CBO STAFF MEMORANDUM

THEATER BALLISTIC MISSILE DEFENSES:
SELECTED ISSUES

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NOTES

Unless otherwise indicated, all years referred to in this memorandum are fiscal years, and all costs are expressed in current dollars of budget authority.

Numbers in text and tables may not add to totals because of rounding.

On May 13, 1993, Secretary of Defense Les Aspin changed the name of the agency responsible for coordinating the development of ballistic missile defenses from the Strategic Defense Initiative Organization (SDIO) to the Ballistic Missile Defense Organization (BMDO). For clarity, this memorandum refers to BMDO rather than SDIO even in cases in which the name had not yet been changed.

This Congressional Budget Office (CBO) staff memorandum responds to several specific questions posed by the Chairman of the Senate Budget Committee about theater ballistic missile defenses. The memorandum outlines the theater missile defense (TMD) programs that the United States is currently pursuing. It also examines the advantages and costs of overlap among the various theater defenses being developed by all four military services. Finally, it addresses compliance issues with the Anti-Ballistic Missile Treaty raised by several TMD programs.

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The United States is actively developing defenses to protect its troops and the citizens of friendly countries against attack by theater ballistic missiles. Those missiles--the type that Iraq used during the Persian Gulf War--have shorter ranges than the missiles with intercontinental range that the superpowers deploy as part of their nuclear arsenals.

This memorandum is not intended as a complete analysis of issues related to theater missile defenses. Rather, it responds to questions posed by the Chairman of the Senate Budget Committee. It briefly describes the theater missile defense (TMD) programs that the United States is currently pursuing. It also discusses the advantages of overlap among the various systems that all four services are developing and the cost problems that might result. Finally, the memorandum addresses compliance issues with the Anti-Ballistic Missile (ABM) Treaty raised by several TMD programs.

The United States Is Developing Several TMD Systems

The United States is currently developing a number of theater missile defense systems in programs coordinated by the Defense Department's Ballistic Missile Defense Organization (BMDO). The fate of those systems is still in question, however, because the Clinton Administration may reduce the number of programs in 1994 as a result of its ongoing review of ballistic missile defenses. The first of those systems--an upgraded version of the Army's Patriot system used during the Persian Gulf War--may be deployed by 1995. A significantly improved version of the Patriot (the Patriot Anti-Tactical Capability-3, or PAC-3, system) could be deployed near the end of this decade. That system would be able to defend areas with a radius of a few tens of kilometers from attack by missiles like the Scud of Desert Storm fame. The Army is also in the early stages of developing a replacement--called Corps SAM--for its Hawk air-defense system. Corps SAM would be deployed in the next decade to protect Army maneuver forces that were deployed too far forward in the theater of operations to be protected by Patriot batteries.

The other services are developing point defenses as well. The Navy is planning to deploy a system with capabilities similar to PAC-3's on its Aegis-class cruisers and destroyers. And the Marine Corps is in the process of upgrading its Hawk system to increase its ability to protect Marine expeditionary forces against short-range ballistic missiles.

All of these systems are called point defenses because they defend relatively small areas. BMDO sometimes labels these systems lower-tier defenses because they would intercept missiles within the earth's atmosphere.

In contrast, area defenses would be able to defend regions a few hundred kilometers wide--the size of a small country. BMDO calls these systems upper-tier defenses because they would intercept missiles in the upper atmosphere or outside it.

The United States is developing two systems for area defense: the Army's Theater High Altitude Area Defense (THAAD) and the Navy's upper-tier defense. THAAD could be deployed after 2001, although the Army hopes to have a prototype system ready that could be deployed in a crisis as early as 1996. The Navy system could be in place by 2005. The United States is also providing financial and technical support to Israel to develop its own area defense, the Arrow system.

The Air Force has several ongoing TMD programs. For example, it is developing satellite-based sensors that would warn of an impending attack by ballistic missiles and provide data about the trajectory of incoming missiles. (The latter capability would expand the area that ground-based defenses could protect.) In addition, the Air Force is in the early stages of developing several systems that could intercept missiles shortly after they are launched (during the so-called boost phase).

The deployment dates for the proposed systems that are noted in this memorandum are based on statements made by BMDO officials this past spring and BMDO's "1993 Report to Congress on the Theater Missile Defense Initiative (TMDI)." The dates presume the receipt of funding that has been proposed but that has not yet been approved by the new Administration or the Congress. If funding is reduced, deployment of these TMD systems could be delayed. Alternatively, the Department of Defense could preserve deployment schedules for some TMD systems by canceling others.

Overlap Exists Among the Systems

Clearly, overlap exists among the various programs to defend against theater ballistic missiles. Point, area, and boost-phase defenses are all designed to counter some of the same types of missiles. Overlap also exists between the services: the Army and the Navy are each developing systems for point and area defense. The Marine Corps is also developing its own point defense.

Overlap Offers Advantages. Although overlap exists, the various systems would have complementary attributes that would provide more flexibility to U.S. commanders. For example, sea-based defenses could be deployed quickly during a crisis because they would not require access to airfields in order to be delivered to the theater. They would, however, be limited to

protecting coastal regions. In contrast, Army systems could defend forces either near or far from the coast, but they would require defended airfields in order to be deployed quickly.

Overlap would also allow the United States to deploy layers of defenses that would be more effective than any single system. A high level of effectiveness may be important, particularly when defending against missiles that carry nuclear, biological, or chemical warheads or protecting the civilian populations of U.S. allies.

Overlap Is Expensive. Although overlap has advantages, it is expensive. Developing several different systems to counter the same threat will cost billions of dollars a year. Major General Malcolm O'Neill, acting director of BMDO, has testified that "a very aggressive program" supporting all of the systems mentioned earlier could cost as much as $3 billion a year by the mid-1990s. Sufficient money to fund all of the TMD programs currently planned by the services may not be available over the next six years (see the discussion on page 16).

