TAKING NATIONAL MISSILE DEFENSE TO SEA

A Critique of Sea-Based and Boost-Phase Proposals

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CONTENTS

Executive Summary v

I. **Introduction** 1

II. **Sea-Based National Missile Defense Proposals** 3

III. **Where the Technology Stands: Navy Missile Defense Programs** 7

IV. **Constraints on Upgrading Navy TMD Programs** 13

V. **Financial Costs of Naval NMD** 17

VI. **Hidden Costs: Tradeoffs in Core Naval Missions** 21

VII. **Alternative Visions: Boost-Phase Missile Defenses** 25

VIII. **Balancing National Security Risks** 31

IX. **Conclusion** 35

Appendix: **BMDO Summary of Key Findings on Naval NMD** 39

Executive Summary

President Clinton's September 1, 2000 deferral of the decision to begin building a 'limited' national missile defense (NMD) system against attack by a few long-range missiles leaves the issue to the next administration. Many supporters of national missile defense contend, however, that the Clinton ground-based NMD plan is inadequate, and advocate an alternative, sea-based approach to NMD, generally as an interim step toward developing and deploying a comprehensive land-, sea-, and space-based NMD system. Republican presidential candidate George W. Bush's endorsement of research on sea-based, mid-course and boost-phase technology to protect the homeland and allies has heightened interest in alternatives. This report suggests that alternative schemes would not offer easy or quick solutions.

Advocates argue that deploying a global sea-based NMD for defense of the U.S. homeland and allies against strategic missiles could be cheap, quick, and easy. They claim this could be done simply and cheaply by upgrading theater missile defense (TMD) interceptors planned for the U.S. Navy's existing AEGIS ships, and by employing them against long-range missiles from the oceans and connecting seas. Sea-based NMD advocates would link interceptors with space-based tracking sensors, and usually include space-based interceptors in their schemes.

In fact, developing and deploying a global sea-based NMD system would not be cheap, quick, or easy, and installing NMD interceptors in AEGIS ships would compete with other Navy fleet and area defense requirements:

- **It would not be cheap.** Whereas some proponents claim the sea-based layer of a global NMD could be mounted on AEGIS ships at a cost of only $2 to $3 billion, the Pentagon's 1998 estimate for an AEGIS-based, 'limited' NMD system counted at least $16 to $19 billion in direct costs.[1] A more plausible but still conservative cost estimate raises the likely price tag to between $30 and $36 billion, without counting hidden costs to the Navy and the defense budget of replacing assets to cover traditional fleet defense missions, and without adding any of the cost of space-based tracking sensors. The addition of just seven more AEGIS ships to cope with simultaneous geographical threats could raise the above mentioned base price to between $37 and $43 billion.
- **It would not be quick.** Proponents of sea-based NMD claim that the sea-based elements of such a system could be partially deployed by 2003 or 2004, and fully deployed by 2009. The Pentagon's 1998–99 judgment was that initial deployment might begin by FY 2011, if accelerated, but otherwise not before FY 2014, while full deployment would not be completed until about FY 2020.
- **It would not be easy.** Most sea-based NMD schemes call for installation of Standard Missile-type interceptors in the Vertical Launch System (VLS) on AEGIS ships, along with other hardware and software upgrades for long-range missile defense communications and guidance. Interceptors capable of NMD performance will be larger and heavier than those currently used in standard VLS missile cells. Retrofit will require VLS equipment modifications and related manufacturing time and expense, and could pose new safety hazards for operation in inclement weather. It would be impractical to incorporate boost-phase interceptors with very high acceleration and high burnout velocity on AEGIS ships in VLS modules.
- **It would compete with other Navy requirements.** AEGIS missile cells normally are fitted out in homeport, with various types of missiles allocated to land-attack and fleet defense missions, as well as to new theater missile defense missions. The normal inventory will be reduced by NMD interceptors, constraining conventional naval operations. Repositioning of AEGIS ships for NMD

assignments will also draw down their availability for fleet defense and other naval missions. These actions will either degrade the scope of routine naval operations or require more ships, or both, with eventual escalation of Navy budgets.

Recently, interest in the sea-based NMD idea has taken a different twist. Several proposals have emerged to explore the use of interceptors in boost-phase mode against missiles that could be launched by so-called "states of concern" (formerly referred to as "rogue" states).[2] Richard Garwin and Theodore Postol both have argued that dedicated boost-phase interceptors, comparable in size and performance to Spartan missiles or the ground-based interceptor (GBI) being developed for the U.S. territorial NMD, would be preferable to deployment of the ground-based NMD scheme. Boost-phase interceptors, they argue, could be installed in fixed sites on land, in cooperation with Russia, or at sea on easily monitored naval cargo ships. Garwin and Postol believe that basing their heavy boost-phase interceptors on the Navy's AEGIS platforms would be impractical. Restricted land- or sea-based locations could, they suggest, enable the interceptors to counter long-range missiles from North Korea, Iran, or Iraq shortly after launch, without threatening Russia's or China's strategic arsenals. Russian president Vladimir Putin made statements before and after the U.S.-Russian Moscow summit on June 4, 2000, hinting at potential Russian interest in cooperative development of such an arrangement for the defense of Europe.

From a more traditional perspective, former senior defense officials John Deutch, Harold Brown, and John White have urged deferral of a U.S. ground-based NMD and advocate instead accelerated deployment of AEGIS-based theater missile defense systems. Their scheme favors modifying the interceptors to operate in a boost-phase mode, close in, against long-range as well as theater missile threats from states of concern, providing a limited sea-based NMD capability against the near term threats. Stanford researcher Dean Wilkening has outlined yet another alternative—airborne boost-phase defense—for limited NMD objectives against states of concern. More confident about the efficacy of U.S. deterrent capabilities against long-range missile threats from 'states of concern', Wilkening advocates that the United States go slow on a ground-based NMD, leave TMD programs to mature at a normal pace for planned missions against theater missile threats, but expedite development of airborne boost-phase capabilities to counter long-range missile threats from states of concern.

Estimating meaningful price tags or deployment time frames for each of these proposals would be difficult at this time. The Garwin-Postol proposals imply that technology choices, locations and operational control would be subject to U.S.-Russian negotiation as well as new development programs, making their scope, cost and implementation both politically and technically uncertain. The Deutch-Brown-White idea is technically unconvincing. Wilkening's proposal relies on conceptually realistic but less mature technologies than the Navy's planned upper tier TMD, suggesting a long period for technical development and solution of current operational limitations. Beyond that, several other points may be ventured:

- Since the Garwin-Postol, Deutch-Brown-White and Wilkening proposals each advocated the deferral decision on ground-based NMD that Clinton ultimately made, possibly they helped ease that decision. Each proposal focuses near term attention on countering the postulated threats from North Korea, Iran, and other countries by means that would not deeply damage relations with Russia, nor challenge the Chinese strategic deterrent. Deutch-Brown-White believe their approach buys more time to convince Russia to agree to NMD-related modifications to the ABM Treaty.
- The Garwin-Postol versions of boost-phase defense share one possibly fatal political drawback, namely that launch of boost-phase missile defense interceptors based in Russia or other states could be vetoed by them, operationally. Such a condition would not be acceptable if this were a core U.S. program whose objective is to defend the United States and its allies against a long-range missile threat.
- Secretary of Defense Cohen has stated that development of technology for a regional boost-phase interceptor approach probably would take 10 years or more, and that Russian President Putin's vague cooperative concept would not satisfy the U.S. missile defense requirements that underpin the contemplated ground-based NMD system. Defense spokespersons have also noted a deficiency of boost-phase operations, namely, the shortage of time for informed, deliberate decisions.

- Neither the Deutch-Brown-White plan to convert planned Army and AEGIS TMD interceptors to perform boost-phase missions nor their early implementation time frames seem realistic. Defense Secretary Cohen's statement that boost-phase capability would take at least ten years to develop presumably applies not only to ground-based but also to sea-based (and airborne) capabilities against long-range missiles launched from 'states of concern', even a small, peninsular state like North Korea.

A global sea-based NMD capable of intercepting unsophisticated long-range missiles from one or more 'states of concern', and a few strategic missiles from a nuclear weapon state, would be a 'limited' missile defense, and probably not leakproof. It remains to be seen whether it would actually work against strategic missiles, and whether it could be defeated by readily available countermeasures. The sea-based NMD construct assessed by the Pentagon assumes that Navy NMD interceptors would use the same mid-course interceptor technology as the contemplated ground-based NMD system. Such sea-based interceptors would face the same difficulties against strategic missiles in discriminating between decoys, other countermeasures, and warheads in space as would the ground-based interceptors in the Clinton Administration's current program.

Since such a sea-based NMD system, even a 'limited' one, might easily cost between \$30 and \$36 billion (or even between \$37 and \$43 billion) and take nearly two decades to fully deploy, policymakers should know in advance whether and how well it would work, and how much it would realistically cost over time. Since deploying this system would also require withdrawing from or substantially modifying the ABM Treaty—with potentially serious implications for security relations with Russia and China—it is crucial that the net result would be enhanced security rather than increased instability.

Before the next administration moves any distance down the paths of global sea-based NMD or regional boost-phase interceptor systems, it should demonstrate conclusively that the technologies will work and make public what the likely costs would be. Moreover, the public should be apprised of any distinctive implications of forward-deployed mid-course NMD and boost-phase systems for global and regional stability. Close-in boost-phase concepts depend on virtually instantaneous and therefore automatic reaction. The tyranny of reaction time can be so short that the "man in the loop" disappears and the potential for serious accidents rises correspondingly.

I. Introduction

President Clinton's September 1, 2000 deferral of the decision on whether to start building a 'limited' national missile defense (NMD) system this fall to protect the United States against attack by a few long-range missiles leaves the issue to the next administration in 2001.[3] Many supporters of national missile defense contend, however, that the Clinton administration's ground-based NMD plan is inadequate, and advocate an alternative, sea-based approach to NMD. This alternative usually is viewed as an interim step toward developing and deploying a comprehensive land-, sea-, and space-based NMD system. Republican presidential candidate George W. Bush's recent endorsement of research on sea-based, mid-course and boost-phase technology to protect the homeland and allies has heightened interest in alternatives.[4] The findings of this report suggest that alternative schemes would not offer cheap, quick, or easy solutions.[5]

In contrast to what some proponents claim, this report finds that deploying sea-based NMD would not be cheap, quick, or easy.

Advocates argue that deploying a global sea-based NMD for defense of the U.S. homeland and allies against strategic missiles could be cheap, quick, and easy. They claim this could be done simply and at low cost by upgrading theater missile defense (TMD) interceptors planned for the U.S. Navy's existing AEGIS ships, and employing them against long-range missiles from suitable locations on the oceans and connecting seas. Sea-based NMD advocates would feed interceptors data from space-based tracking sensors, and usually include space-based interceptors in their schemes.

President Clinton announced in 1999 that any decision by his administration on whether to deploy a ground-based NMD system would be based on four criteria: the readiness of the technology, the impact on arms reductions and security relations, the cost of the system, and the threat.[6] While each of these criteria also would be relevant to any decision to deploy a global sea-based NMD, this analysis focuses primarily on the issues of cost and readiness of technology. It reflects official information and expert judgments related to the effectiveness of technology, and how it would be applied to threats that have been framed by the policy community, but it does not carry out an original analysis of technology or threat.

Building the ground-based NMD envisioned by the Clinton administration, or any sea-based or boost-phase NMD scheme proposed by others, would require either renouncing the ABM Treaty or substantially altering it. This analysis does not attempt, however, to deal with all the specific arms control implications of each NMD construct. It deals with security, arms control and political-military issues where doing so serves to remind the reader of their importance in the policy context of missile defense activities, and how they have shaped choices to date. Otherwise, the main focus is on the cost of building and deploying a global sea-based NMD system, how long it would take, and what hurdles have to be crossed. In contrast to what some proponents claim, this report finds that deploying sea-based NMD would not be cheap, quick, or easy.

II. Sea-Based National Missile Defense Proposals

This analysis starts with an assessment of proposals to upgrade U.S. Navy *theater* missile defense systems to perform *national* missile defense missions. Proponents of sea-based NMD advocate that missile defense interceptors based on Navy ships be made capable not only of intercepting short-, medium-, and intermediate-range ballistic missiles in distant theaters, as planned in TMD programs already, but also capable of intercepting long-range, or *strategic*, ballistic missiles that might strike U.S. territory over inter-continental distances.

Intercepting *strategic* ballistic missiles is, by definition, the function of anti-ballistic missile (ABM) systems, which the United States agreed with the then Soviet Union to restrict by the terms of the ABM Treaty.[7] While the Treaty as modified in 1974 would allow the United States to deploy a single-site, ground-based ABM system limited to 100 interceptors, it presently stands in the way of a multi-site ABM system or deployment of more than 100 interceptors. The Treaty also prohibits deploying ABM systems in a mobile form, on ships or aircraft, or in space, and thus stands in the way of proposals to build sea-based, space-based or extraterritorial land-based defenses against *strategic* missiles.[8]

Proponents of global sea-based NMD concepts are remarkably optimistic that the systems they envisage would be technically effective and could be deployed at low cost.

The most ambitious sea-based NMD proposals are those put forward by influential Republican members of Congress and by the panel of missile defense experts associated with the Heritage Foundation. Their concept is to build the first phase of a global national missile defense on U.S. Navy platforms, followed in later phases by satellite-mounted interceptors in space.[9] The concept presupposes that U.S. Navy theater missile defense capabilities can easily be upgraded to create a *global, sea- and space-based national missile defense* system. Proponents argue that such a multi-tiered defense system could intercept hostile strategic ballistic missile warheads in the ascent-phase of their mid-course trajectory, well before they arrive over the territory of the United States.[10] (See Figure 1, "Theater Missile Defense Architecture" on page 10, for illustrations in the theater missile defense context of representative target ballistic missile trajectories and intercept phases.)

Proponents of global sea-based NMD concepts are remarkably optimistic that the systems they envisage would be technically effective and could be deployed at low cost.[11] The 1999 Heritage sea-based NMD proposal suggests that a U.S. homeland defense based on Navy assets could be built more quickly (four years), at much lower cost ($2 to $3 billion), and with much better performance against strategic missile threats than the ground-based NMD interceptor system being developed by the Clinton Administration.[12] The proposal assumes that Navy missile defense systems will rely on connectivity between the interceptors and tracking data from space-based infra-red sensor systems (SBIRS) which are still under development and expected also to serve other purposes, such as strategic deterrence and military intelligence.[13]

Heritage proposes not only to upgrade planned Navy TMD systems with higher performance, NMD interceptors but with constellations of space-based (boost-phase and mid-course) interceptors. It advocates that one satellite interceptor constellation be equipped with kinetic homing interceptors (formerly dubbed "Brilliant Pebbles"), and that a second space tier, when the technology permits, be deployed to use long-distance laser-kill mechanisms. (See Table 1, "Heritage Foundation Global Defense Concept.")

TABLE 1 Heritage Foundation Global Defense Concept

Global NMD	Full Deployment Cost	Deployment Schedule**															
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Naval and Space Components																	
Naval (NTW) Interceptors	$2 to $3 billion (650 SM-3 interceptors)				ID						FD						
SBIRS - Low	$5 billion				ID												
SBIs ("Brilliant Pebbles")	$12 to $15 billion					ID											
SBLs	$15 to $18 billion										ID						
Total for Naval and Space (NTW/SBIRS-Low/SBIs/SBLs)	$40 billion																

Key:

ID = Initial Deployment
FD = Full Deployment

SBIRS-Low = Space-Based Infra-Red System
SBIs = Space-Based Kinetic Interceptors
SBLs = Space-Based Lasers

*Source: Defending America: A Plan to Meet the Urgent Missile Threat, Washington, D.C.: The Heritage Foundation, March 1999, chps. 1–5 (website version: <http://www.heritage.org/missile_defense/>).

**Note: Heritage deployment schedule reflects a private Commission's judgments of what would be feasible under reorganized program management, higher front-end spending, and without ABM Treaty or other arms control restrictions, and does not correspond to authorized programs or official estimates.

The global sea-based NMD proposals treat as a "sunk cost" the $50 billion or more already spent over two decades to procure the Navy's more than 50 AEGIS cruisers and destroyers. These AEGIS ships are specially equipped for vertical missile launch and could accommodate significant numbers of missile defense interceptors in their launcher magazines. Proponents of global, sea-based NMD proposals thus imply that an effective NMD system could be mounted in the AEGIS ships easily, quickly, and at low additional cost.

On the contrary, as this analysis shows, that view is at least misleading. Advocates of global sea-based NMD:

- seriously underestimate the technical difficulty of intercepting ICBMs and overestimate the capability of any of the planned AEGIS theater missile defense systems, and particularly of the Navy "upper tier" TMD, to intercept ICBMs;
- underestimate both the time needed as well as the ultimate financial cost to develop and procure an advanced, AEGIS-based, NMD interceptor system;
- overlook the cost of the launch component modifications and ship retrofits, or the cost of procuring new ships needed to field effective NMD capability from the sea;
- fail to take into account the direct and indirect defense costs, or operating tradeoffs, that would be a consequence of diverting AEGIS naval assets from their other forward-deployed missions and traditional fleet defense objectives (e.g., intercepting cruise missiles); and
- underestimate the time and funds needed to deploy the currently planned space-based sensor suites.

Some proponents of global sea-based NMD would dismiss outright the legal constraints of the ABM Treaty. Possibly they believe that the development time frame could be shortened and the costs lowered by moving the Treaty aside. That would not, however, alter the laws of physics or the national pace of solving difficult technical problems, suggesting that the program effects of setting the Treaty aside would be marginal at best. Some proponents do not discuss, let alone try to quantify, the national security costs—in the form of strategic instabilities, new threats, and new demands on U.S. capabilities, all generating new mission requirements—that could arise from unilaterally deploying NMD at sea. These costs, in comparison, likely would be substantial.

Even if a sea-based NMD system eventually could be both effective in its active defense mission and suitable on overall security policy grounds, it is a disservice to mislead the American public that the technical requirements can be easily satisfied or achieved at bargain basement prices. It would be unwise and potentially catastrophic to engage public confidence in fielding a system that—when it must work in a real-world crisis—could fall far short of advertised performance.[14] It would be inappropriate also to imply, by default, that deploying a sophisticated missile defense against a potential ballistic missile threat from hostile states would seal off several more primitive avenues for clandestine delivery of weapons of mass destruction against the United States that may already be feasible, and almost certainly easier, for such states to pursue.

III. Where the Technology Stands: Navy Missile Defense Programs

To understand why the general concept of sea-based missile defense has strong appeal to the Navy and why Navy assets can give rise to the facile, if misleading, idea that a global defense against strategic missiles can easily be mounted on existing ships, it is important to know more about the U.S. Navy's AEGIS ships, the vertical missile launch capability on those ships, the types of missiles carried, and the purposes they serve.

The Navy's AEGIS ships were designed to launch a variety of missile types to support anti-air, anti-ship, and anti-submarine defense of aircraft carriers and other warships in forward-deployed battle groups. The configuration of the vertical missile launchers is ideal for air defense missiles and apparently is flexible enough to adapt to the Navy's currently planned theater missile defense systems. For instance, the "lower-tier" Navy TMD capability (against short-range ballistic missile threats) is just now being retrofitted and tested in AEGIS ships.[15] But there are practical limits on the size of interceptors that can be readily adapted to the AEGIS launch platform and Vertical Launch System (VLS). Installing larger, high-performance NMD interceptors may require major modifications and these may not be prudent or cost-effective.

Installing larger, high-performance NMD interceptors may require major modifications and these may not be prudent or cost-effective.

AEGIS Vertical Launch Platform

In combination, the AEGIS weapon system (AWS)[16] and the Mark-41 Vertical Launch System were first fielded operationally in the early 1980s on Ticonderoga-class cruisers and Arleigh Burke-class destroyers. Improvements have been made to these systems as new AEGIS ships were added to the fleet. Traditionally, the primary naval mission of AEGIS ships has been "fleet defense," i.e., active defense of aircraft carriers and their forward-deployed battle groups.[17] AEGIS ships usually are also equipped to participate directly in "suppressive fire support", i.e., naval attacks on coastal or interior targets, by launching Tomahawk land-attack cruise missiles (T-LAM) or Standard surface-to-surface ballistic missiles from VLS tubes.[18]

The AEGIS weapon system consists of a computer-integrated suite of radar and electronic sensors, data processing and display consoles, fire-control instruments, and an assortment of ready-to-launch missile types fitted out in the VLS missile cells. The AEGIS weapon system and missile consignments have been designed to detect and intercept multiple threats from aircraft, cruise missiles, surface ships, and submarines simultaneously.

