposed CONOPS

Air Force Policy Directive 10-28 provides format guidance. The following few pages are submitted to establish a CONOPS foundation.

1. Purpose. The Missile Defense Agency (MDA) and the Air Force must reprioritize their National Missile Defense (NMD) acquisition budgets to field a theater kinetic air-launched boost phase intercept (BPI) capability within five years. The boost phase layer is the critical foundation for an effective and efficient NMD architecture. The threat of enemies engaging our national interests with theater ballistic missiles (TBMs) is much more likely than an accidental or limited ICBM attack. Therefore, building highly mobile kinetic BPI capability is paramount to fielding a correctly apportioned layered defense against all missile threats.

2. Time Horizon, Assumptions, and Risks. Given the persistent technical difficulties of directed energy programs, it is critical to fill the theater BPI gap within five years. Under the Bush Administration, MDA budgets are significantly robust; therefore, it is unlikely, that funds would be increased again to accommodate another new start. MDA must build an air-launched kinetic BPI capability within the existing budget. By refocusing from strategic

to theater defenses, plus slowing the fielding of terminal defensive systems, MDA's budget is sufficient to accomplish the necessary tasks. The technical challenges are formidable, but most are at or near maturity under existing MDA programs. Re-engineering into a tactical weapons system will actually produce BPI capability sooner and serve as risk mitigation to the full compliment of MDA boost phase defenses.

3. Description of the Military Challenge. Boost phase is the most technically challenging of the NMD layers due to the compressed kill chain cycles. The boost phase defense gap was to be partially bridged by FY2009 with the fielding of the Airborne Laser (ABL), but now that gap appears to have widened and deepened. MDA's current efforts do little to counter this trend. TBM and weapons of mass destruction (WMD) proliferation is the nexus of future regional threats to our national and allies' interests. The challenge of being in the right place at the right time with sufficient capability is threefold:
    a. reliable intelligence warning to support timely BPI deployment;
    b. sufficient number of persistent theater BPI weapons systems to be on-station anywhere within 24 hours;
    c. avoidance of the political costs associated with pre-positioning of the other layers of defense on foreign soil.

For the foreseeable future, it is best met by an air-launched kinetic BPI capability, augmented with sea-based boost and midcourse systems over time. Ground-based boost phase options can't close the TBM defense gap due to four factors:

a. unrealistic requirement for weeks to months advance warning required to support deployment;

b. the unsatisfactory assumptions of secure pre-positioning rights and sufficient numbers to cover all regions;

c. the inherent loss of mission effectiveness due to line of sight impacts to already compressed engagement timelines;

d. the inability to counter interior and/or changing launch zones.

4. Synopsis. Space-based and airborne signal combined with human intelligence (SIGINT/HUMINT) must produce some level of advance warning/predictive analysis of when and where a potential enemy (rogue state or transnational terrorist) might launch TBMs. This BPI CONOPS assumes 24-hour notice as the minimum acceptable to deploy an air-launched kinetic BPI defensive capability. Modified B-52s will carry 20 plus hypersonic BPIs (under 3000 lbs each, reaching velocities up to 6 km/s). Having this capability is a deterrent in itself, especially if the imminent TBM threat is coupled with WMD. In the face of a boost phase defense, an enemy has to weigh the high risk of absorbing the very effects of their own WMD. Upon warning, 8 to 28 of the BPI equipped B-52s will deploy to Guam or Diego Garcia for forward staging, as bombers may be seen as provocative to the region proper. Actual numbers will be classified and depend on the area to be defended, type of threat, and probable launch zones. Forward basing on allied territory may be required or desired. Host nation, and possibly even enemy nation, observers are viable options, given this is a defensive capability.

Figure 14 provides a clear overview describing the series of events involved in a boost phase intercept.