Some TMD Programs Would Raise ABM Compliance Issues

Some theater defense systems--namely area defenses like THAAD and space-based sensors like Brilliant Eyes--will probably raise compliance issues with the ABM treaty. Area defenses could have some capability against long-range ballistic missiles, a capability limited by the treaty. In addition, space-based sensors could act like ABM radars, which the treaty also strictly limits.

It may be possible to resolve these issues in discussions with Russia. But if the United States wishes to remain in compliance with the treaty, it must negotiate and reach an agreement with Russia before deploying area defenses or space-based sensors.

Potential Budgetary Problems Exist Through 1999

It is not yet possible to assess the extent of funding problems with confidence because the Administration has not announced how much it will spend on TMD systems or which systems it plans to develop. But the size of the budgets for BMDO that the Administration is reportedly considering would make it difficult for the United States to finance all ongoing TMD programs and still maintain a program to deploy national missile defenses early in the next decade. (National missile defenses would protect against missiles that can attack the United States.)

To illustrate the potential for budgetary problems over the next six years, the Congressional Budget Office calculated the costs of an approach based on assumptions supplied by the requestor of this analysis. That approach assumes that the United States fully funds the development of only three TMD systems (the Army's Patriot and THAAD defenses and the Navy's lower-tier defense) and the battle management system that would allow those defenses to function effectively together. Beyond 1994, funding for all other TMD programs would be eliminated. Funding for non-TMD systems would rise above the 1994 level requested by the Administration only by enough to offset inflation. (Non-TMD programs include national missile defenses as well as follow-on research on advanced technologies and general research and support.)

Under those assumptions, the total funding required for all missile defenses (both theater defenses and non-TMD programs) would be $24 billion from 1994 through 1999. That requirement equals or exceeds the money that would be available under all of the funding levels reportedly being considered by the Administration for ballistic missile defenses except those that increase funding in real terms.

Moreover, it is quite possible that meeting the Administration's goals would require a higher level of funding than the $24 billion suggested by the illustrative approach. For example, costs could rise if the Administration decided to develop other TMD systems such as Corps SAM or Navy upper-tier defenses in addition to the core package. Moreover, it is likely that funding for non-TMD programs would have to increase in real terms if the United States is to deploy national missile defenses by 2004, a goal reportedly being considered by the Pentagon in its ongoing review of missile defenses. (The illustrative approach would keep funding constant at 1994 levels through 1999 after adjusting for inflation.)

INTRODUCTION

During the Persian Gulf War, Iraqi Scud missiles attacked U.S. and coalition military forces and coalition civilian populations. Scuds are classified as theater ballistic missiles--a category that includes various types of shorter-range missiles--because their range limits them to a theater of operations. The United States is actively developing theater missile defenses (TMD) to protect its own troops and the civilian populations of its allies against such attacks.

Many analysts believe that a pressing need exists for theater missile defenses. Some 20 developing nations already possess theater ballistic missiles. Although several U.S. allies are now within range of some of those systems, none of the missiles has sufficient range to threaten the continental United States. Yet the missiles could threaten U.S. troops deployed abroad.

In contrast, only the United States, Russia, the United Kingdom, France, China, Ukraine, and Kazahkstan possess missiles that can traverse longer, intercontinental distances (known as strategic ballistic missiles). To date, however, Ukraine and Kazahkstan are unable to use their missiles because Russia alone possesses the codes necessary for their launch.

Theater missile defenses will be expensive. The total cost to develop and deploy an extensive system of defenses could well exceed several tens of billions of dollars. Annual budgets for theater defenses are rising sharply while the overall defense budget is declining. When the Congress created the Theater Missile Defense Initiative in 1991, theater systems received about $400 million.[1] In 1993, $1.1 billion, or about 30 percent of funding for all missile defenses, is being devoted to theater defenses. In 1994, total funding for all missile defenses under the Clinton Administration's plan would remain at the 1993 level of $3.8 billion, but funding for theater defenses would increase to $1.8 billion, or almost 50 percent of total funding.

Policymakers are therefore bound to raise questions about how quickly defenses should be deployed. They may also pose questions about how many of the military services should field defensive systems--a decision that will have important effects on costs. Finally, they may wish to know whether any of the TMD systems planned by the Clinton Administration will raise compliance issues with the Anti-Ballistic Missile (ABM) Treaty.

This Congressional Budget Office (CBO) staff memorandum is not intended as a complete analysis of this complex topic. Rather, it addresses specific questions about theater missile defenses posed by the Chairman of the

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1. That sum included funding for TMD in both the Strategic Defense Initiative and Theater Missile Defense Initiative accounts for 1991.

Senate Budget Committee regarding the status of current TMD programs, the overlap among the services' programs, the issues that developing advanced TMD systems may raise with regard to compliance with the ABM treaty, and the costs of the TMD programs.

WHAT PROGRAMS ARE IN DEVELOPMENT?

The military can protect against ballistic missile attacks in various ways. The systems of ballistic missile defenses that are the focus of this memorandum are designed to destroy incoming missiles after launch but before they can reach their targets, an approach known as active defense. The Army has already deployed one active system to defend its forces against theater ballistic missiles. In addition, bombers and other weapon platforms can be used to destroy an enemy's missile launchers and command and control systems, thereby denying the enemy the ability to launch missiles. Passive defenses, such as shelters, can also be employed to protect troops or populations from the effects of an attack.

Types of Ballistic Missiles

Ballistic missiles are typically separated into categories based on the distance that they can travel. Missiles with ranges exceeding 5,000 kilometers (km) are considered to have intercontinental ranges and are referred to as strategic weapons. Intermediate-range missiles can travel anywhere from 500 to 5,000 km. The United States and the former Soviet Union have eliminated all of their land-based ballistic missiles in that category as part of the Intermediate-Range Nuclear Forces (INF) Treaty.[2] Other nations, however, still possess land-based missiles with those ranges. Short-range ballistic missiles can typically travel less than 500 km.