The VLS systems on Arleigh Burke-class destroyers today each contain 90 missile cells while the VLS array on a Ticonderoga-class cruiser normally contains 122. Spruance-class destroyers are not AEGIS-equipped but do carry smaller VLS arrays, usually with 61 missile cells.[19] As of July 2000, the U.S. Navy had some 56 of the AEGIS-equipped ships in commission (27 Ticonderoga class cruisers and 29 Arleigh Burke class destroyers), with a total capacity well over 5,000 VLS missile cells.[20]

Standard Missile Interceptors

To support theater missile defense missions overseas, the Navy chose in April 1998 to upgrade the AEGIS weapon system and modify the Standard Missile air defense interceptors to function as anti-ballistic missile interceptors.[21] Powered by solid rocket motors, the Standard Missile has been deployed by the Navy on ships since the 1970s, earning an excellent reliability record and undergoing refinements during its many years of service. Air defense, anti-ship, and land-attack versions were employed on earlier naval surface ships. In the 1980s, improved versions of the Standard Missile were integrated with VLS systems on AEGIS platforms.

Table 2 on "Standard Missile Characteristics" lists the advertised specifications of the air defense versions of the Standard Missile and compares them with what is known about the modified or redesigned versions the Navy expects to use as theater missile defense interceptors in the AEGIS/VLS environment.

As Table 2 indicates, the Navy plans to use an extended-range SM-2 (SM-2, Block IVA) for its "lower-tier" TMD interceptor against *short-range* ballistic missiles.[22] For "upper tier" TMD interceptors *against medium- and intermediate-range* missiles,[23] the Navy plans to use two variants of the SM-3, a new three-stage Standard Missile concept that has yet to be fully defined, let alone developed as engineering prototypes or unveiled as a proven missile.

Lower- and Upper-Tier Naval TMD

Missile defense systems are categorized, in part, according to their altitude of intercept. Defenses that intercept missiles above altitudes of 80–100 km (above the atmosphere) are referred to as exoatmospheric, while those that intercept below this threshold (inside the atmosphere) are termed *endoatmospheric*. Dropping

TABLE 2 **Standard Missile Characteristics**

	SM-1 Medium Range	SM-2 Medium Range	SM-1 Extended Range	SM-2 Extended Range	SM-3
Primary mission(s)	Air Defense	Air Defense	Air Defense	Air Defense, ATBM, lower-tier TMD	Theater Missile Defense (TMD), upper-tier TMD
Stages	One	One	Two	Two	Three boost stages plus KV
Diameter	13.5 inches (34.3 cm)	13.5 inches (34.3 cm)	13.5 inches (34.3 cm)	13.5 inches (34.3 cm)	21 inches (53 cm) (Thiokol AEGIS EX-72 booster)
Length	14.6 ft (4.41 m)	14.6 ft (4.41 m)	26.2 ft (7.9 m)	26.2 ft (7.9 m)	26.2 ft (7.9 m, est.)
Weight	1,100 lbs (495 kg)	1,380 lbs (621 kg)	2,980 lbs (1,341 kg)	2,980 lbs (1,341 kg)	3,100 lbs (1,395 kg)
Slant-range	17–23 mi (27–37 km)	46–104 mi (78–176 km)	75–175 mi (121–283 km)	75–175 mi (121–283 km)	185–620 mi (300–1,000 km)
Flyout velocity				2.5 km/sec for Block IVA	>3 km/sec for Block I 4-4.5 km/sec for Block II
Power plant	solid-fuel	solid-fuel	solid-fuel	solid-fuel	solid, high-energy HTPB-AP
Guidance	semi-active radar homing	semi-active radar homing	inertial, semi-active radar	inertial, semi-active radar	inertial, radar and IR homing
Warhead	HE/proximity fuse	HE/proximity fuse	HE/proximity fuse	HE/proximity fuse	kinetic kill/LEAP (light exoatmospheric projectile)
Date first deployed	1970	1981	1981	2003 est. for SM-2, Block IVA	2008 est. for SM-3, Block I
Air Defense versions		SM-2 Blocks II, III-A/B		SM-2, Block IV	
NAD ATBM version				SM-2, Block IV-A	
NTW TMD versions					SM-3, Block I, II
NMD-capable version					Upgrade of SM-3, Block II 5-6 km/sec

*Sources: Director, Operational Test & Evaluation, FY 99 Annual Report, Washington, D.C.: The Pentagon, February 2000, Section on Navy Systems, chapters on "Standard Missile - 2" and "Navy Theater Wide (NTW) Defense"; US Navy, Navy Fact File, "Standard Missile," at <http://www.chinfo.navy.mil/navpalib/factfile/missiles/wep-stnd.html>; <http://www.fas.org/man/dod-101/sys/missile/sm-2.htm>; Dean A. Wilkening, Ballistic-Missile Defence and Strategic Stability, Adelphi Paper No. 334, London: IISS, Oxford University Press, May 2000, chp. 3; Henry F. Cooper and J.D. Williams, "The Earliest Deployment Option–Sea-Based Defenses," Inside Missile Defense, September 6, 2000.

below the 80–100-km threshold, the atmosphere exerts increasing atmospheric friction on descending objects. This atmospheric drag may separate lightweight decoys from incoming warheads, aiding the performance of endoatmospheric defenses. Below 40 km, however, the denser atmosphere exerts greater force, enabling incoming warheads with certain aerodynamic features to maneuver, placing special demands on the engagement sensors and the homing capabilities of the interceptors. In American terminology, "upper-tier" TMD systems are designed to intercept targets above 40 km, and "lower-tier" TMD below this altitude.

For its *lower-tier* TMD system, the Navy plans to use the SM-2, Block IVA interceptor in an endoatmospheric role at altitudes above 30 km, against shorter-range ballistic missiles or their warheads in their descending or terminal phase. (See Figure 1 illustrating missile defense engagement phases and altitudes from a theater perspective.) Formerly described as an ATBM program,[24] this lower-tier TMD is now called *Navy Area Defense* (NAD).

NAD's kill mechanism is a high-explosive fragmentation warhead with proximity fusing—similar to the aerodynamic warheads that high-altitude air defense interceptors use to shoot down hostile aircraft and cruise missiles. The SM-2, Block IVA interceptor's fly-out velocity is designed to be about 2.5 km/sec. NAD's defended area (or footprint) of approximately 40 to 60 km diameter is relatively compact and suitable primarily for "fleet defense."

When close to land and located between inbound missiles and their aim points on land, NAD can provide some inland defense of marine expeditionary debarkation and nearby coastal operations. NAD is essentially, however, a "terminal defense" system, for ships clustered in a battle group.

The Navy's *upper-tier* TMD, called *Navy Theater Wide* (NTW), is being designed for an exoatmospheric role—to intercept medium- and intermediate-range ballistic missiles (or their separated warheads) above the atmosphere, during the mid-course phase of their ballistic flight.[25] Upper-tier Navy plans call for interceptor missiles with considerably greater range, acceleration, and fly-out velocity than the SM-2. Three-stage versions of the Standard Missile (SM-3) are being designed to provide enhanced performance.[26]

The NTW program's plan in the first phase is to use SM-3, Block I, with a fly-out velocity of about 3 km/sec, while the second phase calls for the SM-3, Block II, with a fly-out velocity of between 4 and 4.5 km/sec.[27] The cryogenically-cooled infra-red seekers on kinetic kill vehicles can operate only above the atmosphere, setting a lower limit of 70 km altitude for NTW interceptors. The diameters of the NTW defended footprint reportedly can vary from several hundred to 1,000 km, many times the size of NAD's.[28]

The Navy's planned kinetic kill vehicle for NTW is designated Light Exo-Atmospheric Projectile (LEAP). LEAP has self-contained long-wave, infra-red (IR) sensors and small maneuvering thrusters—the means to detect and discriminate among moving objects above the atmosphere, and to maneuver into direct collision with a target warhead. As long as the interceptor kill mechanism has enough mass,[29] the closing speeds in a direct collision with a compact warhead would generate extraordinary kinetic forces and completely destroy both objects.[30] Layering NTW and NAD as upper- and lower-tier TMD is expected to provide much higher efficiency in intercepting ballistic missiles than either layer alone.

NTW, when located far from the threat missile launch point and close to the defended area, will also perform late mid-course and high altitude terminal defense. In this situation NTW is also, despite its much larger footprint than NAD, an extension of the fleet air defense mission. NTW will be designed, however, to provide some area protection against medium- and intermediate-range ballistic missile threats to the landing of expeditionary forces, their staging points, and nearby ports and airports, as well as to allied or friendly military facilities on a coastline, and even to populated areas further inland.

In the best case, a single AEGIS NTW ship suitably prepositioned between North Korea and Japan, using the higher velocity Block II interceptor against target missiles in their ascent-phase, theoretically could provide defense area coverage of almost all of Japan against medium- and intermediate-range North Korean missiles.[31]

In a crisis like that of Desert Storm, for example, the Navy's rapid offshore deployment of layered air and missile defense could liberate U.S. air and naval transport to concentrate on introducing air and ground combat forces, without first transporting the heavy equipment for ground-based missile defense systems (e.g., the Army's lower-tier Patriot-3, and upper tier THAAD). Effective local defenses against ballistic missile threats could have powerful foreign policy and security assurance implications. Such defenses could reinforce general deterrence posture against hostile threats and bolster the confidence of threatened allies

Theater Missile Defense Architecture (Overseas)

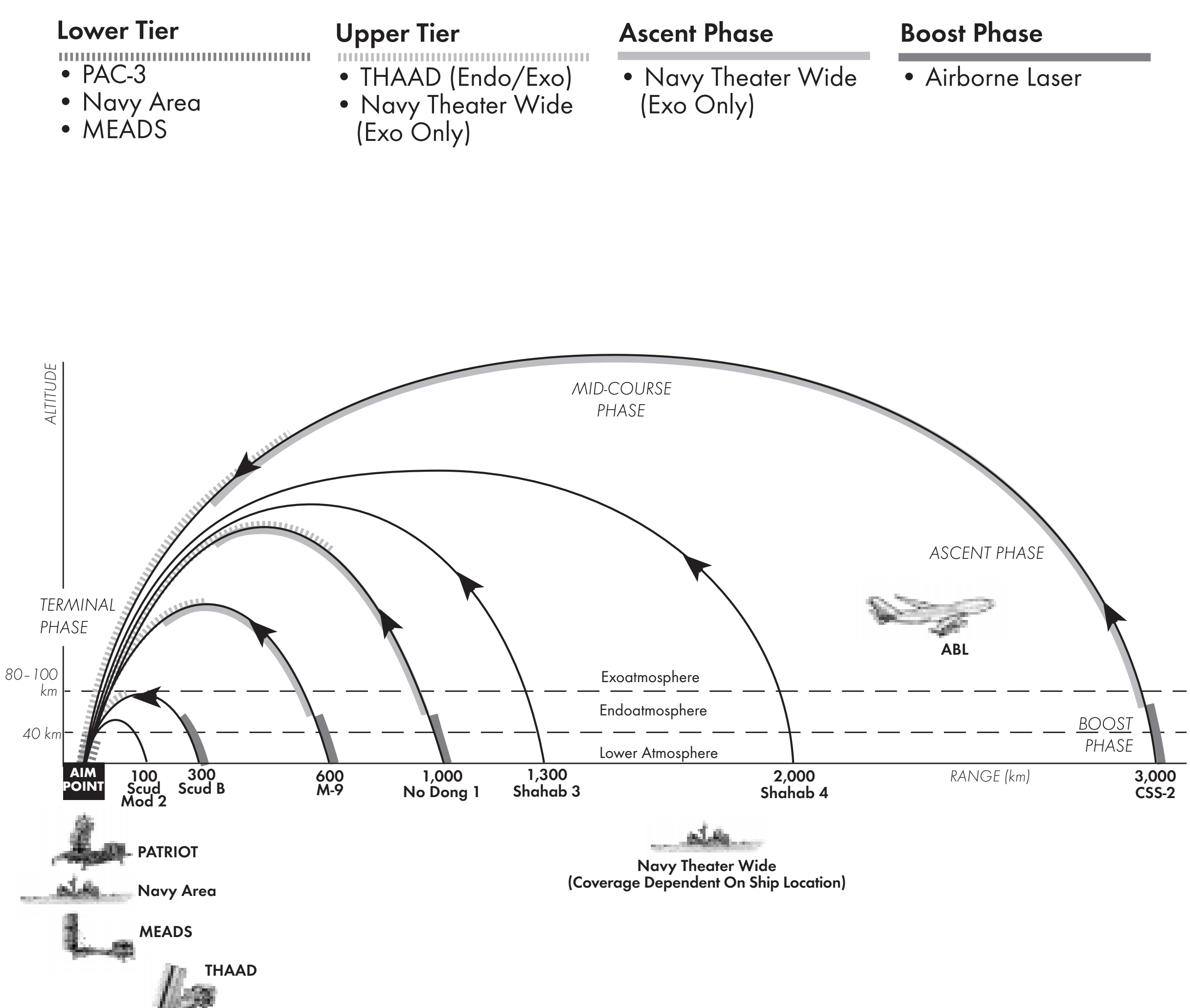
Figure 1 compares approximate range and altitude relationships among representative theater ballistic missiles when focused on a common aim point. The figure identifies which U.S. theater missile defense systems operate inside (endo-) and outside (exo-) the atmosphere. It also illustrates visually the phases of ballistic missile trajectory in which interceptors may engage.

In general, the longer the range of an attacking ballistic missile, the greater is its burn-out velocity, the higher is the altitude it reaches above the earth's surface, and the longer is its travel time through its trajectory. Strategic or long-range ballistic missiles (not depicted here) have ranges exceeding 5,500 kilometers (can be as high as 15,000 km) with commensurately higher velocities, higher apogees, and somewhat longer travel times. But the intercept phase terminology is the same.

Boost Phase

The boost phase for medium- and intermediate-range missiles typically extends beyond the lower atmosphere altitude of about 40 km, but usually

FIGURE 1 **Theater Missile Defense Architecture**



Source: BMDO, Department of Defense

terminates within the thinned out endoatmospheric domain, between 60 and 80 km altitude. Boost phase ends when the missiles engines stop firing. Boost-phase interceptor seekers have the technically simpler task of seeing the entire missile and its plume, a bigger target with a hot and highly visible flare, and may engage the target at lower speed, before it can reach its ultimate velocity. However, predicting the intercept point of an unevenly accelerating target before committing the interceptor is challenging. Infra-red sensors in space would not detect a missile launch, if it is obscured by cloud cover, until it has broken through the clouds at up to 10 km altitude, and some additional time is required to project the approximate trajectory and azimuth—to judge its likely destination. Successful boost-phase intercept of a missile before it leaves the atmosphere has the advantage that the debris will fall back to earth, short of the missile's aim point.

Ascent Phase

After the boost phase is over, the target missile continues to rise with its inertial velocity towards the apogee, or highest point, of its trajectory. This ascent phase is essentially the first part of the mid-course phase. For longer-range ballistic missiles, most of the ascent is exoatmospheric. The kill vehicles (KVs) for ascent-phase must meet the same technical challenges as interception anywhere in the mid-course phase. However, the proximity to the launch point of the target missile required for ascent-phase intercept can provide a larger defense footprint than late mid-course and terminal defense.

Mid-course Phase

The mid-course phase of the trajectory is exo-atmospheric, and for all but very short-range missiles, is the longest and most geographically exposed portion of the trajectory. After the missile's last booster stage has burned out, the warhead(s) separate from residual missile components. If there is any residual atmospheric drag, the jettisoned booster may fall back, but if separation occurs in space, the residual missile components will also travel by inertia as part of a "debris cloud." For tracking purposes, velocity and azimuth are constant in mid-course. The KVs for mid-course interceptors in current U.S. programs rely on highly sophisticated, ultra-cooled, infra-red seekers designed to differentiate incoming warheads (which may retain more residual heat and be visible against the cold background of space) from gas-filled decoys, and from any residual debris. The kinetic KV has sophisticated thrusters to enable it to maneuver into the path of the incoming warhead, to collide directly with it for kinetic destruction. Figure 1 illustrates "late mid-course," when the missile warhead travels down from its apogee towards the atmosphere and the terminal phase. The planned U.S. ground-based NMD system, and the Navy upper tier TMD systems, are designed to operate in the mid-course phase.

Terminal Phase

Once the incoming warhead begins to encounter atmospheric drag, the terminal phase begins. The intercept technologies in the terminal phase must deal with endoatmospheric conditions. Typically, terminal interceptors rely more heavily on radar guidance and use fragmentation warheads rather than kinetic kill vehicles. An advantage for terminal defense is that the atmospheric drag strips away decoys and exposes the warhead(s) to local radar sensors. However, the engagement time is very short, and the defense area footprint is relatively small.

As a two-dimensional illustration, Figure 1 cannot depict the geometry of actual interaction between target and interceptor, except to suggest that the interceptor will have better intercept opportunities if it can be launched down range from the launch point of the target missile. The interaction between targets and interceptors is better understood in three dimensions.

by maintaining unequivocal U.S. ability to project its forces in unstable regions.

It is a big leap from deploying Naval TMD systems that may be militarily effective against short-, medium- and intermediate-range missiles overseas, however, to upgrading those missile defenses to stop *strategic* missile warheads launched at the United States (or major allies). Strategic warheads travel at much higher velocities over intercontinental range, imposing much more strenuous requirements for tracking, discrimination, and successful kinetic intercept.[32]

In essence, this would require mounting NMD (or ABM) interceptor capability on naval platforms. The problem has many facets to consider. A reliable capability to shoot down long-range ballistic missiles aimed at the United States (or major allies) from ships at sea would not only be scenario-dependent, but conditioned, for example, by the range and velocity of the hostile missiles, the reach and intercept-angle of AEGIS interceptors from available maritime locations, the availability, range, and effectiveness of tracking and engagement sensors, and the effectiveness of the kill vehicle in final engagement.[33]

These performance factors could be influenced in turn by competing naval fleet defense and other mission requirements, Navy standard operating procedures, and threatened regional conflict contingencies or even the unfolding of an actual theater battle, along with safety and weather (or "sea-conditions") in the theater of operations.

Operationally, a fundamental requirement for NMD (homeland defense) is that the system be on station and ready to fire every day of the week, at all hours, and under any weather conditions. It would not do for homeland defense against long-range missiles to be hostage to storms at sea. Navy standard operating procedures for safety could inhibit launch of long-range, heavy interceptors in extremely turbulent conditions.

IV. Constraints on Upgrading Navy TMD Programs

To grasp what it would take to upgrade Navy theater missile defense systems to perform NMD missions, one must examine what has actually been done so far in the Navy TMD programs. The U.S. Navy is committed to developing and deploying TMD under the Navy Area Defense and Navy Theater Wide programs already mentioned. These Navy TMD programs have been designed by the Pentagon to be ABM Treaty-compliant. They are considered to fall outside the limits and restrictions set forth in the ABM Treaty on ABM systems. The missile defense components are being developed and tested to intercept *non-strategic* ballistic missiles, and are supposed to be incapable of defending meaningfully against an attack by strategic missiles.

Choosing the AEGIS platform and its VLS tubes for missile defense places important engineering constraints on the size and capability of the interceptors that can be used.

The Demarcation Criteria

The Navy's TMD interceptors are expected to be consistent with criteria in the TMD "demarcation" agreements, signed by the United States and Russia in New York in September 1997. The provisions in these demarcation agreements were negotiated to clarify testing and performance thresholds for TMD.[34] Operating below these thresholds, TMD interceptors (whether land- or sea-based, fixed site or mobile) would not amount to ABM-capable interceptors and therefore would not conflict with the provisions of the ABM Treaty. Senior Republican members of Congress have objected to the basic purpose and contents of these demarcation agreements, however, and the administration thus has delayed setting them formally before Congress.[35]

In contrast to global, sea-based NMD proposals, the Navy's TMD programs do not call for mounting ABM capability on AEGIS platforms, and, through the 1990s at least, did not anticipate the Navy performing the NMD mission. In comparison with the preference in most global, sea-based NMD proposals for the higher interceptor velocities and unconstrained external sensor support that would enable AEGIS-based interceptors to reach more often into the ascent-phase, the Navy "upper-tier" program is simply based on "mid-course" intercept requirements and technology. The Navy does not rule out ascent-phase intercept when location and operating conditions make this feasible.[36] The Navy "lower-tier" program, however, essentially envisages a "terminal" phase interceptor system.

