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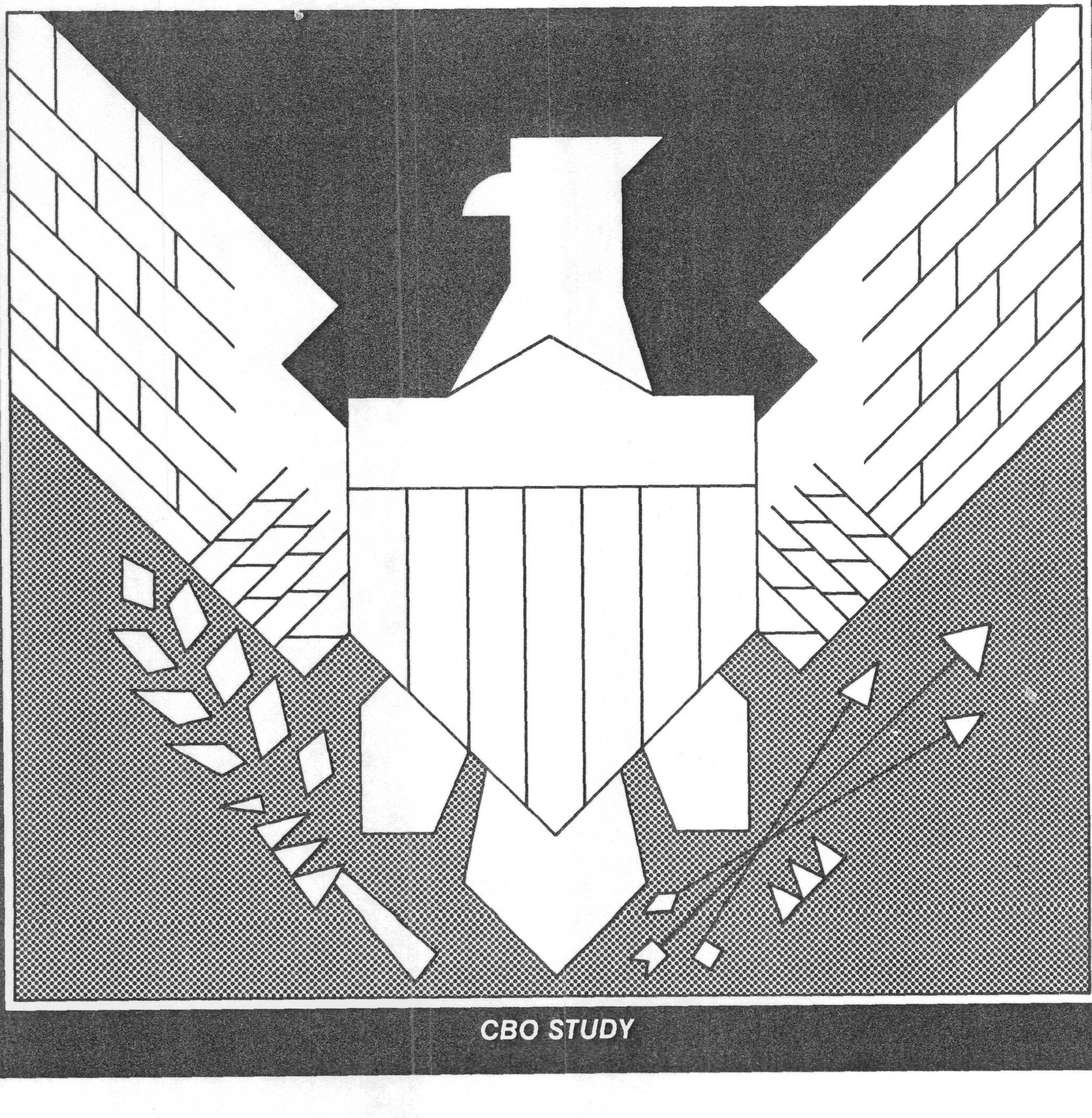
Army Air Defense for Forward Areas: Strategies and Costs



CBO STUDY

ARMY AIR DEFENSE FOR FORWARD AREAS:

STRATEGIES AND COSTS

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NOTES

Unless otherwise indicated, all years in this report are fiscal years.

All dollar amounts are in 1987 dollars unless otherwise noted.

PREFACE

The Army's forward air defense program was thrown into disarray when the Secretary of Defense cancelled the plagued DIVAD anti-aircraft gun in August 1985. Since then, the Army has been in the process of defining a new air defense program to present to the Congress. The program that the Army ultimately chooses will have significant implications for funding requirements and conventional force survivability not only during the next five years, but for years thereafter. Air defense programs will compete for funds with other high priority programs at a time when growth in defense spending is being slowed significantly. This analysis by the Congressional Budget Office (CBO) presents alternatives for improving the Army's air defense capability, particularly against attack helicopters, and compares the costs and capabilities of the various options. The study was requested by the House Committee on Armed Services. In keeping with CBO's mandate to provide objective analysis, the study offers no recommendations.

Frances M. Lussier of CBO's National Security Division prepared the study under the general supervision of Robert F. Hale and John D. Mayer, Jr. William P. Myers, Diane Griffith, and Michael J. McCord of CBO's Budget Analysis Division assisted with the cost analysis. The author gratefully acknowledges the contributions of Elizabeth S. Sterman and Martin Regalia. Patricia H. Johnston edited the manuscript and Rebecca J. Kees prepared it for publication.

Rudolph G. Penner
Director

June 1986

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SUMMARY

The Army's plan to modernize its air defense was set back significantly when tests demonstrated that the DIVAD gun could not adequately perform its air defense mission, and Defense Secretary Caspar W. Weinberger subsequently cancelled the program in August 1985. The 40mm DIVAD anti-aircraft gun was intended to replace the 1960s vintage Vulcan 20mm anti-aircraft gun, which currently provides air defense for the Army's tanks and fighting vehicles--the "forward maneuver elements" of the Army's "heavy" divisions. Vulcan, however, offers little capability against enemy aircraft, especially helicopters that can stand off at long ranges while attacking tanks and other armored vehicles. The loss of time that was invested in the DIVAD program has created a sense of urgency within the Army for devising a new air defense program to provide protection for its forward maneuver elements. As a result, the Army is considering a number of approaches to improve its forward air defense that cover a wide range of capabilities and costs.