Missiles in the latter two categories are often called theater ballistic missiles: their ranges constrain them to targets within a limited theater of operations. Some 20 developing nations possess theater ballistic missiles. Short-range ballistic missiles are scattered in countries throughout the world, frequently in nations that were allied at some time with the former Soviet Union. Among developing nations, those in the Middle East and Southwest Asia are most likely to possess theater ballistic missiles. The most common theater ballistic missile, the Scud-B, has a range of roughly 300 km. The Scud-C and the Iraqi al-Hussein missiles (both derived from the Scud-B) have

2. The INF treaty does not limit ballistic missiles or cruise missiles with ranges between 500 km and 5,500 km that are carried by submarines. Both sides continue to deploy those types of submarine-launched weapons.

ranges of 550 km and 650 km, respectively. Iraq used al-Hussein missiles to attack Israel and Saudi Arabia during the Persian Gulf War. North Korea is reportedly developing another missile based on the Scud, the No Dong 1, which could have a range as long as 1,000 km.

Few countries in the developing world possess missiles with ranges longer than those of the Scud derivatives (that is, ranges that exceed 1,000 km). There are, however, several exceptions. The Chinese CSS-2, which has been sold to Saudi Arabia, reportedly has a range of roughly 2,500 km, and Israel has the Jericho 2 missile with a range of approximately 1,500 km.

Several other countries may be developing such longer-range theater ballistic missiles. North Korea reportedly is developing a longer-range version of the No Dong, and India is developing the Agni missile. (Estimated ranges for those missiles are 2,000 and 2,500 km, respectively.) Iraq was thought to be developing a long-range missile in this class, but in the aftermath of the Persian Gulf War, the status of that program is unclear.

Types of Theater Ballistic Missile Defenses

Theater ballistic missile defenses come in two basic types. Point defenses are designed to protect a relatively small area such as the territory occupied by an artillery battery, an Army battalion, or important fixed targets such as airfields, ports, or logistical centers. (Point defenses are also referred to as lower-tier defenses.) Area defenses are designed to protect larger areas such as a city or small country. They are often referred to as upper-tier defenses because they intercept missiles in the upper portions of the earth's atmosphere or outside it.

Both types of defenses consist of radar to detect incoming missiles, interceptor missiles to destroy them, launchers that transport and launch the interceptors, and a battle management and command and control system to tie all of the components together and make them function as a system. The characteristics that separate point and area defenses are the capability of the interceptor (its range, speed, and whether it must function inside or outside the atmosphere) and the power of the radar. A defense can also be aided by space-based sensors, which could improve the effectiveness of the system and increase the defended territory. (Space-based sensors would alert the system to an impending attack and provide detailed information about the attacking missiles.)

Along with the Ballistic Missile Defense Organization, or BMDO (formerly the Strategic Defense Initiative Organization, or SDIO), the Army

and the Navy are both developing point and area defenses (see Table 1). The Marines are also developing a point defense. In addition, under the aegis of BMDO, the Air Force is developing space-based sensors. The Air Force is also exploring a boost-phase system that could attack theater ballistic missiles shortly after their launch.

Point Defenses

The Army, Navy, and Marines are all developing point (lower-tier) defenses. In addition to defending against theater ballistic missiles, point defense systems can defend against aircraft and cruise missiles that fly much lower and more slowly than ballistic missiles.

The Army's Systems. The Army has already deployed one system of point defenses--the Patriot Anti-Tactical Capability-2 (or PAC-2) system of Desert Storm fame. The service is now in the latter phase of developing further improvements to the PAC-2 system, including missile guidance and radar enhancements; it plans to deploy the fully upgraded system in 1995.[3] The Army is also developing a significantly improved Patriot, the PAC-3, which will extend the area that the system can defend and correct some of the problems discovered during Desert Storm. Improvements to the interceptor missile and radar will allow the PAC-3 system to destroy missiles at greater ranges than the PAC-2.

The final architecture of the PAC-3 system has yet to be determined. The Army is in the process of developing two different interceptors (including the seekers, warheads, and missiles) and will select one of them in the next year. One package (called the multimode missile) would destroy the incoming missile with the fragments from an explosion, the method that the Patriots used during the Persian Gulf War. The other (a so-called hit-to-kill interceptor) is based on technology from the Extended Range Interceptor (ERINT) program and would destroy the missile by colliding with it.

Compared with the PAC-2 version, the new system should be able to protect a wider area. Each Patriot battery consists of up to 8 missile launchers, each carrying 4 multimode seeker missiles or 16 ERINT missiles, and one search radar. Reportedly, a battery equipped with PAC-3 missiles could defend an area with a radius of up to a few tens of kilometers, although

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3. The deployment schedules cited in this memorandum for the Patriot and other systems are based on BMDO's "1993 Report to Congress on the Theater Missile Defense Initiative (TMDI)" and on briefings to the Congress by BMDO officials in April 1993.

TABLE 1. MAJOR THEATER BALLISTIC MISSILE DEFENSE SYSTEMS CURRENTLY BEING DEVELOPED OR CONSIDERED BY BMDO

System	Service
Lower-Tier (Point) Defenses	
Patriot PAC-2 Upgrades	Army
Patriot PAC-3 Multimode Missile Extended-Range Interceptor (ERINT)	Army
Corps SAM	Army
Navy Lower-Tier Defense	Navy
Hawk Upgrades	Marines
Upper-Tier (Area) Defenses	
THAAD (Includes TMD-GBR)	Army
Navy Upper-Tier Defense	Navy
Arrow	Israel[a]
Boost-Phase Defenses	
Boost-Phase Interceptor[b] RAPTOR/Talon Airborne Laser Airborne Interceptor	Air Force
Space-Based Sensors	
Brilliant Eyes	Air Force

SOURCE: Congressional Budget Office based on Department of Defense data.