Launch Platform Constraints on Naval Interceptor Performance

Choosing the AEGIS platform and its VLS tubes for missile defense places important engineering constraints on the size and capability of the interceptors that can be used, and therefore limits the acceleration, fly-out velocity and range of those interceptors. The interior depth of launch locations in the territory of hostile states, and the maritime locations accessible for interceptor ships also establish physical constraints on where, how, and even whether, it would be possible to intercept a hostile missile. Further, the acceleration, burnout velocity and fly-out direction of attacking missiles may vary considerably, and determine whether intercept opportunities actually materialize for interceptors located on one or more sea-based platforms. Finally, the quality and availability of tracking information from external sensors can affect the range of intercept opportunities and the system's effectiveness.

Consider the Navy's TMD interceptor technology choices to date. The threat from theater ballistic missiles to Navy battle groups and coastal debarkation operations may originate at distances of hundreds to thousands of kilometers. But attacking missiles in such cases would be coming towards the Navy battle group or the ground-based operations it is protecting, not flying away in other directions. The shipboard AN/SPY-1 search and fire-control radar's missile detection and tracking range is limited to 200–300 km and even with planned improvements is unlikely to be reliable beyond 500 km.[37] Given the constraints of the AEGIS/VLS platform and its sensors on the size and performance of interceptor missiles, the basic choices of intercept are in the "mid-course" and "terminal" phases of the trajectories of attacking missiles.

To achieve the upper tier of the layered defense architecture, the Navy has planned the SM-3, Block I and II "mid-course" TMD interceptors already described. Although these three-stage interceptors will be considerably more powerful than any previously available in the Standard Missile production series, the Navy expects to be able to accommodate them (packed in modified Mk-21 canisters) in the current AEGIS/Mark-41 VLS "strike" modules without heroic modifications. The current eight-pack VLS modules on AEGIS ships each contain eight rectangular missile cells. Each missile cell is about 21 inches wide (square cross-section). Although there are three standard modules and missile cell lengths available (according to the types of missiles to be loaded), the relevant "strike" length modular cell slightly exceeds 20 feet.[38] The missile cell cross-section and maximum length in existing modules become outer constraints on the maximum diameter and length of the tubular missile launch-canister that a missile cell can accommodate. Either of the Navy's SM-3 NTW interceptors, with velocities of 3 km/sec at the low end and 4–4.5 km/sec at the high end, equipped and canisterized with the LEAP kinetic warhead, evidently will exhaust the interior space available in an eight-pack type missile cell.

In order to assess the feasibility of upgrading the NTW interceptors to make them NMD-capable, the Navy reportedly has been studying six-pack missile cell modules for the VLS system. In this case, the cross-section of each missile cell would be about 26 inches (5 inches wider). This cross-section would be just sufficient to accommodate the diameter of the EKV, the heavier exoatmospheric kill vehicle that BMDO is developing for NMD. It would also permit interceptors with larger diameters and, in turn, more powerful rocket motors, as would be needed to upgrade the NTW program to some mid-course capability against strategic missiles. Velocities for this still notional capability have not been published, but presumably would be upwards of 5 km/sec.

Attempting to integrate *boost-phase* intercept capability with VLS on existing AEGIS platforms may prove impractical for most maritime scenarios. The short boost-phase reaction times would call for nearly double the burnout velocity of the more powerfully NTW interceptor (from between the 4–4.5 km/sec projected for SM-3, Block II to between 7 and 8 km/sec). Such an interceptor would be much heavier and larger than could be accommodated in the contemplated six-pack VLS module.

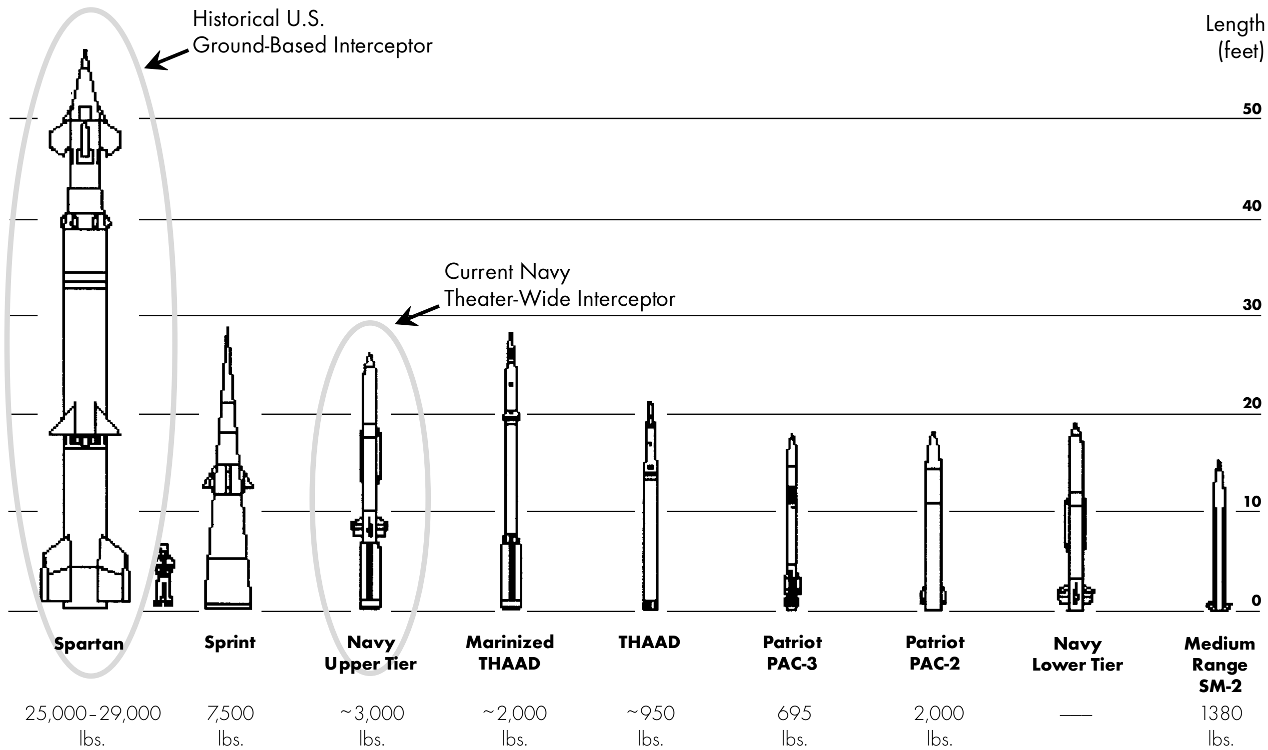
Indicative of boost-phase constraints, the notional interceptors used in the analyses of Richard Garwin and Theodore Postol resemble the Spartan missile (see Figure 2 depicting the relative size of existing U.S. interceptor missiles, and Section VII on "Alternative Visions") and the NMD ground-based interceptor (GBI) that is still being developed. The Spartan missile (between 25,000 and 29,000 pounds) weighs from eight to ten times the largest Navy TMD interceptor currently in active development (NTW, SM-3/Block I, weighs about 3,100 pounds).[39] Ships refitted or designed to launch a Spartan-size missile and procured expressly for this purpose could be built, but would not be AEGIS/VLS platforms, and would require a program and entail substantial costs of their own.

The acceleration and burnout velocity of interceptors is not only a matter of their fuel type, fuel volume, nozzle design, and streamlining against atmospheric drag, but also depends importantly on the payload weight.

This is part of the explanation for the Navy's choice of LEAP, a relatively light kinetic KV, as the business end of its planned NTW TMD systems. A light payload (e.g., about 25 kilograms) may be necessary in order for the Standard Missile variant to get the system altitude and range needed for exoatmospheric, mid-course intercept.

Garwin and Postol argue, however, that off-the-shelf interceptor warheads capable of destroying long-range missiles in their boost-phase must be quite heavy (to achieve the last-second KV acceleration and axial divert movements needed to catch a target missile body still accelerating in the final seconds of its burn), and thus require very large interceptor missiles. But unless a radical departure is made in Navy planning and AEGIS engineering, the Navy has to fit missile defense interceptors into the existing AEGIS/VLS systems, where a heavy missile of the Spartan's (or GBI's) dimensions would not fit.

FIGURE 2 **Indicative Physical Characteristics of Representative U.S. Interceptors**



Source: Theodore Postol, 2000

A rough calculation of the additional fuel volume that would be permitted by expanding the VLS missile cell cross-sections from 21 to 26 inches—a possible means of accommodating an NMD-capable ('modified' SM-3, Block II) naval interceptor in a six-pack VLS module—suggests that the solid fuel volume could be increased by about half again as much.[40] With the same payload weight as LEAP, this would permit design of a three-stage interceptor with more range and higher flyout velocity than the unmodified Block II, but not close to double the velocity.

An NMD-capable naval interceptor, however, would require multi-spectral infra-red sensors and a heavier warhead than LEAP for effective mid-course intercept of strategic missiles. This could mean the EKV warhead being designed for the ground-based NMD system. Given the greater weight of the EKV, it is doubtful that exploiting the additional volume of the 26-inch missile cell would increase interceptor velocity much beyond the nominal 4.5 km/sec of Block II, if at all. Moreover, for the mechanics of boost-phase intercept, unless the new interceptor warhead was much lighter than LEAP, the needed acceleration would be unavailable. But lightening the warhead would impair its lethality, probably an unacceptable tradeoff.[41]

In short, upgrading TMD to achieve the loads and fly-out velocities required for NMD missions with Standard Missile variants launched from AEGIS/VLS represents a serious engineering challenge. Such upgrades would run up against the velocity thresholds in the demarcation accords. Upgraded naval TMD interceptors could not perform NMD functions effectively if supported only by the existing AEGIS shipborne AN/SPY-1 radars, but would have to be linked to much more powerful, ABM-capable, external tracking and engagement sensors (high-power X-band radars on land or at sea, or space-based infra-red sensors) and this is presently barred by the ABM Treaty.[42] Thus, while building a global NMD system on the Navy's AEGIS platforms might seem at first glance to be a potentially efficient use of existing assets, it would not be a minor modification that could be done quickly and easily, or cheaply.

V. Financial Costs of Naval NMD

Pentagon figures developed for Congress on the possible cost of building a sea-based NMD indicate that even a system of *limited capability* would be far more expensive, involve greater technical risk, and take longer to develop and deploy, than most proponents have acknowledged. These figures were assembled when senior members of Congress directed the Ballistic Missile Defense Organization (BMDO) in 1997 to report on the feasibility and estimated costs of upgrading Navy TMD programs to provide a *limited* sea-based NMD capability. BMDO was also instructed to address whether and how such a sea-based system could be integrated with and support the anticipated U.S. ground-based NMD system.[43]

In essence, BMDO judged that a stand-alone Navy NMD system would cost more, probably be less effective, and take longer to develop and deploy than the ground-based NMD system.

In response, BMDO submitted a classified report to Congress on June 26, 1998[44] and later issued an unclassified "summary" version to the public.[45] The BMDO public summary provides an estimate, albeit a very cautious and tentative one,[46] of the possible costs of a *limited, stand-alone Navy NMD* system.

BMDO assumed a system based on AEGIS assets, with a capability to defend the United States equivalent to the homeland defense capability of 100 ground-based NMD interceptors located at a single site in the United States, i.e., the C-2 threshold in current NMD planning.[47] BMDO estimated that such a stand-alone Navy NMD would cost $16 to $19 billion in FY1997 dollars. This naval NMD would be more costly, BMDO noted, than building the C-2 threshold capability of the contemplated ground-based system. BMDO estimated the latter would cost between $13 and $14 billion.

In essence, BMDO judged that a stand-alone Navy NMD system would cost more, probably be less effective, and take longer to develop and deploy than the contemplated ground-based NMD system.

BMDO's summary document does not disaggregate the costs of specific naval NMD components, but does stipulate that the naval system would need at least the same external sensors contemplated for the ground-based NMD at the C-2 threshold in order to perform the NMD (homeland defense) mission. BMDO notes that the external sensors and BM/C3I [48] for the sea-based NMD mission would cost $8 billion—not counting the cost of SBIRS-Low, the new generation of low-orbit tracking satellites.[49] BMDO included 3 to 6 new AEGIS ships (dedicated to the NMD mission), at a likely cost of between $3 and $6 billion (this evidently explains the "range" between $16 and $19 billion in the BMDO estimate). After sensors, BM/C3I and ships, the balance of the estimate could be attributed mainly to the post-1997 development and procurement cost of interceptors equipped with EKVs, about $5 billion. A rough breakdown of the BMDO total therefore would allocate the total among the following general categories:

- Sensors and BM/C3I: $8 billion
- Interceptors: $5 billion
- AEGIS ships: $3 to 6 billion

In contrast to the Heritage proposals, BMDO's cost estimate of a sea-based NMD includes the heavier and more capable EKV being developed for the ground-based NMD. Unlike Heritage, BMDO assumes that the existing inventory of AEGIS ships would be insufficient, and therefore adds the notional cost for 3 to 6 new AEGIS ships. BMDO also excludes any reference to the space-based interceptors that Heritage advocated.

Beyond that, BMDO offers a very tentative estimate of what it would cost to upgrade elements of the Navy's currently funded NTW interceptor program to give it

NMD mid-course intercept capability.[50] The BMDO summary assumes the operational availability of space-based, infra-red sensors (existing DSP in the near term, and SBIRS-High and SBIRS-Low once they come on line), but excludes their cost from the estimate, presumably because the satellite sensors are being funded under an Air Force program as military intelligence rather than missile defense assets.

As its "baseline" for a naval NMD interceptor comparison, BMDO uses the Navy Theater Wide second-phase, SM-3, Block II construct—still a planned system and one that has neither been completely defined nor fully funded. (See Table 2.) The Navy regards the somewhat better defined SM-3, Block I capability (the slower, first phase, LEAP-equipped NTW interceptor) as "substantially less capable" than Block II, and therefore not even worthy of analysis for capability against strategic ballistic missiles.

Still in evolution, SM-3, Block II interceptor technology would be analyzed in accordance with the demarcation criteria for "inherent" capability against strategic missiles, but presumably the Block II was planned as a TMD interceptor that would comply with those criteria. Thus BMDO's conceptual extrapolation of NMD-capability from NTW assets had to be based on a more capable interceptor. This would involve major "upgrades beyond Block II," but today this is a missile on paper, not than anything resembling an operational prototype.[51] The closest BMDO comes to labeling this naval NMD capability—the system that would be used to defend against *strategic* missiles—is by reference to it as the "SM-3, 'modified' Block II system."

The BMDO findings on cost and relative effectiveness of naval NMD capability are centered on evaluating the notional construct of a *stand-alone* Navy NMD capability (see BMDO's "Summary of Key Findings," quoted in full below, in the Appendix). Paraphrased here in simpler language, the BMDO found that:

1. *Naval TMD assets alone would make no meaningful contribution to intercepting modern strategic missiles* (i.e., those deployed by Russia and China); but NTW Block II TMD deployed near the U.S. coastline could offer some protection of coastal facilities (including defense of ABM radars) against ship-launched short- and intermediate-range ballistic missiles;

2. *If prepositioned with enough warning at suitable launch locations, and linked with the external sensors planned for ground-based NMD*, NTW Block II TMD would also have a mid-course intercept capability against *unsophisticated*, long-range missiles (i.e., from 'states of concern') launched against the United States;

3. *A naval NMD capability that is also effective against more sophisticated missiles from 'states of concern', as well as against accidental or unauthorized launch of a few modern strategic missiles* (i.e., those deployed by Russia and China) *would require much more powerful and sophisticated interceptor systems* than is currently envisaged in NTW Block II capabilities, in several ways (e.g., would require a faster interceptor that has better seeker performance and kill vehicle divert capability, and increased nuclear hardness—like the EKV being developed for the ground-based NMD system);

4. *The most useful performance of a Navy NMD capability would be as a supplement to ground-based NMD*, in a fully integrated NMD architecture, rather than as a stand-alone system;

5. *A genuine naval NMD capability, whether a partial system or one that meets the full C-2 requirements, involves higher technical risk and a longer deployment time frame than the ground-based NMD under consideration*; and

6. The *rough order of magnitude estimate of the cost of a stand-alone Navy NMD meeting C-2 requirements would be $16 to $19 billion*, $3 to $5 billion more than the prospective ground-based C-2 NMD system.

BMDO acknowledged that "the use of NTW in support of an NMD system would raise significant ABM Treaty issues" but declined to give a full-fledged assessment of these issues: "The DoD has not assessed the compliance of such use. The DoD assesses the compliance of approved and sufficiently defined programs. However, the architectures and approaches discussed in this report are not under consideration for approval as a program by the DoD, and have not been submitted for compliance review."[52]

Heritage and Pentagon cost estimates of naval NMD diverge sharply, as do their projections of deployment timing. (See Table 3.) Heritage spoke in March 1999, of achieving a global, sea-based NMD for just $2 to $3 billion, with initial and full deployment, respectively, by 2004 and 2009. BMDO, in contrast, estimated in 1998 that a stand-alone Navy NMD system meeting C-2 requirements would cost between

TABLE 3 **Comparison of Heritage and BMDO Cost Estimates for Naval NMD***

	Defense System	Full Deployment Cost	Initial Deployment Date	Full Deployment Date
Heritage	NMD-capable NTW (650 SM-3 Interceptors)	$2 to $3 billion	2003	2009
	SBIRS - Low	$5 billion		
	SBIs ("Brilliant Pebbles")	$12 to $15 billion		
	SBLs	$15 to $18 billion		
	Total Naval and Space (NTW/SBIRS-Low/SBIs/SBLs)	$34 to $41 billion		
Ballistic Missile Defense Organiz-ation (BMDO)	Naval "stand-alone" NMD** (includes 3–6 more AEGIS ships)	$16 to $19 billion	FY 2011–FY 2014	FY 2020

*Sources: For key to acronyms, see Table 1; for documents, see: BMDO, Summary of Report to Congress on Utility of Sea-Based Assets to National Missile Defense, June 1, 1999, at <http://www.acq.osd.mil/bmdo/bmdolink/pdf/seanmd.pdf>; Defending America: A Plan to Meet the Urgent Missile Threat, Washington, DC: The Heritage Foundation, March 1999, chps. 1–5.

**Note: BMDO's naval NMD estimate included cost of ground-based sensors and 3–6 AEGIS ships, excluded cost of SBIRS, and did not address SBIs or SBLs. It noted that up to 13 AEGIS ships could be required for simultaneous threats.

$16 and $19 billion in FY97 dollars, nearly an order of magnitude higher. Initial deployment of this naval NMD probably could begin about FY 2014, according to BMDO, but full deployment would occur close to the end of that decade.

Even if one subtracted the roughly $6 billion cost of up to 6 new AEGIS ships from the BMDO cost estimates (since this was not taken into account in the Heritage proposal), the BMDO cost estimates for a genuine naval NMD system are still four to five times higher than those in the Heritage proposal. The official BMDO figures suggest, at a minimum, that the Heritage proposals vastly understate the cost of a global, sea-based NMD.

Although the BMDO projected cost of a stand-alone Navy NMD system is four to five times higher than the Heritage cost figures, the BMDO estimate itself understates the likely financial cost. BMDO acknowledges that since it had to project an undefined interceptor system, its own figures are "rough order of magnitude" (ROM) cost estimates and are not reliable.[53] As BMDO mentioned in its conclusions (see no. 7 in "Summary of Key Finding," in the Appendix), the "NTW Block II RDT&E, procurement and O&S costs were not included in the ROM estimate." This evidently means that the program cost of the planned NTW ("upper tier") was treated as a sunk cost of the TMD programs rather than assigned as a direct cost to the notional sea-based NMD program. Moreover, BMDO excluded most "operations and support" (life-cycle) costs from its sea-based NMD projection.

Based on the cost overrun histories of most advanced weapon programs, even the official BMDO figures—taken as good faith but "rough order of magnitude" estimates—probably understate the likely costs of a real sea-based NMD system.

The Congressional Budget Office (CBO) has found Pentagon estimates of the cost of a ground-based NMD to be far below the amount that CBO believes is likely. CBO concluded, for instance, that the cost of the planned ground-based NMD system (cumulatively, through construction of its C-3 phase, and adding operations and support costs through 2015, but excluding SBIRS-Low) would rise to at least $49 billion. This was nearly twice the $26 billion figure CBO received from the Pentagon as official estimates of the "expanded C-1" phase of NMD through 2015.[54]

By analogy, the $16 billion to $19 billion BMDO estimate for sea-based NMD in FY1997 dollars might be raised by the same proportion CBO raised the Pentagon figures for deploying and maintaining ground-based NMD through 2015 (i.e., 88.5 per cent). This would suggest the actual future cost of sea-based NMD through 2015 might be between $30 and $36 billion, also in FY1997 dollars—not counting the NTW Block II interceptor development cost mentioned earlier.