The Army and the Department of Defense are currently attempting to decide on a particular approach as they formulate a comprehensive air defense plan to be presented to the Congress next year. The Congress might wish to influence various aspects of the overall air defense plan as it reviews the fiscal year 1987 budget request. Although the funds requested for air defense in the 1987 budget provide mainly for development of a variety of systems and do not reflect any specific configuration, the Congress will eventually have the opportunity to review the Army's more detailed plan for its air defense, probably some time next year.

THE AIR DEFENSE MISSION AND U.S. CAPABILITIES

Groups of armored vehicles, such as tanks and armored personnel carriers, form the front line of defense against any potential Warsaw Pact invasion of Central Europe. Should the Warsaw Pact invade, these groups of fighting vehicles, known as the maneuver elements, would come under fire from enemy aircraft as well as enemy ground forces. The airborne threat would come both from fighter bombers strafing and delivering bombs and from attack helicopters launching long-range antitank missiles. Because modern helicopters equipped for the antiarmor mission can attack targets from long range and low altitudes--from five to six kilometers (km) away and as low as 20 meters--they have a definite tactical advantage over fighter bombers when performing antiarmor missions. For this reason, the emphasis for providing air defense for front line armored forces has shifted over the last 20 years from countering fighter bombers to defeating standoff helicopters, although the need to counter fixed-wing aircraft still exists.

The mission of overcoming enemy helicopters attacking U.S. armored vehicles would fall mainly on ground-based air defense systems. Although the United States has traditionally relied on both ground-based air defense systems and interceptor aircraft to protect U.S. troops on the battlefield, high-speed fighter aircraft are not very well-suited for the antihelicopter role. Attack helicopters fly very close to the ground and hover almost motionless when seeking or firing upon targets. These tactics make them difficult to locate from the higher altitudes used by fighter aircraft and inappropriate targets for typical air-to-air missiles carried on fighter aircraft. Consequently, fighter aircraft are not likely to contribute significantly to the defense against standoff helicopters.

Requirements for a Successful Air Defense

Sufficient range and numbers are the primary requirements for a ground-based air defense capable of defeating modern attack helicopters armed with long-range antitank missiles. Individual air defense weapons, usually located up to a kilometer behind the most forward troops to ensure their own survivability, must be able to destroy enemy helicopters attacking armored assets from ranges of five to six km. Thus, these air defense systems should have a maximum range of at least seven to eight kilometers.

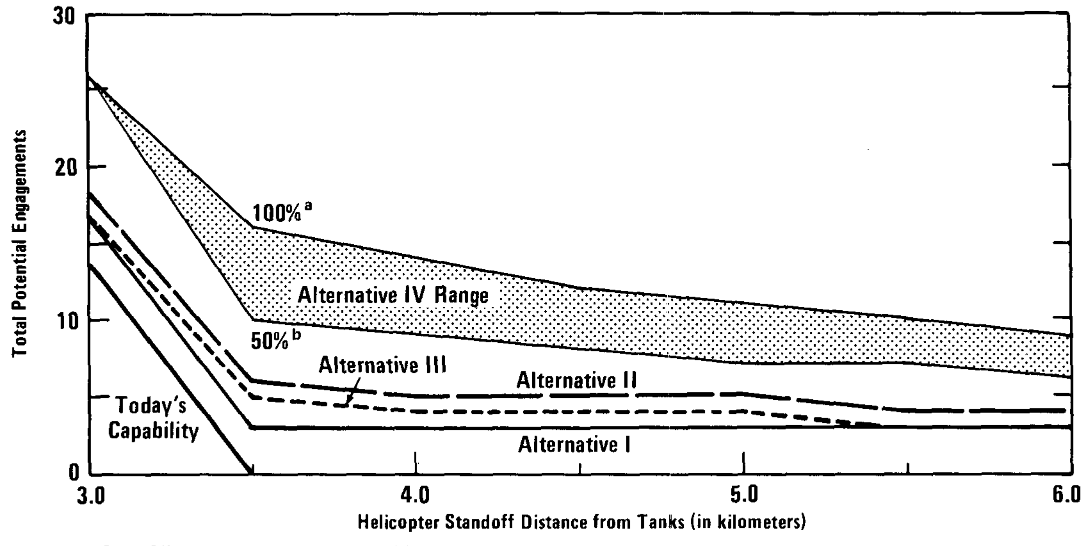
Large numbers of air defense weapons would be needed to protect armored assets from the expected heavy air attack by Warsaw Pact forces in the European theater. Individual air defense systems have a low probability of seeing helicopters at the long ranges and low altitudes from which they could attack. This is especially true in Central Europe where hilly and wooded terrain offers ample cover for enemy helicopters. Thus, many dispersed air defense systems--up to 80 per division--might be needed to provide a reasonable assurance that each attacking helicopter could be engaged. In order to field air defenses in such large numbers, individual systems would need to be relatively inexpensive.

Other characteristics would also be needed in an effective air defense system designed for use in Europe. The air defense weapon should be able to operate at night. It must be able to react quickly to helicopters that pop up to deliver their weapons. Finally, it must be as mobile and as well-protected as the armored systems it is defending.

TODAY'S CAPABILITIES

Today's U.S. air defenses do not have sufficient range, nor are they deployed in sufficiently large numbers, to provide a credible defense against enemy attack helicopters. One measurement of the Army's air defense capability against standoff helicopters is the total number of systems within a battalion-sized task force of 40 to 60 armored vehicles that could potentially engage an enemy helicopter attacking those armored vehicles. This measure of "potential engagements" takes into account the relative positioning of the various armored and air defense systems within the task force, their effective range, and their likelihood of being able to see an attacking helicopter in hilly European terrain. The number of potential engagements is, of course, a simplified measure that ignores many of the complexities of battle, but it does provide a rough guide for comparing the capability of forces containing differing combinations of systems (see Summary Figure).

Summary Figure.
Comparison of Potential Engagements of Hovering Helicopters with Today's Weapons and Those Included in Alternatives I, II, III, and IV



SOURCE: Congressional Budget Office.
NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.
[a] All weapons engage helicopters.
[b] One-half of tanks and fighting vehicles engage helicopters.