NOTES: This table is not meant to be an exhaustive list of all theater missile defense (TMD) programs. Rather, it is intended to illustrate the major TMD systems either being developed or considered by BMDO. The Clinton Administration may cancel some of the programs on this list in 1994 as a result of its review of ballistic missile defense programs.

BMDO = Ballistic Missile Defense Organization; PAC = Patriot Anti-Tactical Capability; THAAD = Theater High Altitude Area Defense; TMD-GBR = Theater Missile Defense Ground-Based Radar; RAPTOR = Response Aircraft Program for Theater Operations.

a. Israel is developing the Arrow system with substantial financial and technical contributions by the United States.

b. The Air Force is still evaluating different approaches to boost-phase defense and has not yet selected an option for development. Air Force officials have mentioned the three programs listed under this heading as possible approaches.

the defended area varies according to the speed of the incoming missile and the availability and quality of early-warning data about the enemy missile's trajectory. According to current Army practice, the Patriot PAC-3 will protect important fixed targets such as logistics centers, airfields, and command and control nodes that are located in the rear area of the theater of operations. It will also provide protection for any troops that are located within its defended area. Troops in forward areas, however, will have to depend on other systems for protection.

Because no country near the United States possesses theater missiles, U.S. defensive systems are designed for use overseas. The ability to transport the system rapidly is therefore of great concern. According to information provided to the Congress by BMDO officials, delivering a complete Patriot battalion, which includes six batteries, requires either 126 flights using the Air Force's large C-5 transport plane or 301 flights with the smaller C-141 transport.

The Army plans to deploy the PAC-3 system beginning in 1998, according to Congressional briefings by BMDO officials in April 1993. The 1998 deployment date assumes that the program receives all of the funding BMDO assumed in February 1993 in its proposed budget for 1994 through 1999. If funding levels are lower, deployment could be delayed.

The same qualification applies to the deployment dates cited for the other systems discussed in this memorandum: delays could occur if funding for a system were reduced below the level proposed by BMDO in February 1993. That proposal assumes that total funding for missile defenses (including both theater defenses and systems designed to defend the nation against longer-range missiles) grows from $3.8 billion in 1994 to more than $6 billion a year in 1995 and beyond. But the new Administration has yet to endorse that baseline. Indeed, actual funding may be reduced below those levels to accommodate the smaller defense budgets proposed by President Clinton. If so, deployment dates for some or all of the systems could be delayed.

In addition to the PAC-3 system, the Army is developing an air defense system (called Corps SAM) to deploy with its maneuver troops. Those forces are often left unprotected by the Patriot system, which is deployed to the rear of the theater to protect important fixed targets.

The Corps SAM system is scheduled to replace Army and Marine Hawk air-defense batteries sometime after 2002. Although it will be designed primarily to defend against aircraft, the system will have some ability to defend against theater ballistic missiles with ranges of less than 600 km; it will have limited ability to defend against missiles with longer ranges. Because it

will be deployed closer to troops near the front lines, Corps SAM will probably be better able than the PAC-3 to protect maneuver forces against the short-range ballistic missiles that they are likely to face. (The PAC-3 would be deployed toward the rear areas of the theater of operations.)

The Navy's System. The Navy is starting to develop its own system of point defenses. Like the Army with its PAC-3 upgrade for the Patriot system, the Navy intends to improve existing interceptor missiles and radars rather than develop new ones. Specifically, the Navy intends to upgrade the radar on its Aegis-class cruisers and destroyers and upgrade an air-defense interceptor missile that will soon be deployed on its ships (the Standard SM-2 Block IV missile). The resulting system could defend an area with a radius of several tens of kilometers, possibly greater than the areas defended by the Patriot because of the more powerful Aegis radar and the larger size of the SM-2 Block IV missile. Provided that the program is fully funded, the Navy plans to deploy its point defense system by 1999, a year after the Army plans to deploy the Patriot PAC-3 system.

Because the Aegis point defense would be deployed on ships and have a relatively short range, it could only defend areas near the coast. For example, it could defend ports or protect Marines during an amphibious assault. Coverage would be reduced if an adversary had antiship cruise missiles that forced the Aegis ship to remain at some distance from the coast. Coverage would be expanded if the ship could be located between the launch site of the attacking missile and the target areas that the ship was defending.

Using the Aegis system to defend against theater ballistic missiles could degrade somewhat the ability of the system to defend against other threats, such as low-flying cruise missiles. Performing its TMD mission could force the Aegis radar to devote less time to searching for those other hazards, although some BMDO officials believe that is not a serious concern.

Perhaps the biggest advantage of the Navy system is that it could be deployed without access to airfields. It might therefore be deployed in a theater of operations sooner than an Army system, which could not be moved until secure airfields were available.

The Marines' System. To protect its forces from short-range ballistic missiles in the near term, the Marine Corps is upgrading its Hawk air-defense system and supporting radar. It also plans to improve the missile's warhead and fuze. Upgraded Hawks will be deployed in the mid-1990s.

Area Defenses

By attacking missiles before they reenter the earth's atmosphere, area (or upper-tier) defenses are designed to protect a larger area than point defenses. By first attempting to intercept missiles far away from their intended targets, a theater defense would in some cases be able to launch a second interceptor at missiles that survived the first salvo. Unlike point defenses, which can defend against aircraft and cruise missiles, area defenses are typically designed to protect exclusively against ballistic missiles.

Area defenses are intended to be integrated with point defenses to create a layered defense. In a layered defense, area defenses would have the first chance to intercept incoming missiles outside the earth's atmosphere. Point defenses deployed around critical targets could attack missiles that evaded the area systems. Deploying layered defenses would increase effectiveness but would also add to costs.