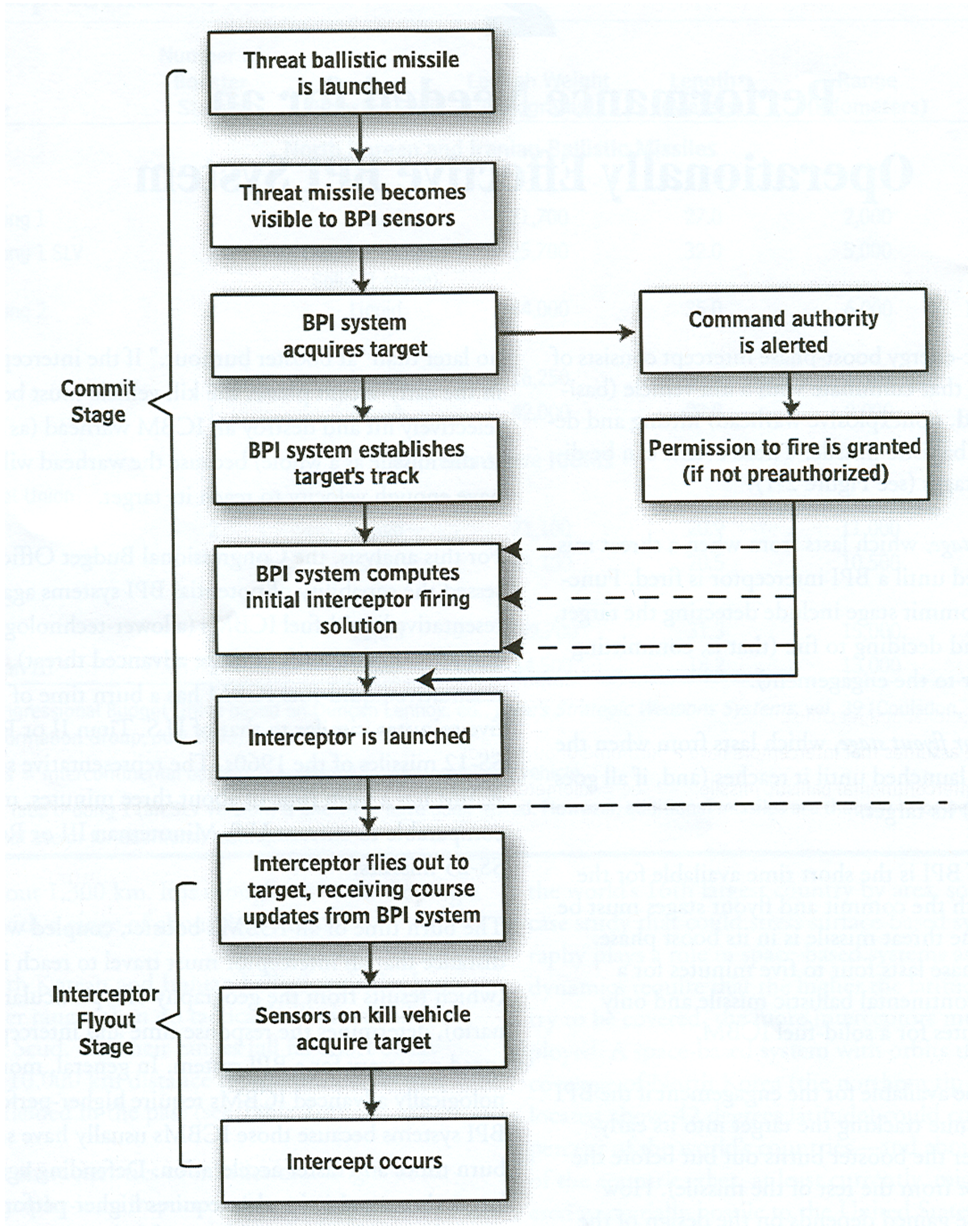


Figure 14. Sequence of Events Involved in Boost Phase Intercept[81]

a. Threat TBM is launched. This reflects that, unless we are launching 100% effective pre-emptive attacks, the enemy has the initiative and that ballistic missile defense is inherently a defensive, reactive mission, at least in the initial launch sequence.

b. Threat missile becomes visible to sensors. This will primarily be done by infrared (IR) detection, augmented by radar. The combination of space, airborne (off and on-board) and ground ISR will be shared tracking data over secure datalinks (TIBS and JTIDS). SIGINT and HUMIT pre-cursors may sharpen our understanding of the enemy's potential actions.