Thus a realistic but still conservative figure for a global, sea-based NMD equivalent to the still *limited* C-3 threshold, and using mid-course intercept technology, probably would be closer to a range of $30 to $36 billion. (See Table 4, "Estimate of the Cost of Sea-Based NMD," and compare with Table 3.) This would be between twelve and fifteen times the amount the Heritage proposals set out in 1999.

This section addressed only the direct costs of building an AEGIS-based NMD. For a meaningful assessment of the overall financial costs, the indirect costs—such as the naval mission and operational tradeoffs discussed in the next section—must also be included, even if they cannot be quantified exactly by the level of analysis possible here.

TABLE 4 **Estimate of the Cost of Sea-Based Missile Defense**

	Defense System	Full Deployment Cost	Cumulative Cost
BMDO baseline	Naval "stand-alone" NMD (includes 3-6 dedicated AEGIS ships)	$16 to $19 billion	
Likely increases	BMDO baseline	$16 to $19 billion	
	CBO NMD differential**	BMDO estimate plus 88.5%	$30 to $36 billion
	7 more AEGIS ships	$7.0 billion	$37 to $43 billion
	Mission tradeoffs	not calculated	not counted here
	CBO SBIRS-Low est.	$10.5 billion	$47.5 to $53.5 billion

*Sources: Congressional Budget Office, Budgetary and Technical Implications of the Administration's Plan for National Missile Defense, April, 2000; available at: <http://www.cbo.gov>; for BMDO, see sources in Table 3.

**Differential between BMDO estimate of cost of ground-based NMD at C-2 level and CBO estimate of cost of ground-based NMD built to C-3 level and maintained through 2015 is 88.5% above BMDO estimate. Differential is applied here to Naval "stand alone" NMD, by analogy, as a rough order of magnitude estimate of this system built to C-3 level and operated through 2015. BMDO and CBO estimates for NMD did not include in the totals the cost of SBIRS-Low, estimated by CBO to cost $10.5 billion, and neither included space-based interceptors in their assessments.

VI. Hidden Costs: Tradeoffs in Core Naval Missions

An indirect cost factor in sea-based NMD overlooked by the Heritage proposals and mentioned but not systematically counted by BMDO, concerns the costs that would result from taking AEGIS ships and some proportion of VLS launch tubes away from their original naval missions in order to perform NMD missions.[55] If the Navy's conventional power projection roles (to reassure allies and help maintain regional stability) and its own fleet defense capabilities are not to be degraded by the NMD mission, the AEGIS/VLS capacity diverted by NMD must be made up in some other fashion, probably by procuring additional AEGIS ships.

This tradeoff cost issue begins with the sequestering of some AEGIS/VLS capacity for TMD missions. To support TMD missions, the usual VLS load-out of Tomahawk strike missiles, Standard air defense missiles and other anti-ship and anti-submarine missiles on AEGIS ships must be reduced by some fraction in order to accommodate TMD interceptor missiles. If the original naval combat missions are not to suffer from this reduction in their "suppressive fire" and "fleet defense" weapon inventories, additional AEGIS ships and VLS capacity will have to be acquired, at substantial cost.

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This problem arguably is less severe with TMD than with NMD because the active defense coverage for "fleet defense" and "area defense" benefits from synergy in the layering of air and theater missile defense, provided the AEGIS ships stay in their normal action group formations. The "lower-tier" TMD interceptors (SM-2, Block IVA) are capable of performing high-altitude air defense—even as they are also designed to perform the more demanding task of intercepting short-range ballistic missiles. Moreover, both "upper" and "lower-tier" TMD interceptors are designed to fit the existing VLS missile cells. Nevertheless, if a typical VLS missile assortment for traditional naval missions is drawn down on any AEGIS platform to accommodate TMD systems, that capacity must be replaced by other AEGIS platforms and VLS capacity, if aircraft carriers and other high-value surface ships are not to be put at greater risk.

The same kinds of tradeoffs would be more demanding and more complicated when integrating NMD interceptors with AEGIS/VLS systems, in at least three ways. First, intelligence or strategic warning of long-range missile threats to the United States from overseas would call for the movement of forward-deployed AEGIS platforms carrying NMD interceptors to optimum NMD launch locations. This may separate AEGIS ships from the action groups (and fleet defense functions) to which they were originally assigned, leaving gaps in local defense and operational support.

This tradeoff can only be remedied on a permanent basis by buying additional AEGIS ships and VLS capacity. It may require a number of more specialized AEGIS platforms be dedicated primarily to the NMD function, such as the 3 to 6 AEGIS ships referred to in the BMDO sea-based construct, or a considerably larger number of AEGIS ships—if close-in boost-phase goals are adopted for sea-based NMD.

Second, NMD-capable, sea-based interceptors driving more sophisticated and heavier exoatmospheric kill vehicles (e.g., EKV rather than LEAP) would need more propellant than TMD counterparts, to achieve the acceleration and burnout velocity required for mid-course intercept of strategic missiles. This implies that the interceptor missiles themselves would be larger in diameter or length, and certainly greater in booster weight, than the currently planned "upper-tier" naval TMD systems. Accommodating bigger interceptors would require modification of the VLS modules and missile cells to the larger dimensions. This would either constrain the customary missile load-outs on existing AEGIS platforms, or require new AEGIS ships with expanded VLS capacity, driving new retrofit or procurement costs.

Bigger and more powerful interceptor missiles would also add, incidentally, to the safety challenges of launching missiles from ships, with much higher risk to the ships and personnel, especially in inclement weather conditions, than is the case today with normal VLS missile inventories. It would not be tolerable for homeland strategic missile defense to have portions of the system go off line, unpredictably, because of bad weather or any other operational down time that might be inherent in AEGIS platforms performing multiple missions.

Third, whereas AEGIS/VLS platforms usually are deployed forward, a mission requirement that could be imposed on them is to support a ground-based NMD system by stationing naval NMD interceptors along the U.S. coastlines. This could protect early warning or X-band radars and communications facilities against a ship-launched missile precursor attack. Since AEGIS ships are not normally stationed on round-the-clock alert close to the U.S. coastlines, new ships probably would have to be procured to meet that requirement.

In addition to procuring new AEGIS ships to fill gaps resulting from the tradeoffs between naval NMD and traditional naval missions, naval NMD probably would require new ships (or retrofit of existing ships) to carry longer-range and higher resolution sensors, comparable to the X-band radars intended to support the ground-based NMD.

Such radars would perform tracking and mid-course discrimination functions at distances that the AEGIS shipborne radar is incapable of. The AN/SPY-1 search and fire control radars on most AEGIS ships can support Navy TMD to ranges of 200 or 300 kilometers, but they do not have the range or resolution to support the engagement of strategic ballistic missiles.[56] Some improvements in the data processing and integration capability of AEGIS radars are currently being pursued, but these improvements will not make SPY-1 radars comparable in range or resolution to the much larger ground-based X-band radars. Furthermore, AEGIS ships do not have sufficient space, as currently designed, to retrofit large X-band radars.

Hence, to provide this sensor support in many forward-based maritime locations, dedicated ships with high-resolution tracking radars would be necessary to support the NMD mission (at a cost of between $250 and $435 million apiece).[57] Space-based sensors (especially SBIRS-Low) could relieve a naval NMD system's need for external X-band radar support, but the SBIRS-Low sensors will not be available until after 2010, at best.

It goes beyond this analysis to conduct a detailed accounting of the hidden or indirect AEGIS/VLS system costs that would result from funding Navy mission tradeoffs, adapting VLS systems to accommodate much more powerful NMD interceptors, and procuring ship-based X-band radars. But a few points may be indicative.

Cost Implications of Adding Ships

Buying AEGIS ships historically costs roughly $1 billion apiece. The BMDO summary report refers to acquisition of between 3 and 6 additional AEGIS platforms to support a limited, stand-alone, Navy NMD capability. But these may be overly optimistic numbers, on the low side, of the additional ships required for a limited but effective sea-based NMD capability.

It is worth noting that BMDO's small number of 3 to 6 additional AEGIS platforms for a stand-alone naval NMD architecture (at the C-2 threshold) seemed plausible because the NMD interceptors are assumed to operate in the "mid-course" phase of the attacking missile's trajectory—which would allow the launch ships normally to operate from further out, in much broader ocean areas, and with somewhat relaxed time lines. At the same time, this essentially requires that these AEGIS platforms be dedicated to the NMD mission, and not overlap with other AEGIS-supported naval action group missions.

The BMDO report notes that if the less capable NTW Block II ("upper-tier") TMD system were augmented by external sensors and BM/C3, it would have some NMD capability against Third World threats (North Korea and so-called "Rest of World" or ROW threats), but this system would call for 3 AEGIS platforms to be ready to operate close-in to each threat location. If strategic warning suggested threats from each of four locations had become active simultaneously, BMDO's summary indicates that as many as 13 dedicated AEGIS platforms might be required on station.[58]

Adding the procurement cost of 7 more AEGIS ships to the upper range of the BMDO estimate discussed earlier would take it from $19 to $26 billion. Similarly, adding the cost of 7 more AEGIS ships to the $30 to $36 billion that this report suggested earlier could be a more realistic cost for a limited sea-based NMD would raise the total estimated cost to between $37 and $43 billion.

Cost Implications of NMD Performance Shortfalls

This report makes no independent effort to assess the technical performance of NMD interceptor technologies, but it is important to recognize that testing and refining requisite technologies in development can substantially increase the full acquisition costs of any new weapon system. Effective NMD system intercept requirements are extraordinarily challenging. Moreover, the demonstration of the effectiveness of the NMD kinetic-intercept technologies planned today for a ground-based NMD system is still at an early stage.

The BMDO's sea-based NMD cost estimates assume that the naval NMD interceptor system will work on the same "mid-course" principles as the projected ground-based NMD system. BMDO envisages that the "hit-to-kill" interceptors in either case would use the sophisticated Exoatmospheric Kill Vehicle that is being developed for ground-based NMD interceptors. This EKV is to be hardened against nuclear effects, and prototypes are currently undergoing live flight tests against ballistic targets, albeit with mixed results.[59]

Evidence has accumulated recently, however, that the current EKV will not necessarily be effective in discriminating and defeating nuclear or biological warheads when they are masked by countermeasures that are readily available even to an unsophisticated missile state.[60] There is reason to believe on this ground alone, therefore, that the current official cost estimates of the ground-based NMD and the still theoretical naval NMD would fall well short of what would actually be spent to make either system viable for limited homeland defense. The evolution of countermeasures against a deployed NMD system would also degrade its effectiveness unless a continual development process is maintained to further improve intercept technologies. These costs cannot be measured in advance, but are sure to be substantial.

The same issues are germane to the Navy TMD programs, especially the "upper-tier" NTW which, as currently planned, would use the hit-to-kill (kinetic) principles against target missiles in their mid-course phase. The General Accounting Office recently pointed out in criticism of the "buy before you fly" features of the current NTW program that adequate operational testing, including sufficient integrated flight tests, are necessary to ensure system effectiveness, and such tests should precede initial procurement and deployment.[61]

Such a prerequisite is equally compelling for any program that might be started for upgrading naval TMD to a possible sea-based NMD system. First it should be determined whether the technology could actually work, and, second, if a decision were also made to deploy such a system, the testing should be sufficient to prove the operational effectiveness of the chosen delivery system and hardware before beginning procurement and deployment.

Cost Implications of Mission Creep

Yet another factor in projecting the ultimate cost of going to sea with a homeland defense against strategic missiles is that allies would also desire coverage under this capability. While a limited sea-based NMD that is designed to protect the geographical United States probably would offer a measure of inherent defense coverage of some allies, pressure would grow to fill geographical and effectiveness gaps—in a form of naval mission creep. While extending such protection to U.S. allies would appeal to a broad domestic constituency, the potential this would represent for cost growth in the thickness of the NMD system would be substantial, and cannot be ignored.

Moreover, as Charles Peña has noted, post-deployment recognition of sea-based NMD system deficiencies and the interest in protecting allies globally would increase pressure to deploy space-based missile defenses, with a much larger escalation of direct costs.[62] No official cost estimate of a global NMD with space-based interceptors has been published, but the Congressional Budget Office estimated in response to Congressional queries in 1996 that a layered ground- and space-based missile defense system would cost at least $140 billion.[63] This approach would also be highly controversial at home and abroad, breaching the tacit barrier for the first time against deploying a strategic weapons system in space.

VII. Alternative Visions: Boost-Phase Missile Defenses

New proposals have sprouted recently that conceive of geographically localized or even custom-designed NMD systems—focused on countering the long-range missile threat from specific 'states of concern', especially North Korea,[64] a small country that is relatively accessible from the sea, but also Iran and Iraq. These new proposals all rely on boost-phase intercept principles.

Their technical appeal is that intercepting an entire missile during its boost-phase would seem much easier, on first glance, than intercepting its separated warhead(s), masked by decoys in space. During boost phase, the target missile is a much larger object, its hot rocket plume is easy for ordinary seekers to home in on, engagement may be possible before its velocity has peaked, and successful intercept could destroy the whole missile together with its warheads and any submunitions and decoys, before they have separated.

The political appeal of these ideas is that geographically localized interceptor systems would not necessarily be able to reach, and therefore would not be as threatening, to Russia's and China's strategic arsenals. Since some of these schemes could be more easily monitored, they also have some prospects for arms control negotiation, agreed limitations, and verification measures.

The crucial difficulty in achieving boost-phase intercept from terrestrial or sea-based platforms is that the interceptors must be located very close to the launch points of the target missiles and also must travel very fast. To achieve boost-phase intercept, the defense system must detect the launch of the target missile, characterize its trajectory, determine that it is a threat, and launch interceptors on a closing path with sufficient time left for the interceptors to cover the distance and strike the target missile before it has flamed out. All this, launch detection and threat determination, trajectory definition, decision to respond, and interceptor travel to a predicted intercept location must be accomplished in a maximum of four to five minutes, even for unsophisticated ICBMs. The reaction times for medium- or intermediate-range theater missiles are considerably shorter.

The automatic response required for success in boost-phase intercept scenarios, especially in the absence of strategic warning, virtually excludes top-level decision making from the loop.

Operating under this tyranny of time is a formidable technical challenge with great potential for error and serious political implications. Shifts from peaceful relations to war between states can be driven in seconds, without meaningful presidential knowledge or conscious deliberation in the national command authority. The automatic response required for success in boost-phase intercept scenarios, especially in the absence of strategic warning, virtually excludes top-level decision making from the loop.

Garwin and Postol: Custom-Designed Boost-Phase System

Richard L. Garwin and Theodore A. Postol have urged consideration of localized, boost-phase intercept proposals that would depend on political cooperation with Russia.[65] Each has illustrated conceptually how dedicated, boost-phase interceptors could be stationed near North Korea, Iran, and Iraq—on land, on ships in inland seas, or on sea-based platforms. The land-based or inland sea-based systems could intersect missile flyout trajectories from these countries toward the United States, Europe and Russia, with Russian, Kazakhstani and Turkish cooperation. The sea-based interceptors in these schemes would not be mounted on AEGIS ships but rather on refitted naval cargo ships, more practical for this purpose, and possibly a smaller investment.

Garwin's boost-phase interceptors would be inherently ABM-capable but he argues that a protocol to the ABM Treaty probably could be negotiated with Russia to exempt ABM-capable interceptors that are located in restricted basing areas (where they can be monitored), and specifically deployed to defend against threatening states that are outside the Treaty. He suggests that Russia might be persuaded to cooperate, particularly if some of these interceptors are operated jointly by U.S. and Russian personnel at ABM test ranges in Russia, or in the Caspian Sea, or in a post-Soviet state like Kazakhstan.

Garwin aims to sidestep the technical problems, long development lead times, and the procurement and support costs inherent in the current U.S. ground-based NMD program and proposed naval NMD schemes. He suggests readily available missile technologies would suffice. His forward-based system would, implicitly, get by with a relatively small number of interceptors, but could be expanded incrementally, if necessary.

He envisages a self-guided interceptor with a high burnout velocity, which he claims would be easier to produce and deploy than the mid-course interceptors now being tested. Garwin's interceptor kill vehicle would use relatively simple (non-cryogenic) seekers. The interceptor would be cued to an approximate intercept point by DSP trajectory information and then on-board sensors would home in, initially, on the plume of the ascending target missile and, closer-in, would discern the missile body and shift course slightly to target the missile itself, destroying it by an explosive charge on impact.[66]

Fitting out naval cargo ships with interceptors presumably would be less expensive than modifications to AEGIS platforms. DSP satellites would provide initial warning of the threat missile launch and indicate approximate trajectory. Garwin claims that sophisticated external tracking and engagement sensors would be unnecessary for his scheme. Postol's otherwise similar concept, however, would employ ground-based X-band radars near interceptor deployment sites.

Deutch-Brown-White (DBW) Naval Boost-Phase Concept

Former senior defense officials John Deutch, Harold Brown and John White have sketched out a localized, boost-phase scheme quite different from the Garwin-Postol schemes in that it would, like the Heritage proposals, rely on the Navy's AEGIS platforms. This sea-based proposal made a case for deferral of President Clinton's then still pending deployment decision on ground-based NMD. The authors argued that the ground-based NMD technology is not ready for deployment and a deployment decision in the near term would be highly disruptive of U.S. relations with Russia and China, and of concern to American allies.[67] They endorsed the view "that an NMD system is critical to the United States' future homeland defense" but added that:[68]

> the system under consideration is not the best approach for initial deployment and fails to address several threats that the United States now faces. We propose an alternative approach that builds on the theater missile defense (TMD) systems now under development for defense against intermediate-range ballistic missiles. We believe this approach is a more balanced way to address the varied missile threats facing the United States and that it has technical and cost advantages over the proposed NMD system. Moreover, our proposal should be more responsive to the concerns of Russia, China, and many of our allies and may therefore ease the process of modifying the ABM Treaty.

The authors go on to propose a more aggressive deployment schedule for current Navy TMD systems, with the following steps:[69]

1. As soon as possible, forward-deploy current systems that are configured to provide *some capability* against North Korean ballistic missiles. Deployment of an AEGIS cruiser equipped with an existing missile and aerodynamic kill vehicle off the coast of North Korea can provide *modest capability* for a boost-phase intercept of the Taepo-Dong missile. This capability could be available well before the initial operational capability of the NMD system in 2005 [emphasis added].
2. Upgrade the forward-based, boost-phase-intercept naval system off North Korea with higher-acceleration boosters and maneuverable kill vehicles already under development. An early possibility is the THAAD; with adequate funding, it could be available between 2005 and 2007. Consideration should also be given to the use of the ground-based interceptor being developed for NMD in a forward theater deployment that permits boost-phase intercept. Deployed off the coast of North Korea, such a system could have significant capability against an attack by Pyongyang. Depending on its geographical deployment, the system could also provide defense against an Iranian threat.
3. Continue research and development, testing, and evaluation of the NMD system and air-launched boost-phase systems. Any future decisions for post-2005 deployment should depend on the nature of the threat, technical advances of the TMD and NMD

> systems, and progress on renegotiating the ABM Treaty with Russia.
>
> Ultimately, we believe this alternative approach provides greater flexibility to meet theater and national ballistic missile threats as they evolve over time. The TMD proposal would be cheaper and technically less risky than the NMD system. Finally, it may prove more amenable to ABM Treaty changes and thus less likely to prompt adverse responses from Russia, China, or U.S. allies.