The Army's System. To protect wide areas against theater missile attack, the Army is developing the Theater High Altitude Area Defense (THAAD). This system will be able to intercept missiles at far greater ranges than the Patriot and therefore will have the chance for another shot at many of the missiles that survive the first attempt at interception. THAAD will be an entirely new system. It will require developing a new interceptor missile, seeker, launcher, radar (called the TMD-GBR, for Ground-Based Radar), fire-control system, and command and control software.

THAAD reportedly will be able to defend an area with a radius of a few hundred kilometers. It will be able to intercept incoming ballistic missiles at higher altitudes and farther away than the Patriot and would intercept missiles both inside and outside the atmosphere.

According to briefings given to the Congress this past spring, the Army plans to deploy THAAD beginning shortly after 2001. However, it expects to be able to deploy a prototype THAAD battery by the end of 1996 that could be used in a conflict if necessary. Because it would take advantage of state-of-the-art technologies, a THAAD battalion (with 288 missiles) should be smaller (that is, take up less space) than a Patriot battalion (with 192 missiles), according to briefings by BMDO officials to the Congress in April 1993. The Army could therefore transport THAAD with one-half to one-third of the aircraft sorties required for a Patriot battery.

The Navy's System. The Navy is in the initial stages of developing its own system for area defense. Rather than developing a new radar system, the

Navy will significantly upgrade the existing Aegis radar that is already installed aboard many cruisers and destroyers.

For its interceptor missile, the Navy plans to pursue one of three options: deploy a version of THAAD, probably modified with an additional rocket booster to extend its range; create an advanced version of the Navy's existing Standard Missile that incorporates technology from another missile defense project (the Lightweight Exoatmospheric Projectile, or LEAP, program); or develop an entirely new missile, possibly using new interceptor technologies. All three missiles would fit into the existing Aegis vertical launch system, which is longer than the THAAD launcher and therefore has room to extend the length (and consequently the range) of the interceptor.

The Navy could begin to deploy its system for area defense by 2005, a year or two after THAAD, provided that it receives full funding. That date is a rough estimate, however, because the program is still in the early stages of development. A deployable prototype could be available around 2000. The biggest advantage of this sea-based system is that it would not need to rely on the availability of secure airfields to be transported to the theater. Thus, it could be deployed more quickly than THAAD, provided that ships were nearby when the crisis erupted.

In recent statements, several Navy officials have indicated that the Navy's area defense may be able to defend a larger area than the Army's THAAD system. Those statements appear to be based primarily on the potential of the Aegis launcher to carry longer missiles with greater range than the missiles in the THAAD system.

The effective range of the Navy and Army systems, however, depends in part on the information available from external sensors such as the Brilliant Eyes system (see the discussion below) about the location, speed, and trajectory of incoming ballistic missiles--so-called cuing information.

Range also depends critically on the nature of the enemy attack. In some situations, Navy area defenses may "waste" a portion of their coverage over the sea because the territory they are defending is between the ship and the attacker. For example, if the ship was in the Mediterranean defending Israel against an attack from Northwestern Iraq, only about half of the area that the ship could defend would be over Israel; the rest would be over the sea. The wasted coverage could be larger if antiship missiles or mines forced the ship to remain well away from land. In contrast, a land-based system could be moved inland so that it could defend the area both in front of and behind the defense.

In other cases, however, ships might be deployed between the missile launcher and its target--for example, if the ships were located in the Mediterranean and were defending Europe against missiles launched from North Africa or the Middle East. In that situation, ship-based systems may have a significantly greater effective range than a ground-based system that could not be placed to its best advantage.

The nature of the enemy attack influences the relative effectiveness of the Army and Navy systems in other ways. If the Navy adopts the LEAP/Standard Missile option, its system could have a capability outside the atmosphere only, whereas the Army's THAAD system could also destroy targets within the upper atmosphere. As a result, although the Navy system might be able to intercept missiles farther away, it would have only limited capability against missiles with ranges short enough (less than 500 km) to fly within the atmosphere. Its capability would also be limited against those longer-range missiles that were intentionally flown on "depressed" trajectories that permitted them to remain within the atmosphere.

Differences between the Army and Navy systems could also shift as development proceeds. The projected extra range of the Navy system, and hence its potential advantage over the Army system, may diminish as the program matures. Conversely, if the Navy's technology proves superior, the Army may also incorporate it into the THAAD program.

Israel's Arrow System. The United States is providing financial and technical support to Israel to develop the Arrow area defense interceptor, which is designed to protect Israeli population centers against theater ballistic missiles. The program, officially a technology demonstration effort, is now entering its second phase, during which a smaller Arrow-2 missile will be developed. Israel hopes to deploy a defense based on Arrow by the mid-1990s. U.S. defense officials have not indicated that they have plans to purchase Arrow missiles from Israel; nevertheless, they have suggested that U.S. area defense programs will benefit from the technology developed in the Arrow program.

Air Force Systems

The Air Force is also exploring a system to defend against ballistic missiles during the early phase of their flight (called the boost phase), when their rocket motors are still burning. Such a system could provide yet another element within a layered defense. In addition, along with BMDO, the Air Force is developing sensors that could assist area defense systems in pinpointing their targets.

Boost-Phase Defense. The idea behind boost-phase defense is appealing: intercept the missile while its rocket motor is still burning (and therefore easy to detect) and before it has a chance to release multiple warheads. This concept was first explored in the context of defenses against long-range ballistic missiles. Unfortunately, boost-phase interceptors are difficult to situate where they will be needed because it is hard to know with certainty either the time or location that the enemy will choose to launch its missiles.

The best-known candidate for boost-phase interceptors is Brilliant Pebbles, small orbiting satellites that would carry an interceptor on board. The Clinton Administration has proposed reducing the pace of this program, however, so that it would become a program to develop technology for possible use in the future.

The Air Force is exploring several other concepts for boost-phase interception, including small interceptors based on unmanned aircraft (the so-called RAPTOR/Talon program), interceptors carried by aircraft, and a powerful laser carried by aircraft.