None of today's weapons have the range needed to engage enemy helicopters where they are most likely to operate. A battalion-sized task force composed of the Army's most capable weapons (M1 tanks; Bradley Fighting Vehicles; and the Chaparral, Vulcan, and Stinger air defense weapons) would have many weapons capable of engaging helicopters at ranges up to three kilometers. Indeed, a typical task force would have the potential for 14 engagements at three kilometers. Much beyond that range, however, today's force could not engage enemy helicopters attacking U.S. armored assets.

PROGRAMS FOR IMPROVING FORWARD AIR DEFENSE

In the wake of the demise of DIVAD, the Army has hastened to beef up its battlefield air defenses. So far, the Army has developed a general plan for improving its air defenses. Many specifics are still to be determined, however. The Congressional Budget Office has examined this plan and four alternatives that the Congress could consider.

Army Plans

Recognizing the need to remedy the sparcity of air defenses against enemy standoff helicopters, the Army has earmarked funds and begun a five-part program to improve its air defense, and in particular its antihelicopter capability. (See the appendix for a detailed discussion of these plans.) In the President's budget for fiscal year 1987, the Army allocated $1.5 billion (in fiscal year 1987 dollars) over the fiscal years 1987-1991 period for the two programs most closely related to forward area air defense. This represents about 1.5 percent of the funds included in the President's budget for total Army procurement for the same five-year period (see Summary Table 1).

One part of the Army's improvement plan for air defense would arm 720 of its scout helicopters with air-to-air missiles. The costs of this program over five years would be $163 million. The second part, the so-called "Air Defense System, Heavy" (ADS, H) program, is also designed to improve air defense for the Army's maneuver elements. The purpose of the ADS, H program is to field, as soon as possible, a system to perform the mission for which the DIVAD was intended--that is, successfully destroy hovering enemy helicopters at their operating ranges. The Army has allocated almost $1.4 billion over the 1987-1991 period for this program. The Army has not, however, decided what specific system to procure to fulfill the ADS,H role, or how many of these systems it wishes to buy. It is, therefore, impossible to determine now whether the funds the Army has allocated for this program could provide enough capable systems to protect the forward maneuver elements.

CBO Alternatives

CBO examined four approaches to improve the Army's ability to defend its forward area assets from air attack. All of the approaches include adding several types of weapons to the Army's current inventory (see Summary Tables 2 and 3). Only those systems that could be available for fielding in five years were included in the alternatives, since the Army appears to have an urgent need to improve its air defenses. The various alternatives were

SUMMARY TABLE 1. FUNDS PROJECTED BY THE ARMY FOR AIR DEFENSE AND TOTAL ARMY PROCUREMENT (By fiscal year, in millions of fiscal year 1987 dollars of budget authority)

Program	1987	1988	1989	1990	1991	Total a/ 1987-1991
Helicopter Air-to-Air Capability	29	42	48	45	0	163
Air Defense System, Heavy	9	63	298	516	486	1,372
Subtotal, Air Defense	38	105	346	561	486	1,535
Total Army Procurement	18,600	20,400	20,300	20,600	21,500	101,400
Percent of Total Army Procurement Devoted to Air Defense	0.2	0.5	1.7	2.7	2.3	1.5

SOURCE: Compiled by the Congressional Budget Office from Army data.

a. Numbers may not add to totals because of rounding.

SUMMARY TABLE 2. PERFORMANCE AND COST OF FOUR AIR DEFENSE ALTERNATIVES

Type	Sophistication	Number per Division	Potential Engagements at Five Kilometers a/	Total Investment Cost (In bilions of 1987 dollars)
Today's Force				
Vulcan	Low	24	0	Not Applicable
Stinger	Moderate	60		
Alternative I--Enhance Current Systems				
PIVADS b/	Low	24	3	0.4
Stinger	Moderate	60		
Scout helicopters c/	Moderate	44		
Alternative II--Deploy Many Simple Systems				
Simple Missile system	Moderate	72	5	3.2
New alerting radar	Moderate	8		
Scout helicopters c/	Moderate	44		
Alternative III--Deploy a Few Sophisticated				
Radar missile systems	High	36	4	4.3
Scout helicopters c/	Moderate	44		
Alternative IV--Provide Tanks and Fighting Vehicles with Air Defense Capability				
Tanks d/	Low	290-350	7-11	3.9
BFV and ITV e/	Low	376-430		
New alerting radar	Moderate	8		
Stinger replacement	Moderate	60		
Scout helicopters c/	Moderate	44		

SOURCE: Congressional Budget Office.

a. By a battalion-sized task force.
b. PIVADS = Product Improved Vulcan Air Defense System.
c. With air-to-air missiles.
d. With antihelicopter round.
e. With replacement missile for TOW 2.
BFV = Bradley Fighting Vehicle;
ITV = Improved TOW Vehicle.

SUMMARY TABLE 3. COST OF ARMY'S PLAN AND CBO ALTERNATIVES
(By fiscal year, in millions of 1987 dollars of budget authority)

	1987	1988	1989	1990	1991	Total 1987-1991	To Complete	Total Cost
Army's Plan a/	38	105	346	561	486	1,535	b/	b/
Alternative I	33	104	117	119	58	430	0	430
Change from Army plan (- or +)	-5	-1	-229	-442	-428	-1,105	b/	b/
Alternative II	65	241	417	779	680	2,171	985	3,156
Change from Army plan (- or +)	+61	+136	+71	+216	+194	+836	b/	b/
Alternative III	29	419	735	1,050	989	3,221	1,055	4,276
Change from Army plan (- or +)	-9	+314	+389	+489	+503	+1,686	b/	b/
Alternative IV	198	552	860	1,002	865	3,468	480	3,948
Change from Army plan	+160	+447	+514	+431	+379	+1,930	b/	b/

SOURCE: Congressional Budget Office.
NOTE: Numbers may not add to totals because of rounding.

a. Includes the Army's program to add air-to-air missiles to 720 scout helicopters and the new Air Defense System, Heavy program--essentially a replacement for DIVAD.
b. These numbers cannot be calculated since a specific Air Defense System, Heavy weapon has not yet been selected.

compared on the basis of the improvement in air defense they could afford over today's capability--as measured in terms of total potential engagements of hovering helicopters--and their associated investment cost. The costs attributed to the various alternatives are highly speculative inasmuch as they are associated with systems not currently under procurement. The costs of the various systems were, of necessity, based on contractor estimates and surrogate systems. Despite the uncertainty associated with the costs, however, they should reasonably represent the relative costs of the alternatives and are useful for comparative purposes.