c. BPI system acquires target. BPI equipped B-52s should be equipped with IR and laser radar capability. By system, we infer all on and off-board acquisition and tracking networked sensors. Since off-board cueing and target updates are integral to BPI fly out, actual interceptors will be integrated into the boost phase datalink. Acquisition of the target is a function of line of sight and cloud clearance (nominally, no more than 30,000 ft). To minimize detection delays and maximize the BPI launch envelop, B-52s will orbit above 40,000 ft.

d. Parallel processes occur at this point—command authority is alerted, the target track is established, and launch platform initiates a turn towards 45 degrees of the threat axis. The first two occur automatically without any operator input required. For boost phase intercept, the default permission to fire will be pre-authorized, unless specifically directed otherwise by the theater Combatant Commander. (COCOM). The BPI computer on-board each B-52 will compute the initial interceptor firing solution and share it on the datalinks. Each BPI-equipped B-52 must have the ability to track and simultaneously engage at least eight TBMs.

e. Interceptor is launched. Again, no action is required by the B-52 crew. Master arming and weapons free for BPI weapons only is done once the B-52 goes on-station with assigned TBM defensive mission tasking. For B-52s equipped with hypersonic cruise missiles, commit authority must be pre-authorized by COCOM or coordinated with COCOM's C2 agency to allow simultaneous engagement of the TBM launch site.

f. Interceptor flies out to target. It essentially flies to a constantly updated lead pursuit predicted intercept box, course updates via the datalink. It is important to note that this may be a sensor to BPI specific datalink, as JTIDS limitations may not fully support the engagement requirements. Again, kinetic BPI will leverage work already implemented by other MDA systems in this area. The KKV (as required) will have its protective coated IR windows shrouded during this portion of flight to protect against extreme thermal heating.

g. KKV acquires the target. Once the KKV reaches the pre-determined shroud off point, its sensor acquires the target, discriminates the missile body, picks an aim point (warhead desired, but not required for boost phase), and KKV maneuvers to optimize impact.

h. Intercept occurs. Closing velocities create catastrophic destruction of the TBM and its warhead over enemy territory.

i. Battle Damage Assessment, to verify a successful intercept, is the next step. If for some remote reason the assessment is negative, the BPI system must launch a pre-computed second BPI (to engage in late boost or early thermally relevant midcourse phase) or pass off the track to the next layer of TBM defense.

5. Desired Effects. Deter enemies from launching ballistic missiles. If deterrence fails, engage and destroy all ballistic missiles at the earliest point of flight. This includes the ability to counter salvos aimed to overwhelm U.S. and allied defenses. Secondarily, use the same system to effectively target launchers simultaneously. Bottom line—air-launched kinetic BPI will largely negate an enemy's ability to ballistically deliver WMD or a WMD effect, and thus form the correct foundation for our NMD.

6. Necessary Capabilities. Chapter 5 outlines required technical capabilities and maturation. Operationally, this is a pure active defense mission, requiring only one change—auto-engage authority for BPI employment. Those B-52s equipped with hypersonic cruise missiles and without pre-authorization to engage will conduct attack operations missions using existing procedures. Lastly, establishing counter TBM patrols (CTP) inside enemy territory will require COCOM approval and adequate counter measures.

7. Enabling Capabilities. Previously mentioned ISR, datalink interoperability, hypersonic propulsion advancements, 28 x B-52 modification, and tactical

KKV are all required. Basing and special weapons handling must be established. Again, this CONOPS reflects adding a new weapons system to an existing mission tasking where tactics, techniques, and procedures (TTP) already exist. This CONOPS supports all current Air Force Task Force CONOPS.

8. Sequenced Actions. Intelligence warning and COCOM request would result in a deployment order for BPI equipped B-52s (operating under a standing 24-hour warning order). The required number of 24/7 CTPs will be established and maintained until diplomatic efforts or successful military actions negate the need. Midcourse and terminal defense layers should be deployed to provide a multi-layered defense.

9. Command Relationships / Architecture (as required). Default BPI launch pre-authorization should be written into existing active defense TTP. COCOM exceptions and hypersonic attack operations must be specifically addressed in the theater rules of engagement (ROE). Datalink architectures must support BPI sensors, battle management, and interceptor requirements. No other C2 changes are required.