Space-Based Sensors. In conjunction with BMDO, the Air Force is developing an advanced space-based system of sensors called Brilliant Eyes. Those satellites reportedly will be able to track ballistic missiles in space and provide accurate data about their trajectories to ground-based defenses. That information could increase the effectiveness of the ground-based defenses and the area they can defend by providing early warning about the existence of any incoming missiles and estimates of where those missiles are likely to land.

In addition, Brilliant Eyes could provide data about the positions of missiles that would be accurate enough to permit a ground-based defense to launch an interceptor in the proper direction without first having seen an incoming missile with its own radar. Such a system is crucial to defending wide areas and providing the multiple opportunities for interception that supporters claim for upper-tier systems like THAAD and Navy area defenses.

The technological challenges in developing such a system are numerous. Among them is developing an effective system to collect information from several satellites, process it to extract the missile's trajectory, and send it to the appropriate defenses quickly enough to be useful. A complete Brilliant Eyes system would consist of 20 to 40 satellites in orbit above the earth. Such a system would cost roughly $5 billion (in 1994 dollars) to develop and deploy, according to BMDO.

DOES OVERLAP EXIST BETWEEN THE MANY TMD SYSTEMS?

Clearly, overlap exists among the capabilities of these various programs to defend against theater ballistic missiles. Boost-phase, area, and point defense systems are all designed to counter some of the same types of missiles. Consequently, the various types of defenses being developed overlap each other to some extent. Some overlap is also evident among the services: the Army, the Navy, and the Marines are all developing systems for point defenses, and the Army and Navy are each developing systems for area defense.

Advantages of Overlap

Overlap offers some advantages. Joining the boost-phase, area, and point defenses creates a layered defense that would be more effective than any single type of system. The degree of effectiveness that the United States requires may depend on the types of targets it is likely to be defending (its troops or population centers of its allies) and the types of threats it is defending against (the range of the missiles and the types of warheads that they carry). For example, greater effectiveness may be desirable when protecting allied civilian populations or when defending against missiles that carry nuclear, biological, or chemical warheads.

Having more than one military service develop a system also offers some advantages. At least to some extent, the different systems that the services are developing could be complementary, providing more flexibility than a single system to respond to a wide range of scenarios. Navy systems, for example, would be on ships that could be deployed in the vicinity of a looming crisis, permitting them to be available quickly and possibly acting as a deterrent. In addition, Navy systems would not have to rely on the availability of defended airfields, a necessity if Army systems are to be transported to the battle area quickly. Nor would the Navy systems need to secure basing rights to be used. Conversely, Army systems, once deployed, could protect troops and populations that are located away from coastal regions.

If the services built their own systems, they could design the defenses to best meet their own particular needs and operational constraints. Having more than one service develop a system can also lead to competitive approaches to solving difficult technical problems. Such competition may lead to a more capable weapon system. The Army and Navy are also pursuing different approaches that could vary in their risk of failure and degree of

effectiveness. Those variations can provide a hedge against unexpected technical problems that might delay one system or even make it unaffordable.

Disadvantages of Overlap

Although overlap has advantages, it is expensive. The total costs for the different TMD systems could be significant; developing entirely different systems to fulfill the same basic need will increase costs by billions of dollars. Indeed, BMDO Acting Director O'Neill, testifying before the Senate Defense Subcommittee on Appropriations on May 4, 1993, stated that funding all of the TMD programs mentioned in this memorandum could cost as much as $3 billion annually by the mid-1990s. Some decisionmakers may find those costs excessive in a period of budgetary austerity.

Furthermore, sufficient funds may not be available over the next several years to finance all of the TMD programs now under development. The Administration is currently reviewing its ballistic missile defense programs. Although no decisions have been announced, the range of funding through 1999 that the Administration is reportedly considering for BMDO would make it difficult to develop all of the ongoing TMD programs and still maintain a program to deploy national missile defenses early in the next decade. The cost section beginning on page 16 discusses issues of affordability in more detail.

Possible Options for the Congress

The Administration and the Congress must weigh the advantages of overlap against its costs. If a decision is made to reduce overlap in order to hold down costs, then the Congress could consider eliminating one type of defense (boost phase, area, or point). As for overlap among the services in point and area defenses, the Congress could elect one of three broad courses with regard to the Army and Navy systems:

- Develop both the Navy and the Army systems for point and area defenses.
- Develop either the Army systems or the Navy systems but not both.
- Develop both land- and sea-based area defenses, but base them on a common missile (and develop the Army and perhaps the Navy point defense as well).

The first approach would be the most expensive but could result in systems that offered the most flexible response to a wide variety of possible wartime scenarios. The Bush Administration apparently was planning to follow this course. The second approach would be the least costly but also perhaps the least flexible.

The third approach would maintain much of the flexibility of the first but could reduce some of the costs. This approach raises other issues, however, that center around the operational requirements of each service. For example, missiles for the Navy system would have to be compatible with its vertical launch system. By contrast, the Army's missiles and launchers must fit within a C-141 transport aircraft and be transported easily on a truck. In addition, the Navy has stringent safety requirements that forbid liquid propellants of the type that the Army is planning to use in THAAD. These problems conceivably could be resolved. But this third approach would require careful planning and coordination to ensure that the operational requirements of the two services were considered in the design of the system.

WHAT ABM COMPLIANCE ISSUES DO THEATER DEFENSES RAISE?

In addition to budgetary concerns, developing theater missile defenses could require renegotiation of, withdrawal from, or abrogation of the ABM treaty. Depending on the extent of the changes required, negotiations could take place in the commission established by the treaty to discuss compliance issues or through formal amendments to the treaty. Developing, testing, and deploying the more advanced systems of area defenses such as the Army's THAAD would raise compliance issues involving the treaty. Space-based sensors like Brilliant Eyes could also raise such issues.