Alternative I--Enhance Two Current Systems

This alternative would provide some defense against helicopters beyond three kilometers--at a total investment cost of $430 million, $1 billion less than the cost projected in the Army's plan--by adding air-to-air missiles to the scout helicopters now included in the divisions. The Army's current plan already includes adding missile launchers to its scout helicopters. The missile intended for the air-to-air role, however, is the infrared guided Stinger currently in the Army's inventory. This missile, or any missile relying on infrared guidance, would have marginal utility against hovering helicopters. Therefore, this alternative, in addition to providing scout helicopters with missile launchers, would equip the scouts with a new air-to-air missile that would be effective against hovering helicopters at ranges up to six km.

Providing the division's scout helicopters with air-to-air capability would be the most productive of any simple improvements that could be made to today's systems. All the alternatives in this report include this simple helicopter modification. Also in this alternative--but not in any of the others--Vulcan, the current anti-aircraft gun, would be upgraded and its range increased slightly, from 1,200 meters to 1,750 meters.

These improvements would add slightly to capability at short ranges and, more important, would provide a battalion task force with modest capability against enemy helicopters standing off at ranges greater than three kilometers. For example, a potential for three engagements of enemy helicopters at ranges from three and one-half to six kilometers would be obtained with this alternative. No capability exists at those ranges today (see Summary Figure).

All the key, long-range improvements provided by this alternative would, however, reside in the scout helicopters. These have other missions to perform that might detract from their ability to defend against enemy helicopters when needed. Nor would this approach do anything to replace aging systems that are currently dedicated to air defense.

Alternative II--Deploy Large Numbers of Simple Air Defense Systems

This approach would emphasize the importance of numbers by providing a large number of new, dedicated air defense systems of moderate sophistication. The 24 Vulcans in each division would be replaced by three times as many simple missile systems with effective ranges of at least seven kilometers and eight new alerting radars would be provided for each division. As in Alternative I, scout helicopters would be armed with air-to-air missiles. The total investment cost of this alternative would be $3.2 billion, of which $2.2 billion would be spent during the next five fiscal years, and about $1 billion in 1992 and later. Compared with the Army program, this alternative would require an additional $836 million during the 1987-1991 period (see Summary Table 3).

Providing each division with 72 air defense systems capable of engaging helicopters at ranges of seven kilometers could--in combination with the division's scout helicopters--provide four to six helicopter engagements at ranges between three and six kilometers. This would exceed the potential engagements provided by Alternative I and, of course, compares favorably with today's total lack of engagement capability. Furthermore, this approach would provide one ground-based and one airborne air defense system, which should complicate the ability of enemy helicopters to survive while attacking maneuver forces.

On the other hand, this alternative would not provide much improvement in capability against fighter bombers or against aircraft operating in bad weather. Such capability would require air defense systems with more sophistication.

Alternative III--Deploy Smaller Numbers of Highly Sophisticated Systems

Emphasizing individual capability rather than numbers of systems is an alternate approach to providing air defense for the Army's forward units. This option would provide 36 sophisticated, radar-equipped missile systems to each of the Army's armored and mechanized divisions. As in all the options, air-to-air missiles would be added to the scout helicopters. The total required investment cost would be almost $4.3 billion--$3.2 billion during the next five years, and $1.1 billion more after 1991. During the period from 1987 through 1991, almost $1.7 billion more would be needed than the Army has included in its two most directly related programs (see Summary Table 3).

Under this alternative, helicopter engagements would increase to three to five engagements at between three and six kilometers, whereas today's force provides none. Moreover, the air defense units in this option would have their own acquisition radars, whereas simpler systems would have to rely on alerting and cueing from the division's early warning radars and on visual or infrared methods for locating individual targets. With their own radars, systems in this option could provide air defense in all types of weather and could engage high-speed, fixed-wing aircraft at longer ranges. These improvements are not captured in the measure of helicopter engagements used in this study, but this capability could be important on the European battlefield. Indeed, the Army has often stated its need for an air defense system directed by radar.

On the other hand, the cost per weapon system of adding a radar could constrain the number that could be deployed. Indeed, although this option would be more expensive than any of the others, it would provide one fewer engagement (a 20 percent to 30 percent reduction) at ranges between three and six kilometers than would Alternative II. Furthermore, the advantages of providing air defense systems with radars might be mitigated by operational constraints such as terrain, the lesser importance of the fixed-wing threat, and the reduced ability of enemy aircraft to operate effectively in bad weather.

Alternative IV--Provide Air Defense Capability to All Forward Combat Systems

Alternative III, with its sophisticated systems--and even Alternative II, with many more simpler systems--would not offer the large numbers of potential engagements that would provide reassurance of an effective defense in the chaotic conditions expected on the battlefield. To increase the numbers of potential engagements significantly, this approach would provide each of the roughly 700 armored vehicles within a division with some air defense capability. For example, the antitank missile of the Bradley Fighting Vehicle would be replaced with one capable of longer ranges and faster speeds. This would enable all of the 300 or more Bradleys within each division to engage helicopters out to a range of seven kilometers. In addition, tanks would be equipped with some antihelicopter rounds; the scout helicopters would be given air-to-air missiles; each division would receive eight alerting and cueing radars; and the Stinger shoulder-fired anti-aircraft missiles would be replaced with a missile having greater effective range against hovering helicopters.