10. Summary. Fielding a true air-launched BPI capability closes the growing TBM and probable WMD gap. It also establishes the correct boost phase foundation for an effective and efficient NMD, and thus, correctly defines the midcourse and terminal layers.

Chapter 7

Conclusions and Recommendations

For the last decade, the U.S. boost phase capability gap to engage TBMs was not filled; thus, our NMD architecture remains hollow and overly stressed at best, or at worst, unable to effectively counter WMD ballistic missile attacks. Building a NMD from the tail (terminal defense) towards the head (midcourse to boost phase) may have been the prudent technology approach, but it lacked the boldness required to take the fight to the enemy's neighborhood. Dr. Richard L. Garwin, member of the U.S. Congressional commission to assess the ballistic missile threat, stated, "It would be complete folly to base our security on a 21st century Maginot line."[82] Unless, we purposefully re-evaluate our boost phase options and priorities, we will likely end up with the same results as the French defenses in World War II. Present MDA acquisition strategies deliver TMD capability too late; they are essentially single layered until 2008; they are too heavily weighted on systems that require pre-positioning of ground forces; and they can't guarantee the ability to kill most of the warheads, especially prior to fractionation.

The QDR's judgment of ABL's potential and timeline clearly define not a gap, but a hole, in our missile defense architecture...a sinkhole. The boost phase layer should be the foundation of our ballistic missile defenses and should be initially focused on the more likely threat—TBMs, then ICBMs. The convergence of new technologies and the growing operational need open a second window for air-launched kinetic BPI. It's analogous to a residential construction site. Ten years of MDA investment represent preparation of the building site, procuring permits, lining up subcontractors, and purchasing materials. While the windows and doors are the terminal defense, the first thing we must do is lay the correct foundation—boost phase intercept. Theater kinetic capability represents the footers that define the shape, size, and weight bearing capacity. Pouring the foundation concrete is all about the kinetic boost phase, and the walls are the single integrated NMD structure that supports all else. The second floor is ascent midcourse capability. The roof is post apogee midcourse. The amenities, landscaping, and neighborhood patrol are directed energy and space weapons. Now is the time to build the correct NMD foundation.

This paper is meant to pave a new diagonal runway, one that crosses a very mature and sound MDA base of operations but that also allows engaging the enemy earlier with more lethal and deterring capability. The recommendations to MDA, STRATCOM, Congress, and warfighters are straight forward:

1. Immediately commission a six-month operator-in-the-loop simulation test to further define the kinetic BPI systems requirements and CONOPs proposed in this paper. The simulation capability of Distributed Mission Operations (DMO) will tie the joint warfighter and the acquisition/test/training communities together with industry—cradle to grave.
2. MDA should reprioritize its budget to a minimum of 30% on kinetic BPI, with the majority focused on developing and fielding a theater air-launched capability in three to five years. The CBO study estimated $15-24 billion for a 6 km/s BPI

against ICBMs.[83] Let's focus our air-launched BPI efforts toward fielding operational capability, as outlined in the proposed CONOPS, for $10-12 billion.

3. Establish a cutoff decision of 18-months whether to pursue rocket, scramjet, or hybrid technologies to address the propulsion requirements. This will require a plus-up of $20M to AFRL and the KEI project to effect a fly-off in early 2007.

4. To provide the equivalent effect of adding a fourth layer (more effective boost and midcourse layers), continue the pursuit of multi-kill vehicle capability.

5. Leverage advancement in sensor technologies (IR and radar) to expand their launched kinetic BPI and KEI envelopes to include ascent midcourse.

6. To address regional issues, KEI should be sea-based.

7. Continue ABL as a directed energy testbed critical to the spaced-based laser/relay mirror system.

The intersection of the most likely and most devastating ballistic missile threats, is where our national missile defense must focus. Can we negate a rogue merchant ship or submarine TBM launch that creates an electromagnetic pulse 40 km above St. Louis, and in an instant, unseats the U.S. as the world's sole hegemon? Can we prevent an enemy WMD ballistic attack on an ally that seeks to destroy a sovereign nation or turn a regional power balance upside down or drive the world economy into chaos? These threats are not only plausible but are being voiced by our foes, who don't have ICBMs. The U.S. must commit to delivering a true boost phase capability in sufficient numbers in the next three to five years to address this combat deficiency. A correctly apportioned layered defense will save billions. "Heads, not tails;" it is time to act decisively on this re-evaluation of BPI.