Issues Raised by Area Defenses

The ABM treaty applies only to defenses against "strategic" ballistic missiles--missiles with ranges long enough to threaten U.S. territory. But the treaty does not supply a definition of strategic missiles. Because systems like the Army's THAAD may have some capability against missiles (particularly submarine-launched ballistic missiles) that were in use and considered "strategic" when the ABM treaty was signed in 1972, testing and deploying those types of defenses could conflict with treaty prohibitions.

Furthermore, according to some Navy officials, the Aegis area defense deployed on ships operating off the coasts of the United States could defend

much of the country against an attack by a small number of intercontinental ballistic missiles. Such a defense would most likely violate the terms of the ABM treaty, which prohibits testing and deploying defenses that are able to defend large portions of national territory. The ability of the Navy's proposed system of theater defenses to provide some defense against longer-range missiles also highlights the problem of delineating the difference between strategic and theater defenses.

ABM issues of this sort have caused concern in the past. Throughout the 1980s, the United States raised questions about whether the former Soviet Union's SA-10 and SA-12 air-defense missiles were in compliance with the treaty. Those systems are point defenses like the Patriot. Because the THAAD and Navy area defenses would be much more capable than the Russian systems, those issues are likely to surface again.

The United States might address potential ABM conflicts in negotiations with Russia. The two countries could clearly distinguish between strategic and nonstrategic missiles or develop strict controls on deployments within national territories. The current environment may make it easier to resolve this issue than in the past: the nuclear arms race has abated, and Russia faces a theater ballistic missile problem on its borders.

However it is handled, ABM treaty compliance must be addressed before THAAD-like systems can be tested and deployed. Testifying before the Senate Defense Appropriations Subcommittee on May 4, 1993, the acting director of BMDO stated that under the current schedule, THAAD would raise compliance issues by late 1995.

Issues Raised by Brilliant Eyes

Testing and deploying Brilliant Eyes could also raise compliance issues. Many analysts agree that area theater defenses raise compliance issues with the ABM treaty, but there is considerable debate about whether the treaty forbids space-based sensors like Brilliant Eyes. Disagreement revolves around whether the sensors would substitute for an ABM radar. The treaty clearly forbids U.S. ABM radars other than those deployed at Grand Forks, North Dakota. Yet the extent to which Brilliant Eyes acts as a surrogate radar is unclear and would depend in part on the capability of the system. To explain this debate fully would require a foray into treaty issues that are beyond the scope of this memorandum. Regardless of how the debate is resolved, however, the United States might want to seek an agreement with the Russians about the legality of Brilliant Eyes before developing, testing, and deploying them in order to preserve the current state of friendly relations.

ARE BUDGETARY PROBLEMS LIKELY THROUGH 1999?

It is not yet possible to estimate with confidence the size of TMD budgets through 1999 because the Administration has not announced which systems it will continue to support, when they will be deployed, and the amount that it plans to spend on them beyond 1994. But BMDO officials have indicated a range of funding that is likely to emerge from its review of ballistic missile defense programs. That range applies to the total BMDO budget, which includes many other elements besides TMD (efforts to develop national missile defenses, for instance); a subtotal for TMD is not available. BMDO officials have also indicated that what they term a "core" program of three theater systems--Patriot PAC-3, THAAD, and Navy lower-tier defenses--is included in all of the alternative missile defense programs being considered by the Department of Defense in its ongoing review of defense programs, known as the Bottom-Up Review.

To illustrate the possible extent of budgetary problems through 1999, CBO calculated the cost of one approach to developing ballistic missile defenses, using assumptions specified by the requestor of this analysis. For 1994, the illustrative approach assumes the Administration's level of requested funding. Beyond 1994, the calculation assumes that the core TMD programs--the Patriot PAC-3, THAAD, and the Navy lower-tier defenses--receive enough funding to be deployed according to the schedule described by BMDO officials in briefings to the Congress in April 1993. The calculation assumes funding as well for the battle management systems that allow these core systems to function together effectively. Funding for all other TMD programs is eliminated; funding for non-TMD defenses through 1999 is assumed to remain at the levels requested by the Administration for 1994, adjusted to keep pace with inflation. The next two sections describe those assumptions in more detail.

TMD Programs

Under the illustrative case, funding for two of the three core programs--Patriot PAC-3 and THAAD--would match the levels discussed in briefings presented to the Congress in April 1993. Those levels of funding, which are similar to what the Bush Administration proposed, should allow the United States to begin deploying the Patriot PAC-3 by 1998 and THAAD shortly after 2001. Funding levels for the third core system--the Navy's lower-tier defenses--are not available. But the April briefings suggested the level of funding that would be available for all Navy TMD programs, which include both lower-tier and upper-tier defenses. The illustrative approach assumes

that beyond 1994, the Navy allots 50 percent of its TMD funds to lower-tier defenses.

The illustrative approach also assumes that BMDO spends an additional $300 million per year, adjusted for inflation, to develop the battle management systems that tie theater defenses together. Those funds would pay for support activities as well and for developing alternative technologies that provide a hedge in case the chosen technologies encounter technical problems.

Finally, beyond 1994, the illustrative approach assumes that all funding to develop other TMD programs is eliminated. Those systems include the Army's Corps SAM, the Navy's upper-tier defenses, the Air Force's Brilliant Eyes space-based sensors and boost-phase interceptors, and the Arrow program.

The Administration requested about $1.8 billion in 1994 for theater missile defense programs (see Table 2). CBO estimates that annual funding requirements could reach $2.1 billion through 1999 under the illustrative approach.

Non-TMD Programs

The illustrative case assumes that, beyond 1994, funding for all non-TMD programs is kept constant at the levels requested by the Clinton Administration in 1994, after adjusting for inflation. Non-TMD programs include national missile defenses, follow-on research on advanced defensive systems, and general research and support. As shown in Table 2, the Administration requested about $2 billion for those efforts in 1994. CBO estimates that, with inflation, they could cost slightly more than $2 billion a year by the end of this decade.