This Deutch-Brown-White (DBW) proposal lacks technical detail and is therefore difficult to evaluate for missile defense technology readiness, effectiveness and costs. It is possible that it reflects a more affirmative view in some BMDO or Navy circles about the merits of sea-based NMD than was reflected in BMDO's May 1998 classified report to Congress, and the unclassified, June 1, 1999, summary discussed above.[70] BMDO reportedly has prepared another classified report and was due to submit an unclassified version to Congress in March 2000, but this report has been held back and, as of this writing, its contents have not been divulged.[71]

The DBW paper endorses moving forward more rapidly with the existing Navy "lower-tier" NAD program, in order to provide "as soon as possible. . . *some capability* against North Korea." The crucial operational difference with NAD is that the DBW proposal would reconfigure the endoatmospheric naval interceptors for *boost-phase intercept* rather than just terminal defense against North Korean missile threats. This probably would not be a plausible use of the "lower-tier" interceptors, which are just now being introduced to AEGIS for field testing, and likely to be deployed incrementally between FY 2003 and FY 2009.[72]

The NAD interceptor is equipped with an aerodynamic, high-explosive warhead that could destroy a missile in powered flight if it could reach it. But to meet the vague test of "some capability" against North Korea's Taepo Dong missile, whose boost phase, depending on the version, could last three to five minutes, the operators of AEGIS-based NAD interceptors would have to have virtually immediate notice of launch and be ready to fire interceptors in less than a minute, from very close in. To be close enough to perform a boost-phase intercept on short notice, the AEGIS launch platform probably would have to be stationed in the Japan Basin 50 to 100 kilometers from the North Korean coast, requiring additional warships nearby to provide a security cordon.[73] Stationed in the Arabian Sea, this sea-based endoatmospheric capability could not be deployed close in enough, on a regular basis, to catch an Iranian or Iraqi missile in tail chase along a northward flyout trajectory.[74]

The DBW proposal implicitly acknowledges this shortcoming by adding a new wrinkle to sea-based missile defense constructs, the notion that the Navy might use the Army's THAAD TMD interceptor (which already uses an "aerodynamic" warhead, albeit as a kinetic kill mechanism), rather than an upgraded variant of the Standard Missile.[75] It is not clear whether the authors believe THAAD could be made compatible with the AEGIS/VLS system, or would instead require another type of launcher ship.[76] Even the authors seem to recognize that this idea is a temporary gap-filler and therefore propose forward deployment of the planned NMD ground-based interceptor (GBI), a much larger and heavier missile, for later stages of their boost-phase scheme. The THAAD TMD interceptor is closer to operational reality, to be sure, than the NTW SM-3, Block II, let alone a modified NMD version of Block II upgraded for NMD missions. This may explain the DBW claim that their sea-based boost-phase interceptor proposal could reduce both technical risk and projected cost.

The Garwin-Postol and DBW schemes each appear intended to shift attention in the NMD debate away from a U.S. territorial, mid-course NMD system (and also, incidentally, shift attention away from global, space-based interceptor constructs), to focus instead on geographically-localized, sea-based (and foreign land-based), interceptor systems—snugged in against North Korea, Iran, Iraq, and perhaps Libya, all states of concern. While the strategically-capable, sea-based components in these proposals certainly would run up against basic restrictions in the ABM Treaty, especially the prohibitions on "mobile" and extraterritorial ABM interceptor systems, arguably they would not be quite so directly at odds with the central strategic stability purposes of the ABM Treaty as would a global, sea-based NMD system.

Russia Flags Cooperative Boost-Phase Concept

Russia might find such proposals acceptable as joint defense arrangements, provided they are focused on regional states that potentially threaten Russia (and Europe) as well as the United States.[77] While not conclusive, President Putin's remarks leading up to, and following, the Clinton-Putin summit held in Moscow on June 3–4, 2000 were suggestive of such Russian interest.[78] Putin's post-summit statements that joint missile defense arrangements could be multilateralized with European participation also hint, however, at a potentially divisive political agenda.[79] It remains to be seen whether a potential U.S.-Russian rapprochement will crystallize on these issues and whether it could somehow evolve to accommodate Chinese participation and support, or instead would exclude China and therefore be seen in Beijing as a strategic challenge or mechanism for containing China.

These location-specific missile defense proposals are politically significant in their potential to shift the polarization over TMD and NMD towards a cooperative concept—both domestically in the United States, and bilaterally between the United States and Russia. But the authors' optimism about the technical ease and financial cost of moving along the lines they have proposed may be excessive.

Airborne Boost-Phase Analysis

Another variant on geographically localized, boost-phase constructs is the *airborne boost-phase* concept that Stanford researcher Dean Wilkening favors.[80] Wilkening argues that boost-phase interceptor missiles launched from fighter aircraft or from unmanned air vehicles (UAVs, or "drones") would be a better response to emerging nuclear states' long-range missiles than early deployment of the contemplated ground-based NMD. He suggests that airborne boost-phase interceptors probably would be more flexible and effective for NMD (homeland defense) purposes against 'states of concern' missiles than boost-phase interceptors launched from ships or land. For theater defense purposes he suggests, however, that the layered combination of airborne boost-phase and sea-based or ground-based TMD would provide the most effective wide-area protection in any engagement zone (e.g., the defense of all of Japan). His analysis focuses on North Korea, the easy case of geographical accessibility, but also touches on Middle East and Mediterranean 'states of concern'.

Wilkening draws on U.S. Air Force experience with air-launched missile technology, USAF technology demonstration programs for the airborne missile interceptor (ABI) as well as airborne laser interceptor (ABL),[81] and both U.S. and Israeli experience with drones. A fast-flying, infrared homing ABI launched at high altitude, aided by external sensors, could operate against theater as well as strategic missiles in their boost phases. With intercept range depending both on the burn-time of the target missile and the 5.1 km/second velocity of the reference interceptor, he posits an ABI range of about 850 km, for example, against a nominal North Korean ICBM (liquid-fueled *Taepo-dong* 2 or 3).[82]

In Wilkening's opinion, neither Russia nor China need fear U.S. adoption of this ABI boost-phase missile defense on strategic stability grounds. He believes it would be self-evident in Moscow and Beijing that U.S. ABI systems could not be deployed around the clock against their main, interior- and sea-based, strategic missiles without inordinate expense, and because aircraft platforms loitering in their airspace would not long survive Russian (nor, probably, China's) air defenses. Smaller numbers of ABIs, but commensurate with the threat, could be kept aloft near many Third World locations, however, with greater geographical accessibility and survivability, and at much less expense.

Based on notional measures of the maximum launch-rate of a theater missile attack from a 'state of concern' (e.g., North Korea), certain postulated effectiveness criteria of layered TMD in a representative "engagement zone," the ABI loads and endurance times of fighter aircraft and UAVs, and a logical number of airborne radar aircraft, Wilkening provides rough *procurement* cost criteria for ABI systems.

The procurement of 800 ABIs and the requisite number of aircraft to support *five engagement zones* (further expansible on a modular basis), he suggests, would amount to between $8 and $13 billion, depending on whether the ABI launch platforms were cheaper UAVs or costly fighter aircraft.[83] This estimate does not include what would be large operations, support and maintenance costs, or the forward basing costs, on allied territories or on ships. The estimate is for just a five-zone ABI architecture that assumes the co-existence of layered TMD and thus is not a substitute for sea-based or land-based TMD. His ABI concept would handle long-range missile threats only from 'states of concern' (not accidental or unauthorized launch of modern strategic missiles). Its requirements are not comparable, in this respect, even to a limited, global sea-based NMD nor the administration's contemplated limited ground-based NMD.

Boost-phase ABI systems face unresolved problems that imply more than a decade of development and testing would be needed before initial military deployments would be practical. One problem is the low survivability of airborne sensor adjuncts against air defenses. Another is the high cost of maintaining ABI launch platforms aloft around the clock, particularly if they are fighter aircraft. A third involves the technical command and control issues of supporting platforms loitering in hostile airspace and of safely retrieving and rotating forward-deployed UAVs carrying live missiles.[84]

Boost-phase ABL systems would require a smaller number of expensive platforms[85] but represent less mature technology even than airborne missile interceptors. ABL faces other technical hurdles, such as a shorter lethal range than ABIs (assuming the ABLs are fired from outside hostile airspace), the difficulty of achieving in-flight laser beam stability, pointing accuracy and dwell time, and countermeasures that can be employed on the hostile missile.[86] Although technical advances in the commercial and military laser fields are proceeding rapidly, deployment of airborne and space-based laser systems that would be effective in stopping long-range ballistic missiles evidently would be at least two decades off.[87]

Boost-phase intercept seems a seductively simple problem compared with kinetic mid-course intercept, the latter often compared to shooting a high-speed bullet with a high-speed bullet in space (i.e., at a combined closing speed of up to 15,000 miles per hour). Homing in on the flame from a long-range rocket before it burns out is a much easier job for a missile's built-in guidance sensors, than discriminating among multiple objects in the cold reaches of space—after warheads and decoys have separated from the boosters. But the requirements of compressed reaction time, immediate launch warning, cueing of the initial trajectory, ruling out innocent events (e.g., lift off of a space launch vehicles) and other possible errors in interpreting remote data, rapidly launching interceptors, and having interceptors capable of catching the ascending missile before it flames out, all within a time frame of 3 to 5 minutes, is a monumental challenge.[88]

As representatives of the Pentagon have pointed out, moreover, a boost-phase NMD system would have to operate automatically and flawlessly, no such technology against strategic missiles would be demonstrably available by 2005, and any future systems would not be easy to master nor inexpensive to deploy.[89] The short time available after a booster has lifted off in a country of concern, and then to commit and fire a U.S. naval interceptor to achieve boost-phase intercept, could preclude knowing whether the launch was an offensive threat and what its likely targets are, and this would take "the man out of the loop." In Defense Under Secretary Jacques Gansler's words, "Certainly there is no time [in boost phase] for human decision-making."[90] There would be insufficient time after satellite warning to apprise and inform the President so that he could make an informed decision, nor even sufficient time for naval operators to actually discuss possible ambiguities or errors in the incoming data stream. It would be a tripwire operation with potential for grave error, such as initiating acts of war in peacetime.

High-acceleration and high-burnout velocity interceptors sufficient to that task will not come cheaply. Using cargo ship launch platforms rather than AEGIS, and land-basing in cooperative arrangements with Russia, may be less expensive in principle than systematically upgrading Navy TMD to a Navy NMD (to provide homeland defense from the sea), but neither would the cost be small. Negotiating with Russia on the terms of implementing such a concept, if a U.S. decision were made to do so, probably would take many years, and the building of such a system many more.

At the end of the day, irrespective of basing mode, these boost-phase schemes would not be cheap, quick, or easy to develop and deploy. Nor would they provide homeland defense against other limited long-range missile threats, such as unauthorized or accidental launch of modern strategic missiles—the C-2 and C-3 stage requirements of the limited ground-based NMD now under consideration. Indeed, if the DBW sea-based scheme was expanded to perform homeland NMD against unauthorized or accidental strategic attack by modern strategic missiles, the costs, and the overseas political reactions, would balloon rapidly to the same levels as those of the global, sea-based NMD concepts described earlier.

VIII. Balancing National Security Risks

Current momentum to build a limited, ground-based NMD system as soon as the technology can be demonstrated is a result of revised assessments of the political-military threat from a finite number of so-called 'states of concern'. Beginning in mid-1998, long-range missile threats emerging in these states were reassessed to have greater immediacy than was thought earlier in this decade.[91] By their nature, these long-range missile threats exceed the "theater" intercept capabilities of the TMD systems which the U.S. had designed in the 1990s, on policy grounds, to fall short of ABM capability.

Defense experts fear that one or more of these 'states of concern' may attack neighbors or allied forces, and back its aggressive campaign with a long-range ballistic missile threat against American cities, expecting thereby to neutralize U.S. military response. Under these circumstances, some policy-makers and experts believe that traditional deterrence based on the unmistakable capacity to inflict overwhelming destruction may not provide a reliable guarantee that the threatening state would not recklessly launch a long-range strike. Thus the danger that American cities could be held hostage at long-range, paralyzing U.S. (and allied) decision-making while overseas aggression unfolds with impunity, has become a high profile concern. This is the core national security worry that now drives the broadening of support for NMD, despite its uncertain technical effectiveness and foreseeably heavy, long-range financial costs.

> *Proposed military and technical responses should meet effectiveness tests, not only operationally, but also in terms of broader international security consequences.*

This emerging national security problem must be taken seriously, but not by exaggerating it, nor by sending a signal that U.S. leadership may be losing confidence in U.S. deterrence capacity. Nor is this class of threat exempt from the general rule that all national security threats require a balanced response, with proportional and affordable counter-measures. By definition, modern threats of mass destruction, especially in clandestine form, represent a class of dangers against which national security cannot be perfected absolutely. On the other hand, striking the United States with long-range missiles armed with mass destruction munitions would be a suicidal act. The odds of saber rattling by a 'state of concern' are not necessarily low, but the odds of it launching a suicidal attack would be negligible. If there is any doubt about this, that would seem to be where public diplomacy and defense policy attention should be focused first. Extending deterrence against such threats to allies and friends is, however, a greater challenge, and active theater defense may be a usefully added ingredient in that equation.

Proposed military and technical responses should meet effectiveness tests, however, not only operationally, but also in terms of broader international security consequences. While it is vital to conduct research and development vigorously to determine technical military response possibilities, it is no less important to explore what can be done with the full range of diplomacy and related policy alternatives before going down a technically uncertain and expensive military response path that foreseeably could generate new and more formidable national security challenges than those it was intended to redress.

Sea-based NMD proposals fall into two different classes, politically speaking. One class assumes that consultations and negotiations with major powers—potential adversaries as well as allies—are indispensable in the current world environment in order to win support for a radical change in strategic defense posture. Readiness to negotiate signifies confidence in the merits of the proposal and an interest in minimizing potentially disruptive foreign and defense policy consequences. The DBW and Garwin-Postol sea-based NMD proposals fall in this class.

These negotiations-oriented proposals recognize that the ABM Treaty would have to be amended substantively to permit sea-based NMD. But the authors would prefer to salvage, if possible, an ABM Treaty framework that is conducive to strategic stability (i.e., avoids pressures that could trigger inadvertent response and keeps the lid on any propensities to resume an escalating offense-defense competition). To that end, these authors would also preserve the START treaties, for codified and verified nuclear arms reductions. The authors would try to avoid giving easy pretexts to opponents to attack meaningful U.S.-Russian cooperation in threat-reduction and non-proliferation measures. While none of the authors of this class of proposals would willingly abandon arms control and none would drop efforts to negotiate acceptance of U.S. initiatives, some of them may be readier than others to cross lines of no return if Russia proves totally uncooperative on strategic defense.

There are several possible scenarios for acceptance or non-acceptance of these sea-based missile defense proposals. The easiest architecture to win support for would be geographically restricted missile defenses focused on North Korea, Iran, and Iraq, the three most prominent long-range missile states of concern. In principle, the locality restrictions and system parameters could be recorded with monitoring criteria in an annex or protocol to the ABM Treaty. One scenario could be some measure of Russian acceptance or even cooperation with U.S. deployment of sea-based NMD in the Pacific and Indian Oceans, in the face of Chinese opposition and increased hostility. Alternatively, adopting sea-based NMD might win strong allied support but face hostile and sustained reactions from Russia as well as China. Less plausible but still conceivable is that Russian acceptance and close cooperation with the United States of jointly managed boost-phase missile defenses would stimulate deepening anxiety among traditional U.S. allies.

Chinese opposition to U.S. TMD and NMD plans has been vigorously expressed and should be easy to understand. China fears that sea-based U.S. TMD deployments near Taiwan could be used as a defense umbrella over Taiwan, encouraging Taiwanese aspirations for independence. Sea-based TMD interceptors could neutralize the political intimidation implicit in China's coastal buildup of short-range missiles opposite Taiwan. Sea-based interceptors that are effective against long-range missiles, especially in the mid-course phase, theoretically would have the potential to neutralize China's still small number of (about 20) ICBMs. China may believe this would undermine the deterrent value of these missiles, both against Russia and the United States, perceivably increasing China's vulnerability and reducing its freedom of maneuver in the region.[92]

The DBW and Garwin-Postol sea-based proposals both focus on boost-phase intercept. Whereas their sea-based interceptors may not have the reach and response time to conduct the boost-phase mission against strategic missiles based in the interior of China, the land-based concept would be a matter of Chinese concern. Garwin and Postol would contemplate basing larger boost-phase interceptors at key locations in Russia (or nearby), with Russian cooperation—a concept President Putin showed interest in before and after the June 2000 Moscow summit. Boost-phase interceptors in Russia could, depending on their location, threaten Chinese ICBMs in their northward flyout corridors. It seems unlikely that China could be drawn into a cooperative boost-phase interceptor scheme focused narrowly on North Korea, even in exchange for demonstrated geographical and velocity restrictions that avoid putting long-range Chinese missiles at risk. Some may believe, however, that Chinese opposition to this idea would soften through consultation on the details.

It is worth bearing in mind that China has pursued a relatively low-cost, and therefore relatively slow, strategic modernization course, and could continue to do so. But more than two decades of rapid economic expansion and Chinese imports of relevant strategic technology in the 1990s mean that China could instead, with belt-tightening, pursue a more rapid modernization and buildup of its strategic missile arsenal. China is midway in a transition from large liquid-fueled to smaller solid-fuel, long-range missiles and could deploy a larger number of the new missiles than it had planned. China could also more rapidly increase its intercontinental nuclear delivery potential three- or four-fold by MIRVing the existing ICBMs and the new solid-fuel, mobile ICBMs and SLBMs, go to higher alert procedures, and develop and retrofit modern penetration aids on all its long-range missiles.[93]

In contrast to the negotiations-oriented sea-based NMD proposals, acting on Heritage's global sea-based and space-based NMD construct probably would generate much more hostile Russian and Chinese responses. Both Russia and China probably would view policy based on that proposal not as an effort to adapt the ABM Treaty to modern circumstances but rather as a unilateral act to shed ABM Treaty constraints. The authors of the Heritage proposal leave no doubt that they believe the ABM Treaty should be abandoned as a vestige of the Cold War, and that it is no longer relevant after the demise of the Soviet Union.

Abandoning the ABM Treaty could have a number of serious consequences that are not, however, the subject of this paper. Sea-based NMD costs and technology are the core subjects of this paper, and these do not require a detailed assessment of arms control consequences or evolving threats.

IX. Conclusion

Growing interest in the use of sea-based assets and boost-phase principles for NMD purposes calls for a clearer picture of what naval NMD would cost, how effective it would be, and when it could be fielded. Systematic answers to these questions are made difficult by the limitations of publicly available official data and the sketchiness of sea-based NMD proposals. But even within these limitations, the estimates provided in this report should put the feasibility, cost, time frames, and consequences of deploying sea-based NMD in a more realistic perspective. This report will be service enough if it helps improve the interested public's ability to evaluate the practical aspects of proposals on their merits.

On Financial Cost

- Fielding effective sea-based, national missile defense systems would not be cheap, quick, or easy. Some NMD advocates have misled the public when they claimed our past investment in Navy AEGIS ships and their missile launch capacity offers a cheap and easy short cut to homeland defense against long-range ballistic missiles. Some suggest a bargain basement price tag for sea-based NMD could be as low as $2 or $3 billion dollars. The facts are quite different.
- The Pentagon's report to Congress on the feasibility and cost of creating a stand-alone Navy NMD system based on AEGIS ships and "hit-to-kill" technology—to be able to intercept a small number of long-range missile warheads launched at the United States—estimates this would cost at least $16 to $19 billion dollars.
- The Pentagon report also warns of a large measure of technical risk related to the ultimate performance and cost of NMD-capable naval interceptors, which have not yet been physically developed or tested. It also admits that the cost estimate does not include any detailed assessment of naval mission tradeoffs in diverting existing AEGIS ships to NMD missions.
- A more realistic estimate of the cost of this limited Navy NMD system, assuming the same equipment and capability postulated by the Pentagon while allowing for typical cost growth and operating costs over 10 to 15 years, suggests the price might be closer to $30 to $36 billion—ten to twelve times the amounts suggested by the Heritage Foundation experts. Even these figures do not cover the hidden cost of naval mission tradeoffs. Moreover, simultaneous hostile country threats could require acquisition of 7 more AEGIS ships, for another $7 billion, possibly raising the overall price to between $37 and $43 billion.
- Recent proposals that would make sea-based, boost-phase interceptors available to shoot down long-range missiles launched by 'states of concern', locally, before those missiles climb into space, represent a different line of thought. Rather than attempt to field a global, sea-based NMD and unilaterally break out of the ABM Treaty, these proposals seek Russian (and possibly Chinese) cooperation in containing the threat from 'states of concern', locally, as well as in negotiating changes to the ABM Treaty.
- The Deutch-Brown-White proposal is too sketchy on technology and operations to estimate cost, but adapting Navy AEGIS TMD programs to boost-phase intercept missions involves serious technical feasibility and geographical accessibility issues—higher acceleration interceptors, extremely short response times, and close-in operations. Safe to say, this approach which builds on naval TMD is not a cheap alternative, but rather a scheme for hastening the introduction of low-end missile defense capabilities nearby 'states of concern'. In any case, the Navy AEGIS-based TMD programs could not

turn on a dime from exoatmospheric intercept missions to the quite different task of boost-phase intercept.