Appendix A

Gulf War Scud Facts (1990-91)

- The Iraqis had 500-600 missiles and upwards of 36 transporter-erector-launchers (TELs) but fired only 88 Scuds.[84]

- The US Defense Support Program (DSP) electro-optical satellites detected all 88 launches.

- Less than 4% of the 42,000 strike sorties were flown against elements of the Iraqi ballistic missile target set.[85] However, counter-Scud efforts represented 11.5% of all new sorties added to the daily air tasking order.[86]

- The Scud hunts involved AC-130H, F-15E, A-10, F-111F, B-52G, A-6E, F-117, F-16C, and F/A-18 aircraft.[87] Additionally, there were innumerable C2ISR (airborne and ground) and tanker assets also committed to support the "four percent" 24-hour anti-Scud missions.

- "Declassified records noted that in 42 Scud-hunting missions, ordnance was dropped only eight times and there were no verified missile kills."[88] U.S. and Coalition air forces found it extremely difficult to locate and destroy mobile Scud targets.[89]

- Scud hunting missions were ineffective if measured in terms of numbers of Scud-associated vehicles destroyed—some TELs may have been destroyed, but none could be confirmed.[90]

- The constant pressure of air power did seem to constrain Iraqi Scud employment--launches occurred primarily at night (under cloud cover) and the number of launches decreased as compared with those in the War of the Cities (Iraq/Iran War).[91] "Coalition domination of the air and vigorous attack operations provided a disincentive to launch Scuds."[92]

- PATRIOT performance has since proven to be far from the initial optimistic claims. The Army claimed 80% success in PATRIOT employment in Saudi, and 50% success in Israel against Scuds predicted to impact in the defended areas.[93] The "near-perfect record" proclaimed on CNN by political and military leaders was misleading. Yes, PATRIOT fired at incoming Scuds, but often at debris caused by tumbling Scuds, or the

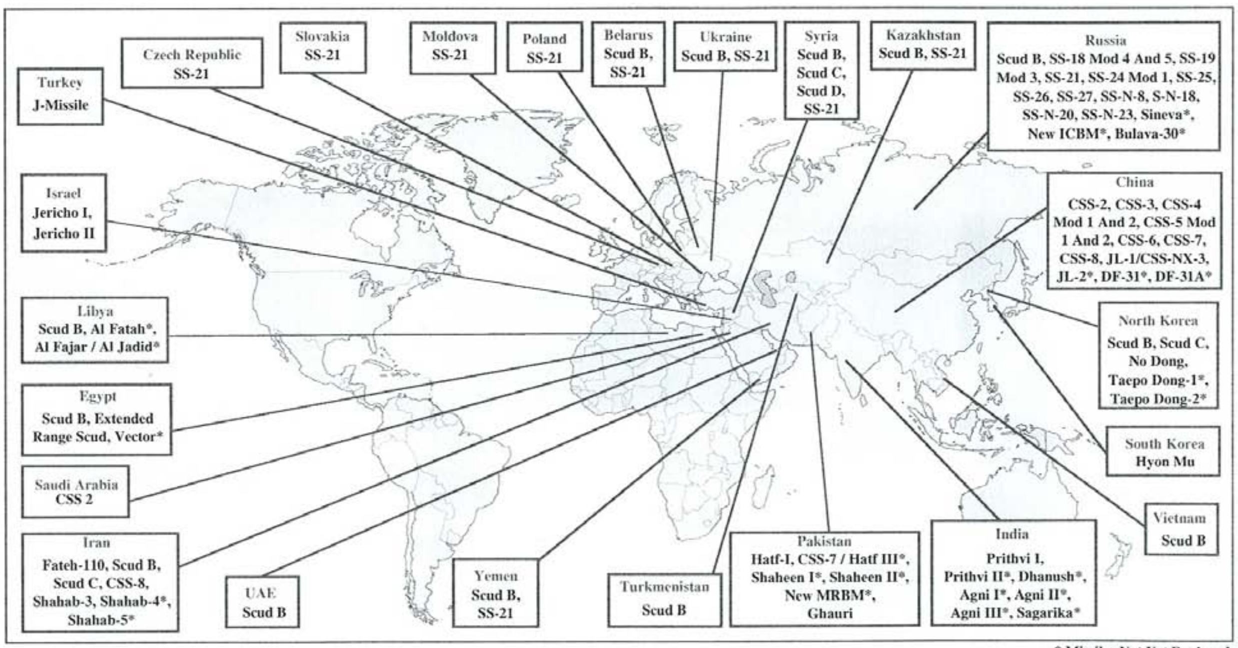
PATRIOT missiles self-destructed when they failed to acquire their intended target. Subcommittee investigators spent two months examining Army and Raytheon evidence, and found strong evidence of a warhead destroyed by the PATRIOT in only one case. Additionally, review of 140 videos provided no conclusive evidence of any Scud warhead kills.[94]