Under the illustrative approach, the annual funding required for all ballistic missile defenses, including TMD and non-TMD programs, would rise from the Administration's requested level of $3.8 billion in 1994 to $4.0 billion in 1999. Total funding during those six years would equal about $24 billion.

Potential Funding Problems

The Clinton Administration is considering a variety of funding options for ballistic missile defenses in its Bottom-Up Review. The $24 billion required to support the program assumed in the illustrative approach through 1999

would equal or exceed all of the funding paths that the Administration is apparently considering--except those that would grow in real terms. For example, the illustrative approach would be affordable under two of the three funding paths included in one set of alternatives being considered by the Administration (see Table 3).

The Administration could not fully fund the illustrative approach if total funding for ballistic missile defenses were held constant at the 1994 requested level of $3.8 billion through 1999 (Alternative 1 in Table 3). In that case,

TABLE 2. FUNDING PROFILE FOR ILLUSTRATIVE MISSILE DEFENSE PROGRAMS
(In billions of dollars of budget authority)

Description	1994 Budget Request	1995	1996	1997	1998	1999	Total, 1994-1999
Theater Missile Defenses							
Core Package							
Patriot[a]	0.4	0.8	0.6	0.5	0.4	0.3	3.0
THAAD/GBR	0.7	0.6	0.6	0.8	0.9	0.8	4.4
Navy Lower Tier[b]	0.2	0.3	0.4	0.4	0.5	0.5	2.1
Battle Management and Support	0.3	0.3	0.3	0.3	0.3	0.3	1.9
Subtotal, Core Package	1.5	2.0	1.9	2.0	2.1	1.9	11.4
Other TMD Programs	0.3	0	0	0	0	0	0.3
Subtotal, TMD	1.8	2.0	1.9	2.0	2.1	1.9	11.7
Non-TMD Programs							
National Missile Defenses	1.2	1.2	1.2	1.3	1.3	1.3	7.6
Follow-On Technologies	0.4	0.4	0.4	0.4	0.4	0.4	2.5
Research and Support	0.4	0.4	0.4	0.4	0.4	0.4	2.3
Subtotal, Non-TMD	2.0	2.0	2.0	2.1	2.1	2.2	12.3
Total	3.8	4.0	3.9	4.1	4.2	4.0	24.0

SOURCE: Congressional Budget Office based on Department of Defense data and assumptions supplied by the requestor of this analysis.

NOTE: THAAD/GBR = Theater High Altitude Area Defense and its Ground-Based Radar; TMD = theater missile defense.

a. This funding also supports the Extended Range Interceptor program as part of the Patriot Anti-Tactical Capability (PAC-3) program.

b. The estimate assumes that lower-tier defenses would receive 50 percent of all Navy TMD funding beyond 1994.

funding would amount to $22.6 billion over the 1994-1999 period--$1.4 billion less than that required by the illustrative approach. The required funding for the illustrative approach through 1999 could be provided, however, by an alternative that would allow BMDO budgets to grow just enough to offset inflation (a so-called real freeze); however, the size of the annual budgets through that period would be slightly different from those assumed in the illustrative program. Such a course (Alternative 2) would result in an annual budget of roughly $4.2 billion by 1999 and provide $23.9 billion over the next six years.

Only a program that allowed some real growth in funding beyond 1994 would provide enough money to develop TMD systems other than the three core programs. One approach reportedly being considered by the Pentagon would slowly increase annual missile defense budgets until they reached $5 billion in 1999 (see Alternative 3). That alternative would provide $27.2 billion in the 1994-1999 period--about $3 billion more than the funding required by the illustrative approach.

It is possible that the illustrative program overstates funding requirements and thus the extent of the budgetary problems the program poses. The Administration could, for example, decide not to deploy all three of the core TMD programs, or it could make other reductions in ballistic missile programs.

TABLE 3. POSSIBLE LEVELS OF FUNDING FOR BMDO RESULTING FROM DOD'S BOTTOM-UP REVIEW
(In billions of dollars of budget authority)

Alternative	1994	1995	1996	1997	1998	1999	Total, 1994-1999
1. Nominal Freeze	3.8	3.8	3.8	3.8	3.8	3.8	22.6
2. Real Freeze	3.8	3.9	3.9	4.0	4.1	4.2	23.9
3. Moderate Growth	3.8	4.3	4.5	4.8	4.9	5.0	27.2

SOURCE: Based on "Terms of Reference" document for the Task Force on Missile Defense Programs for the Pentagon's Bottom-Up Review and statements by BMDO officials. See, for example, Andrew Weinschenk and Joseph Lovece, "Options Papers Give Clues to Pentagon's Missile Defense Review," *Defense Week*, May 3, 1993, p. 10; and "Bottom-Up Review Weighing Three Alternatives For SDI Funding," *Defense Daily*, April 30, 1993, p. 167.

NOTE: BMDO = Ballistic Missile Defense Organization; DoD = Department of Defense.

Yet it is more likely that the illustrative approach understates the funding needed for ballistic missile defenses. The Administration could decide to deploy other TMD systems--such as Brilliant Eyes, Corps SAM, or some version of a boost-phase interceptor based on aircraft--beyond the core program assumed in the illustrative case, which would certainly increase costs. In addition, technical problems could increase the cost of developing and deploying the three planned TMD systems. Furthermore, the funding discussed above for the illustrative case and for the alternatives shown in Table 3 excludes the cost of operating and supporting the defenses once they have been deployed. Estimates of those costs have not yet been released by the Administration.

Perhaps more important, the illustrative approach assumes no real growth in funding for national missile defenses. With such a flat funding profile, there is little likelihood that enough funds would be available to permit deployment of national defenses by the middle of the next decade, a goal reportedly being considered by the Pentagon in its review of ballistic missile defenses.