- Sea-based NMD designed to protect the homeland from overseas with mid-course interceptors will have many of the same technical effectiveness problems as a ground-based NMD. Hit-to-kill interceptors impose a formidable technological challenge. Sea-based interceptors can add depth, from varied geographical locations, in the cumulative number of intercept opportunities (shoot-look-shoot sequence), but would have essentially the same problems with mid-course countermeasures as ground-based interceptors. Adapting to the evolution of countermeasures will drive up long-term costs for any NMD system, ground- or sea-based.
- Airborne boost-phase concepts could, some day, supplement and thereby increase naval and ground-based TMD efficiency, but either would not provide global NMD capability or, if expanded to deploy such capability in all plausible engagement zones, would be excessively costly and probably strategically destabilizing.

On Deployment Time Frames

- Deployment of a global, sea-based NMD cannot be done quickly. The Pentagon estimated that a stand-alone, sea-based NMD system based on upgrading NTW probably could be initially deployed by 2011 (if accelerated) and more likely not before 2014 (on a more normal schedule), but not fully deployed until close to 2020.
- The DBW proposal calls for urgent boost-phase intercept solutions between 2005 and 2007, presumably adapting NAD, the earliest available Navy TMD system, and possibly installing THAAD in AEGIS ships to meet those dates. If the real focus of this proposal is on blocking the specific threat from North Korea's Taepo Dong, it is conceivable that a boost-phase system could be developed more quickly for Korean geography than other states of concern. But a full-fledged and geographically flexible sea-based, boost-phase NMD would still take far longer to develop and deploy.
- Garwin's and Postol's country-specific, boost-phase concepts, and the sketchy analogues proposed by President Putin, depend on U.S.-Russian and other foreign cooperation, and on technologies and equipment for which no program baselines have been established. Without resolving both these political conditions and technology choices, an effort to specify deployment time frames would not be meaningful. But historical precedents for concluding sensitive security negotiations with Russia suggest that finishing the political groundwork alone could take decades.
- Any boost-phase defense of the American homeland or Europe whose operation is subject to a Russian operational veto is politically implausible in the foreseeable future.
- Wilkening's analysis acknowledges serious operational limitations with any permanently stationed airborne boost-phase interceptors. The costs could multiply with the number of engagement zones. As a less mature missile defense technology, the timeframe for development and initial deployment would probably exceed that for any plausible sea-based NMD system.

A global sea-based NMD capable of intercepting unsophisticated long-range missiles from 'states of concern' and a few modern strategic missiles from a nuclear weapon state would be a 'limited' missile defense, and not an impenetrable shield. It remains to be seen whether it would actually work against strategic missiles, and whether it could be defeated by readily available countermeasures. The sea-based NMD construct assessed by the Pentagon assumes that Navy NMD interceptors would use the same mid-course interceptor principles as the contemplated ground-based NMD system. Presumably, therefore, the effectiveness of the sea-based interceptors in coping with rapidly moving objects and countermeasures in space would not exceed the effectiveness of the ground-based interceptors, and might be less.

Since such a sea-based system, even a 'limited' one, might easily cost between $30 and $36 billion (or even as much as $37 to $43 billion) and take nearly two decades to fully deploy, it is reasonable to know in advance whether and how well it would work, and how much it would actually cost over time. Since deploying this system would also require rewriting or withdrawing from the ABM Treaty, it is crucial to know whether the net result would be enhanced security or increasing strategic instability.

The Pentagon has not released any detailed public assessment of the feasibility, potential cost, arms control impact or effects on our relations with Russia and China of recent proposals for close-in naval and land-based boost-phase interceptors against long-range missiles located in ‘states of concern’. Secretary Cohen has expressed the view, however, that boost-phase concepts could not be implemented quickly and that while President Putin’s latest ideas are under discussion, they evidently would not meet current, limited NMD requirements.

Before the administration moves any distance down the paths of global, sea-based NMD or the customized boost-phase intercept systems reviewed here, it should know and be able to demonstrate that the intercept technologies are feasible, show how a prospective architecture would actually enhance U.S. security, and elucidate what the actual costs are likely to be. The public should also be apprised of the distinctive implications of forward-deployed NMD, and especially of boost-phase systems, for global and regional stability. Close-in boost-phase concepts depend on virtually instantaneous and therefore automatic reaction. The tyranny of reaction time is so short that the “man in the loop” disappears, and the potential for serious accidents rises correspondingly.

APPENDIX:

BMDO Summary of Key Findings on Naval NMD

The BMDO's "Summary of Key Findings"[94] on the potential utility of sea-based assets for the missile defense of the United States is quoted here in full (author's editorial clarifications inserted in square brackets):

1. "*Without upgrades, the NTW Block II system would have no useful capability against ICBMs or SLBMs* [strategic missiles]. *However, the unmodified NTW Block II system could have a capability against shorter range threats attacking US coastal targets.* [Emphasis in original.] Consistent with the theater mission for which it is intended, the NTW Block II system could have the capability to defend against tactical and intermediate range ballistic missile threats provided the NTW-capable ships are given sufficient warning of the impending attack to deploy within a few hundred kilometers of the threat launch location or of the area to be defended."

2. "*The NTW Block II interceptor analyzed in the NTW Analysis of Alternatives, when employed with the same sensors as planned for the NMD architecture,*[95] *could provide protection of the US against attacks by unsophisticated Third World threats.* Sea-based interceptor missiles require the same target identification and track accuracy as their land-based counterparts [i.e., both would operate as mid-course exoatmospheric interceptors]; hence they need the same sensor support. In addition, unless they are already operating in areas favorable to their participation in NMD, the sea-based assets require sufficient warning time to allow deployment to specific areas at sea. If the impending attack is from a single nation and its identity is known, then deployment in as few as three locations is required. If the adversary is unknown, or many are suspected, then as many as thirteen deployment locations may be required."

3. "*In order to expand this protection to include attacks by sophisticated Third World threats and accidental and unauthorized launches from existing nuclear powers, the performance of the NTW interceptor missile would have to be upgraded well beyond Block II, and employed with the same sensors as planned for the land-based NMD architecture. The interceptor would require significantly higher burnout velocity, better seeker performance and kill vehicle divert capability, and increased nuclear hardness.* All of the required upgrades are assessed to be technically feasible.

4. "*The most practical and effective role for sea-based systems would be to supplement land-based systems.* An integrated (combined land and sea) NMD architecture could provide more operational flexibility and robustness than architectures that relied solely on sea-based interceptors or on a single land-based interceptor site. However, deployment of such a land-plus-sea-based architecture is not feasible within the land-based NMD schedule [then projected for initial deployment in 2005] and would require additional RDT&E and procurement funding. An NMD architecture integrating sea-based interceptors with NMD sensors and land-based interceptors could provide enhanced protection of the US by reducing the vulnerability of forward land-based radars to defense suppression attacks; providing higher total kill probability by adding additional, earlier engagement opportunities; and reducing the impact of potential single-system failures. It could also provide the flexibility to reconfigure the defensive deployment in response to particular threats, and could provide a hedge against unanticipated threat tactics such as severely depressed trajectories. This integrated architecture could also give the defense planner an alternative to multiple land-based sites as a means to reduce the interceptor flyout velocity, and hence the technical

and engineering risk to the NMD development program. The addition of the mobile sea-based launch platforms could also offer the possibility of extending the NMD mission to include defense of US territories [e.g., Guam, Puerto Rico], and defense against ship-launched ballistic missiles. For some of these roles, upgrades beyond the NTW Block II interceptor would be required; for others, the Block II interceptor envisioned by the Draft CARD dated 29 August 1997 would suffice."

5. "*Deployment of a partial sea-based NMD capability while feasible, has technical risks and engineering challenges that have not yet been proven or demonstrated. In addition, the program is constrained by funding and programmatic factors.* While the evolutionary acquisition strategy that will lead to the NTW Block II system is approved, the Block II system is not completely defined or fully funded because its development and production will occur in a time frame largely beyond the current FYDP. Funds exist in the current FYDP for a portion of Block II Risk Reduction Activities as part of the Block I program. To achieve the most expeditious sea-based NMD capability, the NTW Block II must be completely defined and additional funds programmed. *Given these 2 conditions, it could be reasonably expected that the deployment of Block II could begin within 4 years after the Block I first-unit-equipped (FUE) date.*"[96]

6. "The cost and technical risk associated with the introduction and sustainment of sea-based assets into the NMD BM/C3 architecture is a matter of uncertainty that cannot be reduced without detailed engineering analysis of the most promising integrated architectures. While such architectures are technically feasible and operationally practical, their affordability and their cost effectiveness relative to multiple-site land-based architectures are yet to be determined."

7. "The post-FY97 RDT&E procurement and military construction for the land-based NMD Capability 2 architecture (with 80 to 100 interceptors based in Alaska) is estimated to cost between $13 B to $14 B. *Alternatively, a stand-alone sea-based architecture that could protect all 50 states is estimated to cost $16 B to $19 B* (a rough order of magnitude estimate that includes the cost of 3–6 AEGIS type ships). All costs prior to FY 97 are sunk and were not included. Furthermore, the estimates assume that the NTW Block II program and design are available without cost to the NMD Program (NTW Blk II RDT&E, procurement and O&S costs not included in ROM estimate). The stand-alone, sea-based architecture would require the same sensor suite, BM/C3 system and exo-atmospheric kill vehicle (EKV) currently under development in the land-based NMD program. At the same time, the stand-alone sea-based architecture would be comprised of dedicated ships and to account for ship rotation, significantly more sea-based interceptors than the 80–100 planned for the land-based NMD architecture."

NOTES

1. The Pentagon estimate in this case was given in fiscal year 1997 dollars. The cost figures used in this report are either attributed to cited sources and their methodologies, or use "nominal dollars" (what the Department of Defense calls "then year" dollars). The effects of inflation could result in higher numbers.

2. While this report was in preparation, the U.S. Department of State withdrew the once fashionable but undiplomatic phrase 'rogue state' in favor of the term 'countries' or 'states of concern'.

I. Introduction

3. Eric Schmitt with Julian E. Barnes, "Clinton Delays Missile System, Passing Decision to Successor," *New York Times* (web version), Sept. 1, 2000; Roberto Suro, "Clinton Defers Missile Defense: Deployment Decision Left to Successor; Technical Woes, Diplomatic Costs Cited, *Washington Post*, Sept. 2, 2000, p. A-1, A-14. For analysis of the decision, see also Stephen Lee Myers, "Russian Resistance Key in Decision to Delay Missile Shield, *New York Times*, Sept. 3, 2000.

4. Bush's remarks were made on ABC-TV's "This Week" on July 16, 2000. See Jim Hoagland, "Ballistic Politics," *Washington Post*, July 20, 2000, p. A-25; Tom Bowman, "Consensus Grows for 'Boost-Phase' Missile Defense," *Baltimore Sun*, July 18, 2000.

5. Charles V. Peña's independently produced "From the Sea, National Missile Defense is Neither Cheap Nor Easy," Cato Institute, *Foreign Policy Brief, No. 60*, September 6, 2000 comes to similar conclusions. In the same vein, see Joseph Cirincione's op ed, "Lost At Sea," *Inside Missile Defense*, September 6, 2000.

6. Clinton's statement of July 23, 1999, while signing the National Missile Defense Act of 1999, noted that the legislative language itself stated that it is "the policy of the United States to seek continued negotiated reductions in Russian nuclear forces" and that it is the "Administration's position that our missile defense policy must take into account our arms control and nuclear nonproliferation objectives." The statement noted: "Next year, we will. . . determine whether to deploy a limited National Missile Defense, when we review the results of flight tests and other developmental efforts, consider cost estimates, and evaluate the threat. Any NMD system we deploy must be operationally effective, cost-effective, and enhance our security. In making our determination, we will also review progress in achieving arms control objectives, including negotiating any amendments to the ABM Treaty that may be required to accommodate a possible NMD deployment." *Statement Announcing the President's Signature of the National Missile Defense Act of 1999*, White House Press Release, July 23, 1999. Subsequently, these decision factors were condensed and referred to as four criteria. For example, President Clinton recently stated in response to a question on NMD in his post-Moscow summit press conference: ". . .whether I would make a decision to go forward with deployment would depend upon four things: one, the nature of the threat; two, the feasibility of the technology; three, the cost and, therefore, the relative cost of doing this as compared with something else to protect the national security; and, four, the overall impact on our national security, which includes our nuclear allies and our European alliance, our relationships with Russia, our relationships with China, [and conditions elsewhere]." The White House, press conference transcript, June 28, 2000.

II. Sea-Based National Missile Defense Proposals

7. Insofar as ABM and NMD both refer to active missile defenses against strategic ballistic missiles, they may seem to be interchangeable terms, but this is only partly so. The ABM Treaty imparts legal content to ABM systems and specified ABM components, such as interceptors and radars that are capable of defending against strategic ballistic missiles. National Missile Defense (NMD) is a policy and legislative term that does not appear in the ABM Treaty. As such, NMD is explicitly defense of an entire country. An ABM system could be, and briefly was operational in the United States, for the defense of a limited area containing silo-based ICBMs against strategic attack.
   The interchangeability of the terms ABM and NMD arises in the context of particular systems and components that have ABM capability, i.e., when missile defense systems, or their component interceptors, radars, or sensors are capable of intercepting strategic ballistic missiles. Conceptually, theater missile defense (TMD) systems and components do not have ABM capability and therefore are considered distinct. To upgrade TMD systems and components to endow them with the capability to perform NMD functions, however, is to make them ABM systems. It is here that the terms become interchangeable.

8. The ABM Treaty as amended in 1974 permits a limited ground-based ABM defense, with up to 100 interceptors at one site, on each side, but the parties agreed under the Treaty's terms (Art. I) to forgo "nationwide" ABM defenses, and also agreed (Art. V) to ban mobile and space-based ABM systems. The Clinton administration has been seeking to win Russian assent to an amendment of the ABM Treaty that would permit a *limited* ABM defense of all 50 states, i.e., a thin "nationwide" defense.

9. The Heritage Foundation's Commission on Missile Defense has issued three reports since 1995, the latest being *Defending America: A Plan to Meet the Urgent Missile Threat*, Washington, D.C.: Heritage Foundation, March 1999, chps. 1–5 (website version: <http://www.heritage.org/missile_defense/>).

10. "Boost-phase," the first intercept opportunity, occurs after the target missile has been launched and its rocket engines are still accelerating its flight. After power from the boosters terminates – typically this occurs above the lower atmosphere for all but very short-range missiles—the missile payload continues on a ballistic or inertial trajectory in its "mid-course" phase. Sometimes confused with boost phase, "ascent-phase" refers to early mid-course when the payload is still ascending in space to the apogee (highest point) of the ballistic trajectory. Beyond the apogee, the trajectory slopes down and is referred to as "late mid-course." The "terminal phase" occurs as the payload descends through the atmosphere towards its target.

11. For a recent statement reflecting this optimism, see Henry F. Cooper and J. D. Williams, "The Earliest Deployment Option—Sea-Based Defenses," *Inside Missile Defense*, Sept. 6, 2000. Ambassador Cooper is the chair and Vice-Admiral Williams a member of the Heritage Foundation's Commission on Missile Defense.

12. The Clinton administration initiated active development of a *limited* ground-based NMD system in 1996 on the premise that the United States could decide in 2000, or any time thereafter, to begin deploying NMD in three stages. Each stage envisaged an increased capability level (C-1, C-2, and C-3), to provide a still *limited* capability to protect all 50 states against strategic missile attack. Initially, C-1 would provide such defense against a handful of *unsophisticated* long-range ballistic missiles (from 'states of concern') and, at C-2 and C-3 levels, against limited attacks from accidental or unauthorized launch of a small number of *modern* strategic missiles by Russia or China. The architecture of each level in this ground-based NMD scheme is based on kinetic (hit-to-kill) intercept of attacking warheads in the mid-course phase of their trajectories, above the atmosphere.
   The C-1 threshold, originally, was to deploy 20 interceptors at a newly-constructed ABM site, expected to be in Alaska, coupled with radar upgrades and communications links, as early as 2003, but this date was later reset forward to 2005. At the end of 1999, the administration adopted an "expanded C-1" objective that would raise the goal for the interceptor deployment level at the new site

directly to 100, with 20 interceptors ready for operation at the end of 2005, and 100 interceptors ready by the end of 2007. The C-2 threshold stipulated 100 interceptors and additional tracking radars, some outside the United States, with enhanced warning and cueing from space-based launch-detection satellites and better discrimination potential between attacking warheads and countermeasures, aiming for full deployment after 2007. Finally, the C-3 threshold called for adding a second ABM site, probably at the deactivated ABM site in North Dakota, allocating interceptors between the two sites and raising the total number of interceptors to 250, together with a ground-based tracking radar across the Pacific in East Asia. C-3 deployment was projected for 2010 or soon after. The concepts and schedule of this planned NMD are described for cost-estimating purposes in the Congressional Budget Office's recent report: *Budgetary and Technical Implications of the Administration's Plan for National Missile Defense*, April, 2000; available at: <http://www.cbo.gov>.

13. The U.S. soon will replace the long-lived, early-warning satellites from the Defense Support Program (DSP) with a new, high-orbit satellite constellation called Space-Based Infrared System (SBIRS-High). Operating in both geosynchronous and elliptical (north polar) orbits, SBIRS-High sensors will detect missile launches and characterize trajectories of missiles during their powered flight (boost-stage). The U.S. is also planning to deploy in low earth orbit a constellation of 24 infrared tracking satellites (SBIRS-Low) for TMD missions as well as other military and intelligence purposes. SBIRS-Low is expected to have a high-resolution capability to track missiles and separated warheads in the mid-course phase of their trajectories. SBIRS-Low could significantly enhance the effectiveness of "upper tier" theater missile defense (TMD) as well as any NMD system. The SBIRS development milestones and recent program changes may be found in Director, Operational Test &Evaluation, *FY99 Annual Report*, *op.cit.*; see section on Air Force Systems, and chapter on "Space-Based Infra-Red System" (at <http://www.dote.osd.mil/reports/FY99/index.html>; hereafter cited as DOT&E, *FY99 Annual Report*.

The ABM Treaty permits tracking data to be fed to ABM interceptors from ground-based ABM tracking and engagement radars, to aid the interceptors in pinpointing intercept locations and attacking warheads, but the Treaty traditionally has stood in the way of using space-based sensors to perform the same function for ABM interceptors as ground-based ABM tracking and engagement radars. As traditionally understood, this would restrict feeding strategic missile tracking and warhead discrimination data from space-based sensors such as the SBIRS-Low satellites to ABM (or NMD) interceptors. While the Treaty does not explicitly prohibit feeding space-based tracking and discrimination data to TMD interceptors, the Clinton administration has ruled this out in designing TMD on policy grounds, presumably because it believed this could make TMD systems ABM (NMD)-capable.

14. Patriot-2 air-defense missiles rushed to Israel during the Gulf War to intercept Iraqi Scud missiles may have helped dissuade Israel from entering the war against Iraq. But designed for defense against aircraft rather than ballistic missiles, the Patriot batteries were virtually ineffective in actually intercepting conventionally armed Scud missiles. The Scuds tended to break apart in terminal descent, with the residual pieces following unpredictable trajectories to scattered impact points, and, in Israel at least, caused minimal casualties. Had those Scud missiles carried chemical or bacteriological weapons that survived the breakup of missile airframes and disseminated their agents successfully in populated areas, however, Israeli retaliation might not have been prevented.

III. Where the Technology Stands: Navy Missile Defense

15. The first significant funding ($43.3 million) for modifications of five AEGIS ships to support the Navy's "lower-tier" TMD appeared in the FY 1999 defense budget. The FY 2000 request was $55 million. *BMDO Fact Sheet*, PO-99-01, April 1999.

16. See chapter on "Arleigh Burke (DDG-51) Class Guided Missile Destroyer with the AN/SPY-1D Radar" in DOT&E, *FY99 Annual Report*, *op. cit.*

17. AEGIS "fleet defense" capabilities are popular with allies that can afford to buy them. The United Kingdom procured AEGIS ships years ago, the Netherlands, New Zealand and Australia have or will acquire them, Japan acquired four recently, Spain is building four, Turkey will be a recipient, and Taiwan is interested in acquiring AEGIS ships.

18. The United States has used T-LAM missiles from AEGIS ships and submarines frequently in recent conflicts, including Desert Storm, the Balkans (vs. Serbian forces), and against targets in Sudan and Afghanistan—as retaliation against terrorist acts.

19. The VLS systems are constructed by bolting together modules, each module normally containing 8 missile cells (so-called "eight-packs"). A VLS system on a Spruance ship theoretically could have 8 modules, or 64 cells, but space occupied by cranes and loading equipment displaces three of the cells, leaving 61 usable cells. The Ticonderoga-class cruisers have 16 modules, but 6 cells are similarly displaced by other equipment, leaving 122 cells. Six cells are also displaced on the current Arleigh Burke destroyers, but future ships in this class will have the full complement of 96 cells, using a different solution for the loading equipment. For a description of VLS, see Federation of American Scientists, "Military Analysis Network: MK41 Vertical Launch System (VLS)," <http://www.fas.org/man/dod-101/sys/ship/weaps/mk-41-vls.htm>.