This approach heavily emphasizes quantity over quality since each weapon individually might not be highly effective. Nevertheless, this combination of many air defense systems could potentially provide nine to sixteen helicopter engagements per battalion task force at ranges between three and six kilometers, more than double those provided by any of the other options. If only half of the fighting vehicles were allocated to provide air defense, six to ten engagements at the same ranges would still be possible. Indeed, if only a quarter of the fighting vehicles participated in the air defense role, this alternative would still provide more total engagements than any of the other alternatives. Providing so many systems with an additional capabiity would not be cheap and could require an investment of almost $4 billion--$3.5 billion over the next five years and $500 million thereafter. Consequently, from 1987 through 1991 almost $2 billion more would be required than is currently included in the Army's plan (see Summary Table 3). Still, this alternative would provide the greatest number of potential engagements of any of the alternatives.

This approach could introduce several problems, however. Questions arise concerning the availability for air defense of systems, such as the Bradley and tanks, whose primary role is fighting other ground weapons. In addition, soldiers manning systems like the Bradley and tanks would have to be trained in both ground combat and air defense, and leaders would have to coordinate 700 or more systems capable of engaging both enemy aircraft and ground targets. These concerns, though real, should not negate the potential for self-defense that resides with the Army's current weapon systems. Indeed, the Army appears to be planning to improve the Bradley's ability to engage helicopters, although not to the extent envisioned in this alternative.

THE MAIN ISSUE: QUANTITY VERSUS QUALITY

The alternatives in this study are largely homogenous strategies which could, in actuality, be combined. The options were chosen, in part, to dramatize the trade off between the quality and quantity of air defense systems. In terms of increased air defense capability, the optimal solution would be to field large numbers of highly capable air defense systems. This is not a practical choice, however, because of cost. Thus, defense planners may have to choose between quality and quantity.

CHAPTER I

INTRODUCTION AND BACKGROUND

The U.S. Army's plans for improving its divisional air defenses were dealt a severe blow when Secretary of Defense Caspar W. Weinberger cancelled DIVAD, the Army's new anti-aircraft gun. Designed in the mid 1970s, the DIVAD was intended to replace the 20-year-old Vulcan anti-aircraft gun, currently in the Army's inventory, and to defend the Army's most forward deployed forces against potential attack by enemy fighter bombers and attack helicopters. When finally produced and tested during 1984 and 1985, however, the DIVAD proved incapable of overcoming the threat postulated for the 1990s. Furthermore, its unit cost--over $6 million--severely limited the number of guns that could be purchased and deployed with Army forces. Consequently, Secretary Weinberger, in an unprecedented move, cancelled the program in August 1985, leaving the Army, once again, with an outdated and inadequate air defense system for its forward deployed forces.

In the wake of the cancellation, the Army was forced to develop a new plan to improve its forward air defense. 1/ Although each Army division does include weapons designed specifically for air defense, they are, for the most part, old and ineffective against even today's threat, much less that anticipated in the 1990s. The Vulcan 20mm anti-aircraft gun, for example, entered the inventory in the late 1960s and does not have adequate range to destroy modern enemy aircraft before they launch or fire their weapons. Other air defense weapons have similar defects. Thus, the Army is currently evaluating those air defense systems that could be available quickly and have the potential to provide the short-range air defense that the Army's forward units currently lack.

THE MODERN BATTLEFIELD

Today's Army includes many diverse types of forces designed to fight the land battle anywhere in the world. The units assigned the mission of deterring potential ground attacks on U.S. and allied forces in NATO, and subsequently defending those allies should deterrence fail, are the Army's heavy armored and mechanized divisions (see Figure 1). These so-called "heavy divisions" include about 17,000 soldiers equipped with, among other

1. See the appendix for more details of the Army's current plan.

things, 300 or more M1 main battle tanks and 330 to 370 Bradley Fighting Vehicles. Groups of tanks and fighting vehicles that form the "maneuver elements" of a division would provide the first line of defense against any potential attack by enemy armored forces.

Combat units containing a mix of tanks and fighting vehicles are supported by many other units, such as field artillery, medical, transportation, and engineer groups (for constructing trenches, obstacles, and other fortifications). In addition, all Army divisions include helicopter units for attacking enemy armored forces and transporting cargo and troops. Finally, the U.S. Air Force, when possible, provides air protection and support to U.S. forces on the ground.

The major opponent of NATO is the Warsaw Pact alliance, whose forces include a similar array of air and ground weapons and combat units. During the initial phases of an attack in Central Europe, Warsaw Pact forces would probably outnumber NATO forces by as much as two to one, perhaps by more in specific locations. In addition, attacking ground forces would be supported by both high performance aircraft, such as fighter bombers, and heavily armed attack helicopters. Although air attackers would probably not be as numerous as those on the ground, they could cause considerable damage to U.S. armored forces in the absence of adequate defenses.

History provides little guidance to the efficiency of modern air attackers using sophisticated weaponry. Recent employment of aircraft against armored targets is limited to the Arab-Israeli conflicts in the Middle East. During the 1982 incursion into Lebanon, Israeli attack helicopters and close air support aircraft were credited with destroying and immobilizing Syrian tanks. With only limited recent wartime evidence, analytic results must be used to gauge the possible impact of tactical aircraft on opposing armored forces. According to a recent independent analysis of the European conventional balance, attack helicopters of the Warsaw Pact potentially could destroy 1,950 armored vehicles in two weeks. 2/ Recent Army analyses attribute as much as a quarter of all potential U.S. losses in a short, intense battle to attack by enemy aircraft. 3/

Thus, the concern of the U.S. Army to provide a capable air defense for its heavy forces stationed with NATO is readily apparent. The nature of the threat and the defenses needed to counter it are explored in Chapter II.

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2. Barry Posen, "Measuring the European Conventional Balance," *International Security* (Winter 1984-1985).

3. Department of the Army, Tradoc Studies and Analysis Agency (TRASANA), *Sgt. York Comparative Analysis* (October 1985).

Figure 1.
Corps Sectors of Military Responsibility in NATO's Central Region

SOURCE: Adapted by CBO from Richard Lawrence and Jeffrey Record, *U.S. Force Structure in NATO* (Washington, D.C.: Brookings Institution, 1974), p. 31 and also from U.S. Army materials.

NOTE: NORTHAG (Northern Army Group) and CENTAG (Central Army Group) are the two subdivisions of NATO forces in West Germany. The line dividing the two runs from Belgium through West Germany, just south of Bonn, and into East Germany.