- Saddam did have chemical, biologic weapons available and for some reason chose not to use them as he had in the War of the Cities. Iraq's nuclear capability was assessed as doubtful, although Iraq had over 20,000 people working both overt civilian and covert military nuclear programs.[95] The UN Special Commission on Iraq (UNSCOM) determined at the time of the invasion of Kuwait, Iraq was less than a year from producing one or two nuclear weapons.[96]

- Factors that minimize the potential impact of Iraq TBMs:
  -- effective diplomacy and Israeli restraint averted escalation of the conflict,
  -- Iraqi Scud modifications were aerodynamically imprecise/unstable, thus degrading their long range performance,
  -- Saddam's TBM did not employ WMD, nor did he fully leverage their effects,
  -- and PATRIOT defenses were perceived to be more effective than they actually were by both sides, and attack operations and air superiority seemed to minimize Iraq's ability to carry out Scud operations with impunity.

Appendix B

Growing Ballistic Missile Capability (2004)[97]



* Missiles Not Yet Deployed

Appendix C

Missile Defense Terms

ABL -	Airborne Laser
ABM-	Anti-Ballistic Missile
AF -	Air Force
BDA -	Battle Damage Assessment
BECO -	Boost Engine Cutoff
BM -	Ballistic Missile
BMDO -	Ballistic Missile Defense Organization
BPI -	Boost Phase Intercept
CM -	Cruise Missile
COIL -	Chemical Oxygen-Iodine Laser
CONOPS -	Concept of Operations
CSAF -	Chief of Staff of the AF
C2ISR -	Command, Control, Intelligence, Surveillance, and Reconnaissance
DARPA -	Defense Advanced Research Projects Agency
DEW -	Directed Energy Weapon
DOD -	Department of Defense
DSP -	Defense Support Program
EW -	Electronic Warfare
GPOW -	Global Precision Optical Weapon
IBIS -	Israeli Boost Phase Intercept System
ICBM -	Intercontinental Ballistic Missile
IR -	Infrared
IRSTS -	Infrared Search and Tracking System
JTIDS -	Joint Tactical Information Distribution System
JTMD -	Joint Theater Missile Defense
KEW –	Kinetic Energy Weapon
KKV -	Kinetic Kill Vehicle
LEAP -	Light Exoatmospheric Projectile
LLNL -	Lawrence Livermore National Laboratory
MDA -	Missile Defense Agency
NBC -	Nuclear, Biological, Chemical
NMD -	National Missile Defense
P_k -	Probability of Kill
SECAF -	Secretary of the AF

SM -	Standard Missile
SOF -	Special Operations Forces
SRAM -	Short Range Attack Missile
TACS -	Theater Air Control System
TBM -	Theater Ballistic Missile
TEL –	Transporter Erector Launchers
THAAD -	Theater High Altitude Air Defense
TIBS -	Tactical Information Broadcast System
TMD -	Theater Missile Defense
UAV -	Unmanned Aerial Vehicle
WEZ -	Weapons Engagement Zone
WMD –	Weapons of Mass Destruction

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