20. VLS missile cells are loaded with canisterized missiles while the AEGIS ships are in homeport, being refitted. Currently, the standard operational procedures of the U.S. Navy do not call for reloading missile cells overseas. This would be technically feasible, however, from replenishment ships dispatched to friendly overseas ports or naval bases. The United Kingdom has employed this practice on some occasions.

21. In April 1998 the U. S. Secretary of the Navy and Chief of Naval Operations signed a joint memorandum recognizing the "pressing operational requirement to deploy TBM defenses at sea to counter the existing TBM threat to forces ashore." They also directed the evolution of AEGIS for TBMD as the "most cost effective and operationally sound approach." See "Naval Role in Ballistic Missile Defense: Operational Advantages and Progress," International Defense Consultants, Arlington, VA, at: <http://www.internationaldefense.com/pi-naval_tbmd.html>.

22. The SM-2, Block IVA has begun a series of "engineering and manufacturing development" (EMD) tests but integrated flight tests against live targets are still some time off. The Block IVA is an upgrade of the anti-aircraft SM-2, Block IV, which was tested successfully in at-sea firings from an AEGIS ship in 1999, is in limited production, and has entered the fleet. A Block IVA prototype successfully intercepted a Lance target missile in 1997, and a second EMD flight test demonstrating the new airframe, autopilot and maneuverability was successfully conducted on August 24, 2000, at White Sands Missile Range in New Mexico. See Raytheon News Release, "Raytheon Demonstrates Second Successful Flight Test in Navy Area Theater Ballistic Missile Defense Program," August 24, 2000. For additional background, see DOT&E, *FY99 Annual Report*, *op. cit*., Section on Navy Programs, chapter on "Standard Missile-2 (SM-2)".

23. The standard U.S. designation of ballistic missiles based on range and used here is:

- SRBM (short-range ballistic missile): Up to 1,000 km
- MRBM (medium-range ballistic missile): 1,000–3,000 km
- IRBM (intermediate-range ballistic missile): 3,000–5,500 km
- ICBM (intercontinental ballistic missile): Over 5,500 km

24. ATBM means "anti-tactical ballistic missile." Over time, as tactical ballistic missiles have become capable of striking at longer range, the terminology has shifted and today they are usually referred to

generically as "theater ballistic missiles" (TBMs), to be countered by "theater missile defense" (TMD).

25. Forward-deployed NTW interceptors located near enough to the launch sites of threat missiles may seek to intercept their targets in their "ascent-phase," or the early part of the mid-course trajectory. Other than launch warning rate and interceptor proximity to the target missile launch, there is no substantial technical difference between ascent-phase and mid-course intercept in how the kinetic kill vehicles must perform. A naval interceptor platform stationed between the threat and a defended area, and close enough to the launch of the target missile to achieve ascent-phase intercept, however, would create an inherently larger defense footprint downrange.

    In forward-deployed situations more generally, the size of the defense footprint depends not only on the speed of the incoming target missile and the fly-out velocity of the interceptor, but also on the location of the interceptor relative to the trajectory angle (azimuth) of the target missile and the effective range of the defense system's radar or sensors. Dean A. Wilkening, *Ballistic-Missile Defence and Strategic Stability*, London: The International Institute of Strategic Studies, Adelphi Paper No. 334, May 2000, p. 49.

26. SM-3 is expected to have three powered stages to achieve intercept altitude and range. The first stage may use the first stage booster of the SM-2, Block IV, a second stage dual-thrust rocket motor, and a third advanced solid axial stage (ASAS) that is inertially guided to the general intercept point, aided by signals from the Global Positioning System (GPS) and the ship. The ASAS has thrust vector nozzles, to make exoatmospheric course and attitude adjustments. See LCDR Brian C. Dickerson, *Navy Theater Wide Ballistic Missile Defenses*, Air Command and Staff College, AU/ACSC/0378/97-03, March 1997, p. 27.

    Technically, the SM-3 kill vehicle would be considered a fourth stage because it has independent axial divert and attitude control thrusters to maneuver and home in on the target, but this source of power would not significantly add to the fly-out velocity imparted by the booster stages.

27. According to recent estimates by Congressional Research Service specialists, the FUE for NTW Block I is expected to be FY 2010 (or FY 2007, at best, if an accelerated option with higher annual funding is adopted). Unless accelerated, the main procurement and full deployment of Block I is expected to occur between FY 2010-2012. This would put initial deployment of NTW SM-3 Block II not earlier than FY 2011, and only if it is accelerated. Otherwise, initial deployment would occur about FY 2014, and full deployment near the end of that decade. Upgrading SM-3 Block II to NMD capability could push this schedule out even further.

28. Wilkening, *Ibid.*, p. 47.

29. LEAP, as "lightweight" implies, is much lighter—only one-fourth the mass of the kill vehicle (KV) used on THAAD, the ground-based, upper-tier TMD system. The Navy interceptor warhead has to be quite light in order for the AEGIS-compatible Standard Missile interceptors to achieve exoatmospheric altitudes and adequate range for mid-course intercept. But, as a result, there are doubts about how effective LEAP's hit-to-kill mechanism will be in discriminating warheads from decoys, and in its lethality, especially against target missile warhead canisters containing submunitions. The limitations of its IR sensors restrict its effective use to altitudes above about 70 km. This means that NTW would not defend South Korea well against North Korean missiles with ranges less than 300 km (e.g., Scud-B) because their apogees would be under 70 km. Wilkening, *op. cit.*, pp. 48, 49. In addition, it has been recently recognized that the exoatmospheric dispersal of the propellant plumes from the axial thrusters of the LEAP could obscure its sensor readings and ability to find distant objects, a critical obstacle to effective engagement and lethality. See DOT&E, *FY99 Annual Report*, *op. cit.*, Section on Other Defense Programs, chapter on "Navy Theater Wide (NTW)."

30. This would hold true for an incoming nuclear warhead or a compact, unitary chemical or biological warhead, but special problems may exist in using kinetic interceptors to effectively destroy submunitions filled with chemical or biological agents that could survive reentry and thus that may be disseminated from canisters in mid-course flight.

31. According to DoD, maritime geography provides maximal opportunity for NTW defense area coverage of Japan against North Korean medium- and intermediate-range missiles. A single NTW-equipped AEGIS ship located in the Sea of Japan between North Korea and Japan, DoD claims, could protect almost all of Japan with the higher speed Block II interceptor, although four suitably stationed AEGIS ships would be needed to provide the same coverage with the slower Block I interceptor. The NTW footprint of Block II would cover most of Japan if the AEGIS-based interceptors were suitably located and committed early enough to catch target missiles in their ascent phase. Nothing is said about whether this performance would require external sensors or could be managed instead by the AEGIS shipboard AN/SPY-1 radar, or how well NTW would perform if the threat missiles deploy countermeasures. See *Report to Congress on Theater Missile Defense Architecture Options for the Asia-Pacific Region*, U.S. Department of Defense, May, 1999, Table 3-1; BMDO, *Navy Theater Wide Ballistic Missile Defenses*, Fact Sheet AQ-00-03, July 2000, p. 3; and Wilkening, *Ballistic-Missile Defence and Strategic Stability*, *op. cit.*, p. 49.

32. Navy acquisition chief Lee Buchanan said in an interview with *Defense Daily* that: "'Theater missile defense isn't a process, it's a mission. I can't have an opinion on the mission; that's not my job. What I have to do is tell [missile] defense planners what it's going to cost to get there and what the technological risk is. . . . I've got to say that the physics of it, and the technology, require a set of miracles that may or may not be at hand.'. . .There is a 'popular misconception' that air defense—the basic mission that the Aegis weapon system performs in the fleet, for example—'easily and seamlessly melds into area defense, which seamlessly melds into theater defense, which seamlessly melds into national missile defense. That's the misconception. . . . It's not true. One does not naturally lead into the other.' Buchanan described the correct paradigm for developing missile defense as a progression of 'continuously more stressing functions,' each becoming more stressing technologically, financially and operationally as the goal of NMD is approached. 'There's a great tendency for optimism. . . . There's always been a great optimism that the job is straightforward. The facts are that we haven't been very successful in the things that we've tried. It's a very difficult technological job. I'm not saying people aren't competent; I just don't think the difficulty is widely appreciated.'" See Hunter Keeter, "Buchanan Calls for Reality Check in Missile Defense Deployment," *Defense Daily*, Vol. 206, No. 19, April 27, 2000, pp. 4–5.

33. It is difficult enough to intercept strategic ballistic missile warheads traveling in typical intercontinental-range trajectories at velocities of 7 to 8 kilometers per second. More demanding are the technical problems of intercepting strategic ballistic missiles launched in less efficient "lofted" and "depressed" trajectories. As a strictly hypothetical example, a Chinese ICBM launched at nearby Japan might require a "lofted" trajectory, in which case the warhead would descend at a steeper angle and therefore would, from a given altitude, reach the ground more quickly—a more difficult problem than usual for terminal defenses.

IV. Constraints on Upgrading Navy TMD Programs

34. The demarcation accords signed in New York on September 26, 1997 exclude 'theater' (non-strategic) anti-ballistic missile interceptor systems from the definition of ABM systems (and therefore from the restrictions the ABM Treaty places on ABM systems) as long as those interceptors (and the systems of which they are part) have (a) been developed and declared for non-strategic missile defense purposes, and (b) the interceptors and

ballistic target vehicles employed during flight testing do not exceed specified velocity and range limits. The specified limits for excluding *lower-velocity* theater missile defense systems from the definition of ABM systems are that the velocity of the interceptor being tested not exceed 3 kilometers per second, and that the ballistic target vehicle used for interceptor testing never exceed a velocity of 5 kilometers per second and not exceed 3,500 kilometers range in its flight trajectory. Since the accords do not specify an agreed interceptor velocity limit for *higher-velocity* theater missile defense systems, the second accord calls for information exchange annually and consultations when either party has plans to develop non-strategic ground- or air-based ballistic missile defense interceptors whose velocity would exceed 5.5 kilometers per second, or sea-based ballistic missile defense interceptors whose velocity would exceed 4.5 kilometers per second. The demarcation accords also would prohibit space-based TMD interceptors. See the texts of the "agreed statements" on demarcation (and related understandings), reprinted in "New START II and ABM Treaty Documents," *Arms Control Today*, Vol. 27, No. 6, September 1997, pp. 21–22.

35. Republican opponents of demarcation in the Senate object in principle to preserving the ABM Treaty, given the demise of the Soviet Union, the opposite treaty party. They would reject the demarcation accords as constraints on U.S. development of high-performance TMD systems. The ABM Treaty was designed to limit ABM systems, i.e., systems capable of countering strategic missiles in their flight trajectories, and is silent on missile defenses that do not meet strategic criteria.

36. Once the warhead, decoys or other payload elements of the missile have separated from the missile's final boost stage, the technical requirements for the interceptor's exoatmospheric kinetic kill vehicle remain the same, whether the intercept point is in the ascent-phase or descent-phase segment of the mid-course flight. The main technical advantage of ascent-phase intercept—since it depends on close proximity between the interceptor's launch platform and the target missile's launch point—is that it can intersect with a wider array of target missile flyout angles and thus provide, potentially, very large defended areas downrange.

37. See note 57 on SPY-1 and X-band radars, below.

38. Federation of American Scientists, "Military Analysis Network: MK41 Vertical Launch System (VLS)," *op. cit.* For selective technical information (including some dimensions) on VLS modules and missile canisters, see United Defense, "Vertical Launching System (VLS) Mk41—Strike Length Module," <http://www.udlp.com/markets/defense/weapons/delivery/mk41/strike.htm>.

39. Theodore Postol in a letter to the editor, *Foreign Policy*, Sept.–Oct., 2000, p. 8, notes that interceptor missiles optimized for boost-phase intercept of strategic missiles would need velocities over 6 km/sec, and booster rockets "tens of times heavier than the THAAD booster."

40. This calculation assumes that the proportion of the current 21-inch diameter missile cell capacity that the SM-3, Block II TMD interceptor's three solid rocket stages already occupy would be about the same proportion as that occupied by the "modified" NMD-capable interceptor's motor stages in the enlarged, 26-inch diameter missile cell, and that the combined length of the propulsion stages of the interceptor missile in both cases would be about the same. If the number and combined length of missile stages is about the same, the difference in fuel volume (up to about 50 per cent more for the larger interceptor) would be essentially a function of the difference in diameter. The calculation also assumes that cost-effective design choices in AEGIS-related programs would limit differences in the chemical composition of the solid motor fuel, engine nozzles and stage configuration to ones that would have only marginal effects on performance, compared at least to the contribution to thrust (specific impulse) from increasing the mass of the solid motor fuel.

41. Cooper and Williams make an extraordinary claim that a very light KV based on space-based interceptor technologies under development in the Reagan and Bush administrations could be upgraded rapidly with new sensor and data-processing technologies to enable planned Navy TMD interceptors to perform *both* boost-phase and mid-course intercept of 'states of concern' missiles with the same KV. "The Earliest Deployment Option," *op. cit.*, pp. 8–9. The assertion does not square with the prevailing understanding among technologists that boost-phase and mid-course KVs must be designed differently. See Theodore Postol's letter to the editor, *Foreign Policy*, *op.cit*, which takes issue with the idea that sea-based THAAD could be used for boost-phase; he contends that a suitable boost-phase kill vehicle would be a "directional shape-charge fragmentation warhead." Nor is the Cooper-Williams claim consistent with the Navy's own doubts that LEAP, partly because it is a light KV designed for TMD, can satisfy kinetic lethality requirements against strategic missiles in mid-course. These Navy doubts are embodied in the BMDO conclusions that stand-alone sea-based NMD would have to use an enhanced KV like the EKV being developed for ground-based NMD (see analysis, below, of BMDO, *Summary of Report to Congress on Utility of Sea-Based Assets to National Missile Defense*, June 1, 1999).

42. Linking sea-based interceptor assets with ABM radars, or feeding tracking and discrimination data to NMD interceptors from space-based tracking sensors, is not permitted by the ABM Treaty as traditionally understood. If such data from external sensors is to be employed, however, its volume will require wide bandwidth transmission and fiber optic communications equipment that the Navy has only begun to address.

A related AEGIS fleet- and theater-specific modernization program in operational development since the mid-1990s is the Cooperative Engagement Capability (CEC). CEC holds considerable technical promise for internetting search and tracking data from widely-spaced ship and airborne radars to provide individual AEGIS ships a composite picture of threat activity in an enlarged battlespace, and thus to act as a missile and air defense force multiplier. CEC is designed to enable launch of interceptors from ships downrange of threat aircraft or missiles using threat acquisition and tracking data provided by cooperating ships or aircraft located closer to the origin of the threat, to support efficient allocation of interceptors and effective interceptor engagement by the most favorably positioned ships. Given the advanced processors, complex software, and communications bandwidth required for generation, transmission and utilization of the composite threat picture, however, CEC trials have encountered severe interoperability problems and proved difficult to implement. Successful implementation may take considerable time, probably at least another decade, but could eventually support autonomous naval TMD performance requirements by reducing any individual AEGIS interceptor ship's dependence on its range-limited, SPY-1 fire control radar for tracking long-range ballistic missile threats. Eventually, data-feed from external NMD sensors could also be integrated with air- and sea-based CEC hardware and software. For background on the program, see DOT&E, *FY99 Annual Report*, *op. cit.*, Section on Navy Programs, chapter on "Cooperative Engagement Capability (CEC)."

V. Financial Costs of Naval NMD

43. The Director of BMDO was directed to submit a report ". . .describing whether and how the Navy Upper Tier program could be upgraded in the future to provide a limited NMD capability. The report should address the technical issues associated with a sea-based NMD option as well as costs associated with such a concept. The report should also address whether and, if so, how a sea-based NMD system could be integrated into and supplement a ground-based NMD system, whether and, if so, how a sea-based system would provide additional capabilities in support of the requirements for the existing NMD program, and whether such a system would comply with the ABM Treaty." U.S. Congress, *Conference Report to*

accompany H.R. 1119, National Defense Authorization Act for Fiscal Year 1998, Report 105–340, page 658.

44. BMDO, *Utility of Sea-Based Assets to National Missile Defense (U)*, May 15, 1998.

45. BMDO, *Summary of Report to Congress on Utility of Sea-Based Assets to National Missile Defense*, June 1, 1999. Unless otherwise noted, the material in this section of the analysis draws on this document, cited hereafter in brief as BMDO, *Summary*. This document may be found at: <http://www.acq.osd.mil/bmdo/bmdolink/pdf/seanmd/pdf>

46. For example, the Summary states that: "Neither this investigation nor the [BMDO and Navy] studies from which it draws was as thorough as a Concept Definition Study or an analysis of Alternatives (formerly called a Cost and Operational Effectiveness Analysis). *Thus the results described herein would have to be pursued to greater depth before being used as the justification for estimating costs or proposing program changes.*" (Emphasis in original.) BMDO, *Summary*, p. 1.

47. See note 12 for the equipment and site deployments associated with the ground-based NMD capability thresholds. C-1 was envisaged originally as the capacity from a single ground-based site to block a few warheads and simple countermeasures (such as penetration aids) delivered by an "unsophisticated rogue-state threat." C-2 would provide the capacity to neutralize a few warheads and sophisticated countermeasures delivered by modern strategic missiles (as an accidental or unauthorized and therefore limited attack), or to cope with "a few tens" of warheads accompanied by simple countermeasures from the "rogue-state threat." C-3 would provide the capacity from two sites to intercept a "few tens" of sophisticated warheads and handle sophisticated countermeasures.

48. The BM/C3I acronym stands for battle management, command, control, communications, and intelligence.

49. We assume that BMDO did not include the cost of SBIRS-Low in the $8.0 billion figure for external sensors and BM/C3I, even though BMDO lists SBIRS-Low as part of the C-2 NMD Sensor Suite. The Sensor Suites listed (in addition to DSP or SBIRS-High) in BMDO's summary—for various NMD architecture options using sea-based elements—included: (1) upgraded shipboard radars; (2) new sea-based X-band radars; (3) the C-1/C-2 land-based sensors including 5 upgraded early warning radars (UEWRs) and 4 forward (land-based) X-band radars; and (4) SBIRS-Low. See BMDO, *Summary*, p. 8.

    The Congressional Budget Office projects the costs of C-2 sensor and BM/C3I facilities for ground-based NMD as follows: (1) 4 X-band radars at $2.5 billion; (2) 5 UEWRs at $1.3 billion; and (3) Command and Communications facilities at $2.2 billion, which totals $6.0 billion. This would account for the bulk of BMDO's $8.0 billion estimate for sea-based NMD sensors and BM/C3I, and the balance of $2.0 billion probably is attributable to AEGIS shipboard radar upgrades, ship-based X-band radars (e.g., three would cost about $1.3 billion), and NMD communications links and BM software upgrades for ships. CBO also estimates that SBIRS-Low will cost about $10.6 billion to deploy. CBO does not include this cost of SBIRS-Low in its estimate of the cost of NMD but notes that the availability of SBIRS-Low is integral to the design of NMD/C-2, and without SBIRS-Low, the NMD system would require other infrastructure that would increase its cost. See Table 2 in Congressional Budget Office, *Budgetary and Technical Implications of the Administration's Plan for National Missile Defense*, April, 2000; available at: <http://www.cbo.gov>.

50. The scope of BMDO's report is described in the summary document as follows: "This report summarizes the results of an investigation into the potential utility of sea-based assets to NMD, an investigation that benefited from previous studies performed by BMDO and the Navy. It describes the potential utility of the Navy Theater Wide (NTW) system to the NMD mission; identifies a number of areas in which the NTW program could be upgraded to give it a significant NMD capability; identifies some potentially attractive NMD roles for sea-based elements; addresses how these sea-based roles would benefit the NMD architecture; and addresses technical issues, costs, schedules and risk." BMDO, *Summary*, p. 1.

51. *Ibid.*, p. 2.

52. *Ibid.*, p. 5.

53. BMDO wrote: "By necessity, the cost results presented in this report must be considered only as rough estimates. In the time available, it was not feasible to evaluate the candidate system concepts with detailed engineering analyses of the type required to support credible cost estimates." *Ibid.*, p. 2.