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CHAPTER II

THE POTENTIAL SOVIET AIR THREAT AND U.S. AIR DEFENSE IN EUROPE

The most formidable potential threat likely to be encountered by U.S. forces deployed as a part of NATO in Central Europe is that posed by the Warsaw Pact. The Warsaw Pact as a whole, and the Soviet Union in particular, undoubtedly field more aircraft of great sophistication and capability than any other potential U.S. enemy. This discussion, therefore, focuses on defending U.S. forces from attack by Soviet aircraft in Europe. In keeping with the sectors of military responsiblity within NATO (shown in Figure 1), the U.S. Army would rely on its own air defenses to counter attacking Soviet aircraft.

THE SOVIET AIR THREAT

Over the past 10 years, Soviet attack helicopters have come to assume more and more of the responsibility for potential strikes against NATO armored assets positioned close to the front line of battle, compared with the role assigned to fixed-wing aircraft. In 1972 it was generally believed that the Soviet Union did not possess helicopters capable of antiarmor warfare. By 1975, however, the Soviets were thought to have 200 gunships, including both Hip and Hind helicopters. 1/ While these two large helicopters can carry troops, they are also equipped with guns, rockets, and antitank missiles. Ten years later, various sources credit the Soviet Union with some 1,300 attack helicopters, primarily the heavily armored Hind, but also a small number of the recently introduced Havoc. 2/ Because this new attack helicopter is more agile than either the Hip or Hind, it seems to be designed specifically for the antiarmor role. One final piece of evidence that supports an increased role for Soviet helicopters in attacking armored units is their recent reassignment from larger to smaller organizations, making them more a part of specific ground attacks.

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1. John Collins, *U.S.-Soviet Military Balance 1960-1980* (McGraw-Hill, 1980).

2. International Institute for Strategic Studies, *The Military Balance 1980-1981* (1980) and *1984-1985* (1984); and Department of Defense, *Soviet Military Power* (1985).

In contrast with the growth in its helicopter fleet, the total number of Soviet fighter and ground attack aircraft has remained relatively steady at about 2,600, although they have increased in capability during this period (see Table 1). The U.S.S.R. has also recently introduced a new close air support airplane, the Frogfoot, that is specifically designed to perform the antiarmor mission.

Threat Tactics

A brief discussion of the tactics of air attacks should clarify the helicopter's tactical advantage. Both fighter bombers and helicopters attacking maneuver elements close to the front would attempt to minimize their exposure to enemy air defense weapons by approaching the target area at as

TABLE 1. SOVIET TACTICAL AIRCRAFT INVENTORIES, 1975, 1980, AND 1985

Aircraft	1975	1980	1985
Attack Helicopters			
Hip E	75	125	150
Hind A/D/E	125	750	1,100
Havoc	0	0	10
Subtotal	200	875	1,260
Ground Attack Fighters			
Fishbed J/K/L/N	1,600	1,000	160
Flogger D/J	450	400	730
Fitter A/C/D	600	805	980
Fencer	0	370	630
Frogfoot	0	0	75
Subtotal	2,650	2,575	2,575
Total	2,850	3,450	3,835

SOURCES: John Collins, *U.S.-Soviet Military Balance 1960-1980* (McGraw-Hill 1980); and International Institute for Strategic Studies, *The Military Balance 1980-1981* (1980) and *1984-1985* (1984).

low an altitude as possible. 4/ Army field manuals speculate that most attacks on ground targets near the front line would take place at altitudes of less than 300 meters (m) and at speeds of less than 500 knots. Helicopters can carry out such low-level attacks with greater efficiency and less risk than can fighter bombers.

Fighter Bombers. Fixed-wing aircraft could deliver ordnance using either a "pop up" or "laydown" technique. A pop up profile--a low-altitude flight to the target area followed by a steep ascent to a high-altitude vantage point to locate targets--could be used to deliver conventional bombs, rockets, guided missiles, or cannon rounds and has the advantage of providing ample time to find targets and to allow accurate weapon delivery. As the aircraft pops up to weapon delivery altitude (600 to 2,300m) and then dives to release weapons some 500 to 1,500m from the target, however, it would be vulnerable to both detection and attack by opposing air defense weapons.

A laydown weapon delivery, on the other hand, would minimize aircraft exposure to air defense fire because the pilot flies at a constant altitude of about 150m at maximum feasible speed (350 to 500 knots) to deliver ordnance at low altitudes. This technique, however, would limit the types of ordnance, target acquisition capability, and delivery accuracy. Thus, although fixed-wing aircraft could deliver ordnance with greater speed than helicopters, they would have to approach within short ranges (0 to 1,500m) of their targets and fly at altitudes of 100 meters or more.

Helicopters. On the other hand, attack helicopters could approach targets close to the front line at the lowest possible altitude, possibly below tree level, using terrain, trees, and buildings to shield or mask their movements from enemy air defenses. By operating in coordination with observers on the ground in order to estimate when they are within attack range of their targets but still on their own side of the forward battle area, helicopters could use quick pop ups above terrain and foliage obstacles to locate and fire upon targets.

Guided antiarmor missiles pose the greatest threat to forward deployed tanks and fighting vehicles. The AT-6 Anti-Tank Guided Missile (ATGM), recently introduced into the Soviet inventory, would inflict the greatest damage while minimizing helicopter exposure. Both the Hind and the Havoc are helicopters judged to be capable of carrying at least four of these missiles which the helicopter gunner could guide to their targets

4. The front line is referred to in Army publications as Forward Line of Own Troops (FLOT).

through radio links. Various sources ascribe a five to seven kilometer (km) maximum range to the AT-6. 5/

It is likely that, within the next 10 years, the Soviets will introduce a replacement for the AT-6 that would be similar to the new laser-guided Hellfire missile carried on the latest U.S. attack helicopters. The new ATGM would be guided to its target by laser radiation reflected from the target's surface. Semiactive missiles, as these are known, require that targets be illuminated, or "designated," by a laser which can be mounted on the same platform as that launching the missile (self-designation) or on some other platform (indirect designation) either on the ground or in the air. Although relatively long ranges theoretically can be achieved by semiactive laser missiles, in practice maximum operational ranges are limited to about seven km by visibility constraints when the same platform is used to launch the missile and designate the target. Relying on a separate laser designator could increase the maximum helicopter-to-target range to 10km.