54. The Pentagon estimate of $20.2 billion available to CBO in the December 1999 "Selected Acquisition Report" (SAR) covered only acquisition and support for the "expanded C-1" phase through 2005. To reach the $25.6 figure (rounded to $26 billion in the present report) that CBO considered as the Pentagon estimate for the "expanded C-1" phase, CBO added $7.0 billion to the $20.2 billion for operations and support costs between 2005 and 2015, while subtracting $1.6 billion for pre-1995 design costs and post-2015 procurement costs that CBO regarded as outside its frame of analysis. Beyond that, the principal differences between the lower DoD and higher CBO figures result from the inclusion in the CBO analysis of the construction and procurement costs of phases C-2 and C-3, the operations and support costs of these augmentations from their introduction through 2015, and a modestly higher cost-growth multiplier than that used by DoD. Both the Pentagon estimate and the CBO analysis exclude the cost of planned space-based sensors from their bottom line figures on the total estimated cost of a ground-based NMD. See Congressional Budget Office, *Budgetary and Technical Implications of the Administration's Plan for National Missile Defense*, April, 2000, especially "Costs and Schedule for National Missile Defense" and related "Box 1" in the "Summary and Introduction"; available at: <http://www.cbo.gov>.

VI. Hidden Costs: Tradeoffs in Core Naval Missions

55. The BMDO report begged off this cost analysis task, noting that: ". . .sea-based systems to a large extent would be deployed on platforms that are inherently multi-mission capable. However, in general, ship locations and load outs for NMD tend to conflict with those for theater missions. Sorting and allocating costs among the missions is a complex task beyond the scope of this study." BMDO, *Summary*, p. 2. Much the same caveat appears later in these words: ". . .sea-based [NMD] systems to a large extent would be deployed on platforms that are inherently multi-mission capable. Sorting and allocating costs among the missions is a complex task beyond the scope of this study." *Ibid.*, p. 19.

56. The technical characteristics and performance of the ground-based NMD X-band radars and upgraded AEGIS shipborne SPY-1 radars are not published, and therefore cannot be compared with much precision. It can be said, however, that the ground-based NMD (and smaller THAAD) X-band radars were specifically designed to have the large bandwidths necessary to operate at higher frequencies, essential to their primary mission, whereas the SPY-1 fire-control radars were not. Radars that operate at higher frequencies generally have better range resolution and capability to measure details of targets. The bandwidth of the NMD X-band radar planned for Shemya, Alaska might be about 1,000 MHz, and if so, its range of resolution could be sufficient to measure target details as small as 15 cm (6 inches). The peak bandwidth of the AEGIS SPY-1 radars traditionally was closer to 40 MHz, with a range of resolution of 3.5 to 4 meters (about 10 to 12 feet), sufficient to see aircraft, and larger ballistic and cruise missiles, but not necessarily warhead features of those missiles. This gross limitation continues today, despite evolutionary improvements in the data processing capabilities of the SPY-1 radars, as reflected in the Director, Operational Test &Evaluation's 1999 comment: "The AEGIS radar which is designed for acquisition and tracking of relatively large aircraft targets may have insufficient power to autonomously

acquire low signature ballistic missile targets at long range." See DOT&E, *FY99 Annual Report*, *op. cit*., chapter on Navy Theater Wide (NTW) Defense, p. 3. The ability of a radar to detect targets at long ranges is a function of its power-aperture product. The P-A product of the ground-based NMD X-band radar is believed to be at least a factor of ten greater than that of either THAAD or the AEGIS SPY-1. Although other factors are also involved (such as the reflectivity and radar cross-section of targets), the ground-based X-band radar probably can detect and track targets of interest at ranges of thousands of kilometers, while the SPY-1 almost certainly is limited to hundreds of kilometers—and at that, to larger targets of interest. Discussion of the evolution of the SPY-1 radar series on AEGIS ships may be found in Federation of American Scientists, "Military Analysis Network: AN/SPY-1 Radar," at <http://www.fas.org/man/dod-101/sys/ship/weaps/an-spy-1.htm>.

57. BMDO, *Summary*, p. 15. BMDO estimates that X-band radars with NMD BM/C3 connectivity, and adequate for the naval mission, could be procured and installed on existing ships (but not AEGIS ships) for about $250 million each. *Ibid.,* p. 20. CBO's estimate for each radar-equipped ship is much higher, about $435 million each. See note 49.

58. BMDO notes that even in this augmented NTW scenario, "many of these ship locations are incompatible with operating areas for AEGIS ships supporting the TBMD (theater ballistic missile defense) mission and other theater missions (e.g., Tomahawk strike, anti-air warfare)." BMDO, *Summary*, p. 15.

59. BMDO conducted the first EKV flight-test with "qualified success" on October 2, 1999 (evidently, a more visible decoy aided sensor reorientation and acquisition of the less visible target warhead). The second test on January 18, 2000 failed, due to circulatory failure of the cryogenic cooling mechanism associated with the EKV's exoatmospheric sensors. The third EKV flight test on July 7, 2000 also failed. In fact, the third flight test could be considered a "null" test because the EKV stage failed to separate from the booster stage, precluding operation of the EKV's sensors, and discrimination and homing capabilities.

60. While strongly believing in the utility of missile defense missions and optimistic about the feasibility of using "hit-to-kill" missile defense technology in the "mid-course" regime, a senior, bipartisan panel of defense experts chaired by former Air Force Chief of Staff, General Larry Welch (now head of the Institute of Defense Analysis), has made the shortcomings of the current NMD technology and testing program a credible concern. The Welch Panel examined the results emerging from the NMD development and testing program twice, in February 1998 and September 1999. The panel urged BMDO and the administration to adopt a series of corrective measures in testing design requirements, program funding, EKV prototype hardware acquisition, ground-testing facilities, and the scheduling or synchronizing of component tests—in order to limit technical risk and avoid "a rush to failure." The Welch Panel Report, formally entitled *National Missile Defense Review Committee Report*, September 1999, is available at: <http://www.acq/osd.mil/bmdo/bmdolink/html/docs.html>.

    The Welch panel later submitted a third classified report to the Defense Department, reportedly expressing concern that the complexity of integrating the components of the ground-based NMD make it doubtful that the initial operational capability of the system can actually be brought on line in 2005, irrespective of whether the interceptor flight test then scheduled for July 7 would succeed or not (the test failed, see previous note). Roberto Suro and Thomas E. Ricks, "More Doubts Are Raised on Missile Shield," *Washington Post*, June 18, 2000, pp. A-1, A-16.

    A panel of scientists and engineers convened by the Union of Concerned Scientists (UCS) and the Security Studies Program of MIT was skeptical that NMD using kinetic interceptors in the "mid-course" regime could ever be effective, given countermeasures. See UCS, *Countermeasures: A Technical Evaluation of the Operational Effectiveness of the Planned US National Missile Defense System*, Cambridge, MA, April 2000. This report concluded, *inter alia*, that several "mid-course" countermeasures available even to unsophisticated missile countries could either defeat the ability of cooled-infrared sensors to discriminate effectively between nuclear warheads and decoys, or numerically overwhelm small numbers of hit-to-kill interceptors at strategic closing velocities. Countermeasures highlighted by the study were: (1) biological weapons in a large number of disseminated bomblets or submunitions designed to survive atmospheric reentry; (2) nuclear warheads masked by multiple anti-simulation balloon decoys; and (3) nuclear weapons made invisible by cooled shrouds.

61. The GAO warned that the procurement schedule for the first-phase of NTW would precede operational testing, according to current Navy plans. See GAO, *Missile Defense: Schedule for Navy Theater Wide Program Should Be Revised to Reduce Risk*, May 2000 (GAO/NSIA D-00-121).

62. Peña, "From the Sea," *op.cit.*, p. 7.

63. CBO included in this estimate 300 ground-based interceptors, 500 space-based interceptors, 20 space-based lasers, the space-based satellite sensors known today as SBIRS-High and SBIRS-Low, and a life-cycle cost of 20 years. The information consisted of "Answers to Questions Posed by Senators Exon and Dorgan." *Ibid*., p. 10, note 49.

VII. Alternative Visions: Boost-Phase Missile Defenses

64. The unexpected warmth of the South and North Korean summit meeting in Pyongyang on June 14–15, 2000 suggested that North Korea's rigid and confrontational positions may be softening, and that it might be willing to negotiate stabilizing measures and limit its long-range missile development in exchange for expanded relations. Doug Struck, "Two Koreas Sign Conciliatory Accord," *Washington Post*, June 15, 2000, pp. A-1, A-28; and Steven Mufson, "U.S. Lauds Korean Talks, Says More Work Ahead," *Washington Post*, June 16, 2000, p. A-25. Russian President Putin's claim that North Korea is willing to end its long-range missile development in return for foreign assistance with space launch research and technology, in remarks made during his visit to Pyongyang on July 19, 2000, suggested that it may be possible to neutralize the North Korean long-range missile threat by diplomatic means. See David Hoffman, "Russia Says N. Korea Offers to End Missile Program," *Washington Post*, July 20, 2000, p. A-16. As an indication that progress may prove rocky and slow, however, North Korean leader Kim Jong Il told South Korean media executives that his July offer to scrap the long-range missile program in exchange for foreign assistance had been made laughingly, and was not serious. Doug Struck and Joohee Cho, "N. Korean Dismisses Missile Idea," *Washington Post*, August 15, 2000, p. A-1.

65. See Garwin's *National Missile Defense*, Testimony to Senate Foreign Relations Committee, May 4, 1999, and Postol's *A Russian-US Boost-Phase Defense to Defend Russia and the US from Postulated Rogue-State ICBMs*, Washington, D.C.: Carnegie Endowment for International Peace, October 12, 1999.

66. See Theodore Postol's letter to the Editor, *Foreign Policy*, *op. cit.*, which indicates that he and Richard Garwin share the view that the most suitable kill vehicle for boost-phase intercept would not be any of the KKVs under development for TMD or NMD but rather a "directional shape-charge fragmentation warhead." in order to "increase its chances of hitting an accelerating ICBM." Moreover, he explains that a very large interceptor missile is needed to carry this heavy warhead and still get the "peak-acceleration and total-divert velocity needed to home in on and hit an accelerating ICBM target."

67. "National Missile Defense: Is There Another Way?" *Foreign Policy*, Summer 2000, pp. 91–99.

68. *Ibid.*, p. 92.

69. *Ibid.*

70. BMDO, *Utility of Sea-Based Assets to National Missile Defense (U)*, May 15, 1998; and BMDO, *Summary, op. cit*.

71. See Roberto Suro, "Will Missile Defense Plan to Go to Sea?", *Washington Post*, May 27, 2000. According to Suro, senior defense officials said that the latest BMDO report "concludes that sea-based national missile defenses could be built with existing technology and would add both flexibility and firepower to the landbased system proposed by President Clinton," but that "civilian officials at the Pentagon are now holding up release of the report," apparently because it "will provide ammunition to critics of the Clinton system from all sides of the ideological spectrum who are eager to present credible alternatives to the administration's proposal."

72. The DBW-proposed boost-phase requirement is not consistent with the planned operational envelope of the NTW "first phase" (SM-3, Block I) either, and this system was rescheduled in late 1999 to come on line only between 2006 and 2010.

73. David C. Wright and George N. Lewis in a letter to the editor, *Foreign Policy*, Sept.–Oct. 2000, p. 6, criticize the DBW view as "too optimistic about the ease and speed of implementing such a system." They add, "Our calculations show that [the DBW] near-term, ship-based option, using an 'existing missile and aerodynamic kill vehicle,' would have a very short range against a North Korean intercontinental ballistic missile (ICBM) and could only attempt to intercept missiles launched near the coast." Even this reconfigured NAD concept presupposes that North Korea's test launch site for the Taepo Dong missiles would stay where it is, near the coast, but the country's territorial depth would permit an alternate launch site to be located 200 to 300 kilometers further away from maritime launch points readily accessible to the U.S. Navy.

74. The U.S. Navy's prudent standard operating procedures for high-value, forward-deployed vessels normally keeps them on patrol in "blue water" depths, with only brief intrusions into shallow litoral waters, such as the Persian (Arabian) Gulf. Anti-submarine sensors are less effective in shallow waters.

75. THAAD has been tested successfully with a mid-course KV that is four times heavier than LEAP, the KV currently planned for NTW interceptors. If THAAD were modified to carry a fragmentation warhead similar to that of NAD (SM-2, Block IVA), its acceleration and burnout velocity in a boost-phase mode might well be superior to that of the planned Navy TMD interceptors. See next note, however, on Navy's concern about "marinized" THAAD.

76. The U.S. Navy reportedly is not enthusiastic about incorporating the "marinized" THAAD in VLS cells because the liquid fuel stored in its front section for terminal maneuver of the KV has properties that could damage the VLS system. The Navy's exoatmospheric KV, LEAP, relies on solid fuel jets for divert and attitude control in homing maneuvers.

77. Russia was unreceptive during the Moscow summit of June 3–4, 2000, to the U.S. "grand bargain" proposal in which the U.S. would accept an even lower ceiling of strategic warheads as the START III goal than the 2,000 to 2,500 warhead ceilings contemplated at Helsinki in March 1997, provided Russia would agree to modifications of the ABM Treaty that would accommodate U.S. plans for a limited, ground-based NMD system. See David Hoffman and Charles Babington, "ABM Issue Unresolved as Summit Ends," *Washington Post*, June 5, 2000, pp. A-1, A-10.

78. See Michael Gordon, "Putin Offers Alternative Antimissile Plan," *New York Times*, June 3, 2000. According to this report: "Agreeing with the American assessment that so-called rogue states pose a nuclear threat, Mr. Putin hinted that the United States and Russia could collaborate on new ways to shoot down enemy missiles soon after they were launched, rather than in space. The Russian proposal is intended to replace the plan for a nationwide shield to protect the United States against incoming warheads that the Clinton administration has proposed. Mr. Putin's alternative approach seems to resemble the plan known in the United States as 'boost phase defense,' which has been proposed by a number of arms control advocates. Russian officials have been talking privately to American negotiators about the idea in recent weeks."

79. On the heels of his summit with Clinton in Moscow, President Putin reportedly "used his meeting with Italian officials as an opportunity to use Europe as a wedge in Russia's arms control negotiations with the United States. Mr. Putin's public remarks [in Rome]. . . were aimed at swaying international opinion on arms control, and in particular at exploiting European fears that the United States is embarked on a risky course to refashion the ABM treaty to create a missile defense system aimed at protecting itself. . . . Russia proposed working with Europe and NATO to create an anti-rocket defense system for Europe," Mr. Putin told reporters. "On one hand, it would avoid all the problems linked to the balance of force. On the other, it would permit in an absolute manner a 100 percent guarantee of the security of every European country." See Alessandra Stanley, "Putin Goes to Rome to Promote Russian Arms Control Alternative," *New York Times*, June 6, 2000.

80. Dean A. Wilkening, *Ballistic-Missile Defence and Strategic Stability*, *op. cit.*, chapter 4. Wilkening is director of the Science Program in the Center for International Security and Cooperation at Stanford University.

81. Priority in U.S. TMD programs has been given to the Army's Patriot and THAAD, and the Navy's NAD and NTW. Hence these USAF airborne TMD programs are less advanced and further from deployment and procurement than their ground-based and naval counterparts. *Ibid*. pp. 60–61.

82. The ABI ranges he gives against *Scud B*, *Scud C*, *No-dong* and *Taepo Dong* 1 missiles are 70 km, 135 km, 179 km and 480 km respectively. *Ibid*., p. 62.

83. *Ibid*., pp. 63–64.

84. *Ibid*., p. 65.

85. Relying on official figures, Wilkening estimates the ABL program with seven rotating jumbo aircraft manning two engagement zones would cost $5 billion for procurement and $11 billion for total life cycle cost over 20 years, and therefore possibly the least expensive boost-phase option. *Ibid*. pp. 66–67.

86. Laser beams must dwell on their aim points until the target missile is disabled or destroyed, limiting the number of targets that a single laser can intercept in any engagement period. If laser energy is split among several targets, lethal range also drops. Known countermeasures include reflective and ablative coatings—for hardening of booster skins against laser radiation, rotation of the missile in flight to dissipate laser energy, and salvo launches. *Ibid*., p. 66.

87. The current USAF ABL program, Wilkening notes, plans to have the first operational TMD version of a Boeing 747 ABL platform (a prototype) available between 2007 and 2014—the timespan itself indicating considerable technical as well as funding uncertainty. *Ibid*., pp. 65–66.

88. Boost-phase intercept must project an intercept point for an accelerating target, when acceleration itself varies stage by stage and with interruptions, rather than unfolding as a simple linear function. This makes trajectory prediction more difficult than in the mid-course case, where the target travels at a constant velocity and predictable track. In most boost-phase intercept scenarios, the interceptor homing sensors also face a "plume/hardbody" problem, in that once the target missile ascends above a few dozen kilometers where the atmosphere has thinned, the plume no longer streams out behind the booster, but rather blooms out and envelopes the booster. Finding the small missile inside the large plume at that altitude is not a trivial task.

89. The Under Secretary of Defense for Acquisition, Jacques Gansler, recently addressed this point before the House Armed Services Committee as follows:

> "Other critics have said that, quote, 'it would be much easier to develop a boost-phase system that would hit the

oncoming target shortly after liftoff and that our decision to proceed with a mid-course intercept of an incoming target is much too expensive and much too complicated.'

"For a boost-phase intercept, it would be necessary to place the intercept system in close proximity to the booster. This would require a nearby land-based interceptor, such as recently discussed on a Russia-based joint U.S. and Russian intercept system, or a sea-based system, either surface or subsurface, in close to the target waters, and therefore highly vulnerable.

"In any case, it would be necessary to initiate a very quick response. The first signal that a booster has been launched comes for a satellite detection. With instant reaction and a very high-speed interceptor, which we do not have at this time, we could try to get out and shoot down the booster. But this assumes that you recognize or don't consider the type of launch that is occurring, that it is actually carrying a warhead directed at the United States and not simply a satellite launch or a test launch. Certainly there is no time for human decision-making as there is in our [current mid-course] approach."

Later, Congressman Spratt queried: ". . . Some years ago SDIO concluded that if the boost-phase burnout time were 180 seconds, and if you wanted a man in the loop so that you didn't accidentally launch something, that boost-phase intercept was practically fruitless. Would you agree with that? You've got 250 seconds on your chart for boost-phase. Some of that is under the clouds."

Gansler replied, "You have to take the time—first you have to detect from the satellite and then use that information to launch. And you have to then have a very high-speed interceptor in order to be able to get there, if you're trying to do it during the boost phase. And basically, that does take the man out of the loop, as well as, I suggested, developing the high-speed interceptor. It does make it extremely difficult." See "Hearing on National Missile Defense," House Armed Services Committee, transcript, June 28, 2000.

90. See Gansler's testimony, *Ibid.* In a somewhat different vein, two proponents of naval boost-phase acknowledge that, even in a relatively forgiving defense scenario against a North Korean Taepo Dong, AEGIS interceptors would have to be launched no later than 50 seconds after the Taepo Dong lift off to stop it before it flames out. The authors describe this nearly instantaneous reaction as "a challenging but achievable feat," with no mention of how this could be processed through the national command authority. Cooper and Williams, "The Earliest Deployment Option," *op. cit.*, page 7.

VIII. Balancing National Security Risks and Costs

91. See *Report of the bipartisan Commission to Assess the Ballistic Missile Threat to the United States* (Rumsfeld Commission), Washington, D.C.: Government Printing Office, July 15, 1998.

92. For a recent analysis of the strategic, missile defense, and broad political-military issues in U.S.-PRC relations, See *China, Nuclear Weapons, and Arms Control: A Preliminary Assessment*, New York: The Council on Foreign Relations, 2000 (Chairmen's Report of a roundtable jointly sponsored by the Council on Foreign Relations, the National Defense University, and the Institute for Defense Analyses, Cochairs: Robert A. Manning, Ronald Montaperto, Brad Roberts).

93. *China, Nuclear Weapons, and Arms Control: A Preliminary Assessment*, *op. cit.*, pp. 19–30; also Wilkening, *Ballistic-Missile Defence and Strategic Stability*, *op. cit.*, Appendix 2 on "Future Strategic Nuclear Forces," section on China, pp. 83–85.

Appendix

94. BMDO, *Summary of Report to Congress on Utility of Sea-Based Assets to National Missile Defense,* dated June 1, 1999, pp. 3–5.

95. The sensors planned for the ground-based NMD architecture are: Upgraded Early Warning Radars (UEWRs), forward-deployed X-band radars, the still functioning DSP satellites, and the Space Based Infrared Satellites in high and low orbits (SBIRS-High and SBIRS-Low), after these space-based sensors come on line.

96. See note 27.