After popping up, the helicopter would hover in an attempt to locate, fire upon, and subsequently guide its missile to the target. During this period the helicopter would be exposed to detection and attack by air defenses. If the helicopter pilot should come under attack, however, he could descend rapidly so as to place trees, hills, or buildings once again between himself and would be attackers.

For all the above reasons, both the United States and the Soviet Union have come to rely increasingly on helicopters, rather than fixed-wing aircraft, for the potential destruction of armored vehicles in the front battle areas. The emphasis for air defense, therefore, has shifted from that of countering fixed-wing aircraft to that of overcoming attack helicopters, although the mission against fixed-wing attackers still remains.

DEFENDING AGAINST THE THREAT

The Army could not expect much assistance from Air Force fighter aircraft in routing enemy attack helicopters. Historically, the United States has relied on a combination of ground-based air defense systems and interceptor aircraft to protect its ground troops from air attack. Interceptor aircraft, however, are not designed to attack slow-moving, very low-altitude attack helicopters and, as a consequence, they could not provide an effective defense against them.

5. Department of the Army, *United States Army Weapon Systems 1986* (January 1986); and Flight International, *World Missile Directory* (February 1983.)

Fighter aircraft are ineffective against enemy helicopters for two reasons. First, low-altitude helicopters are very difficult to detect from above, especially when they are hovering. The radar returns from a slow-moving or hovering helicopter are obscured to a great extent by the reflections from nearby trees and hills. This phenemenon, called ground clutter, would prevent a fighter aircraft from using its radar to find enemy helicopters. Second, even if an interceptor aircraft should locate an enemy helicopter, its weapons, which are designed for use against high-speed aircraft, would not work well against helicopters close to the ground. Although the Air Force's interceptor's might be able to provide more effective defense against enemy fixed-wing aircraft than against helicopters, there is no guarantee that they will be able to stop them all. Thus, the Army must depend on ground-based air defense systems to protect maneuver elements at the front.

Types of Air Defense Weapons

Army air defense assets are assigned the mission of destroying, driving away, or reducing the effectiveness of enemy helicopters and high-performance aircraft attacking friendly assets. The Army has traditionally performed this mission using a combination of widely disparate air defense weapons.

Highly sophisticated U.S. missile systems, such as Hawk and Patriot, provide umbrella coverage for long ranges and high altitudes, particularly against high-performance enemy bombers, fighter bombers, and intercepter aircraft. Patriot has the longest range of all the Army's air defense systems and forms the centerpiece of the Army's European air defense. It is designed primarily to prevent enemy bombers and accompanying aircraft from penetrating into West German airspace and attacking NATO airbases. Patriot fire units would not typically be assigned to defend particular Army organizations; rather they are designed to protect the entire European theater. On the other hand, each corps (the managerial unit directly above the divisions) and some Army divisions are typically supported by at least one Hawk battalion with 24 launchers. Hawk is designed to provide medium-range coverage (to about 40km) against attacking enemy aircraft flying at low to medium altitudes--from 0 to 15,000m--over an entire divisional area.

Systems such as Hawk and Patriot, which are designed to destroy enemy aircraft at ranges beyond 10km must rely on radars to detect those aircraft. These long-range air defenses would typically be located to the rear of the battle area--at least 10km from the front in order to protect delicate radars and missile launchers from the effects of enemy artillery.

From this position, they would be unable to detect aircraft flying at low altitudes so as to use terrain, buildings, and trees as a shield from air defense radars. Thus, each Army division also includes air defense weapons that are limited in range (Short Range Air Defenses or SHORADs). These are smaller and more mobile than the longer-range systems and would be deployed close to the assets that they are assigned to protect. The Army currently deploys three short-range weapons: Chaparral, Vulcan, and Stinger, which are described in Chapter III (see Figure 2).

SHORAD systems are responsible for defending command posts, supply depots, field artillery units, and groups of armored combat vehicles. In order to provide continuous coverage of maneuver units, such as tank or mechanized infantry battalions that typically include 50 to 60 tanks and armored fighting vehicles, SHORAD systems must be able to accompany defended units as they travel in convoy or proceed into battle. It is essential, therefore, that a system assigned to protect the maneuver elements be able to operate while moving or shortly after stopping.

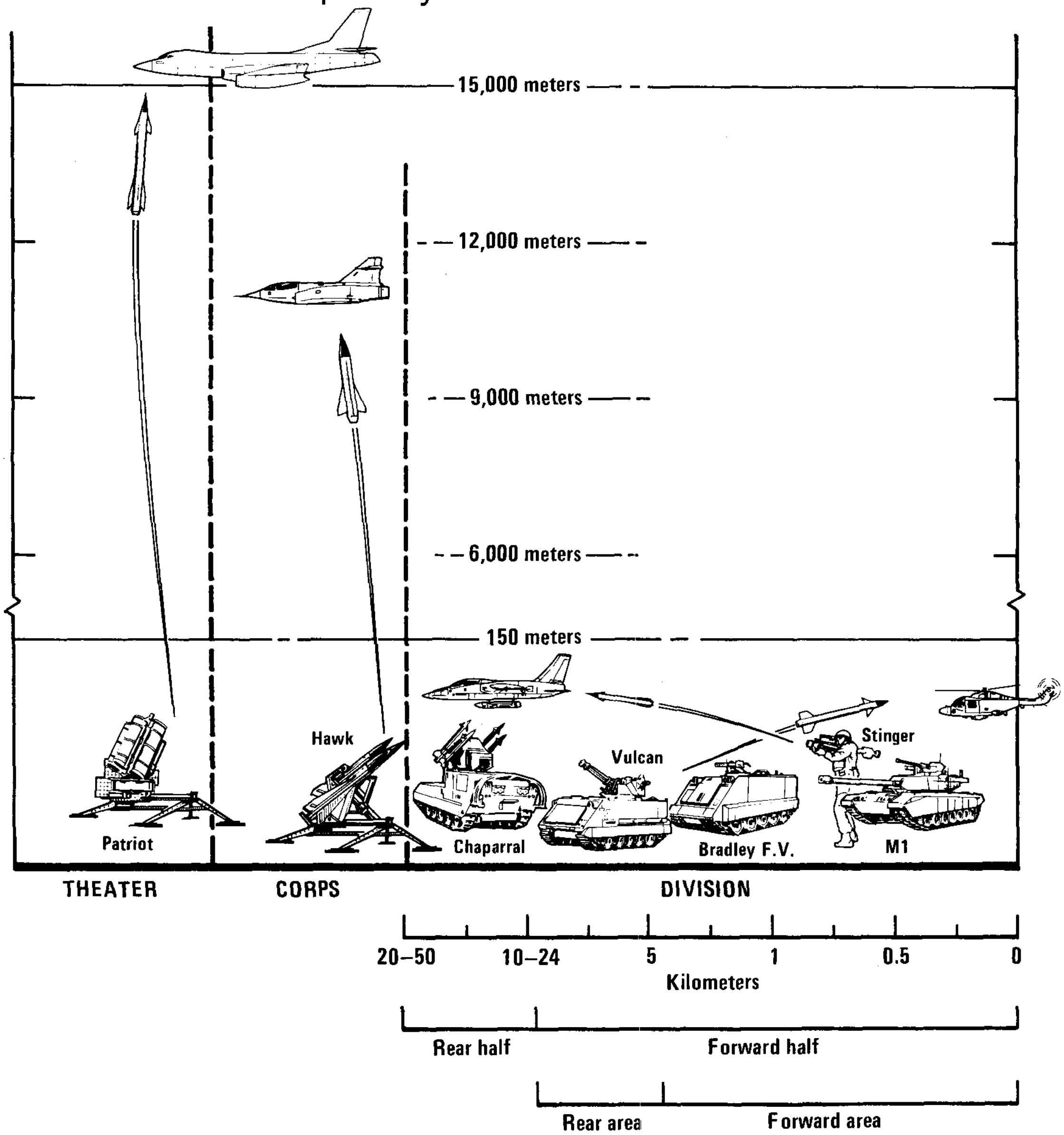
Air Defense Survivability

Air defense assets must also be able to survive in the very hazardous modern battlefield if they are to perform their mission. Air defense weapons close to the forward battle area, however, would themselves come under both direct fire from enemy systems, such as tanks and antitank weapons, and indirect fire from enemy artillery. Inasmuch as air defense weapons are not typically designed to withstand antitank munitions, they would not long be able to survive if positioned too close to the front line. Furthermore, SHORAD systems typically have rather distinctive physical profiles and would stand out even among large numbers of tanks and other armored vehicles. Considering the small number of air defense systems protecting a typical maneuver element, these distinctive systems would soon become lucrative and early targets for the large numbers of enemy weapons that would most likely be included in an opposing force. 6/ Therefore, according to Army field manuals, air defense weapons should be placed **behind** the maneuver elements in what is called an "overwatch position." 7/ Thus, in order to survive and still perform their air defense mission, effective air

6. A battalion-sized task force of 19 M1 tanks and 30 fighting vehicles, including Bradley fighting vehicles, improved TOW vehicles, and cavalry fighting vehicles, would typically include four SHORADs and could be opposed by as many as 91 Soviet tanks and 85 ATGM-equipped armored personnel carriers.

7. An overwatch position is one that enables an air defense unit to remain behind the asset it is defending in a relatively safe location while still providing coverage above and in front of the defended asset.

Figure 2.
U.S. Air Defense Weapons Systems



defense systems must have sufficient range to be able to cover the distance from their rearward position to standoff helicopters attacking the maneuver assets.

DESIRED CHARACTERISTICS OF AN EFFECTIVE AIR DEFENSE

Based on the air threat and potential battlefield environment in Central Europe, it is possible to identify several features that would be desirable in an air defense capable of destroying standoff helicopters. Among other things, the threat and environment determine the required range and number of individual air defense units. These two characteristics--range sufficient to reach out and negate an enemy helicopter's standoff capability and numbers large enough to ensure multiple engagements of each attacking helicopter--are the keys to fielding an effective air defense.

Air Defense Systems Needed in Large Numbers

In Central Europe, where the landscape is generally hilly, the use of terrain to hide movements would be particularly advantageous to fighter bombers and attack helicopters and disadvantageous to the U.S. air defense systems attempting to track them. This situation would be exacerbated by the extremely perilous environment in which the air defense unit would have to operate. To provide an effective shield, therefore, air defense systems would have to be deployed in large numbers. They could position themselves on high points that would afford them good views of likely aircraft approach routes. Such sites, however, would also be exposed to enemy artillery, tanks, and antitank weapons. Air defenders at the front, therefore, would have to sacrifice visibility in the interest of survivability.

Probabilities illustrate the importance of having large numbers of widely dispersed air defense systems. The probability that a particular air defender, located in a forward position immediately behind the armored units, would have a clear line of sight--unobstructed by trees or hills--to a fighter bomber six km away at an altitude of 100m is only 50 percent. Thus, only half the air defenders randomly placed in the forward area would be expected to see this aircraft. The other half would have their view "masked" by hills or other impediments. The same limitations apply to sighting helicopters, of course, and, since helicopters can safely operate at much lower altitudes, the likelihood of seeing them at long ranges is much lower. As an enemy helicopter "stands-off" from its target at a typical hover altitude of 20m, the probability of locating it at six km is only 21 percent. 8/ Thus, only about one-fifth of the deployed air defense systems would be able to "see" a helicopter at this distance. The remaining 79 percent would have their view blocked by hills or other terrain features. Since the likelihood is small that any one particular air defense unit would be in position to locate a helicopter when it pops up to attack, large numbers of dispersed units would be needed to guarantee that at least one or preferably two air defenders would be in position to see it. 9/

The number of air defenders needed would increase with the standoff range of the helicopter (see Figure 3). If an enemy helicopter was able to engage a U.S. battle formation from five km away, as many as eight air defense units could be needed to achieve a 50 percent probability that at least two air defenders could see the target (assuming that the air defense units were situated one km behind the battle formation). If the helicopter could increase its standoff range to six km, the number of air defenders required would increase to 11 under the same assumptions.

Effective Range and Air Defense Density

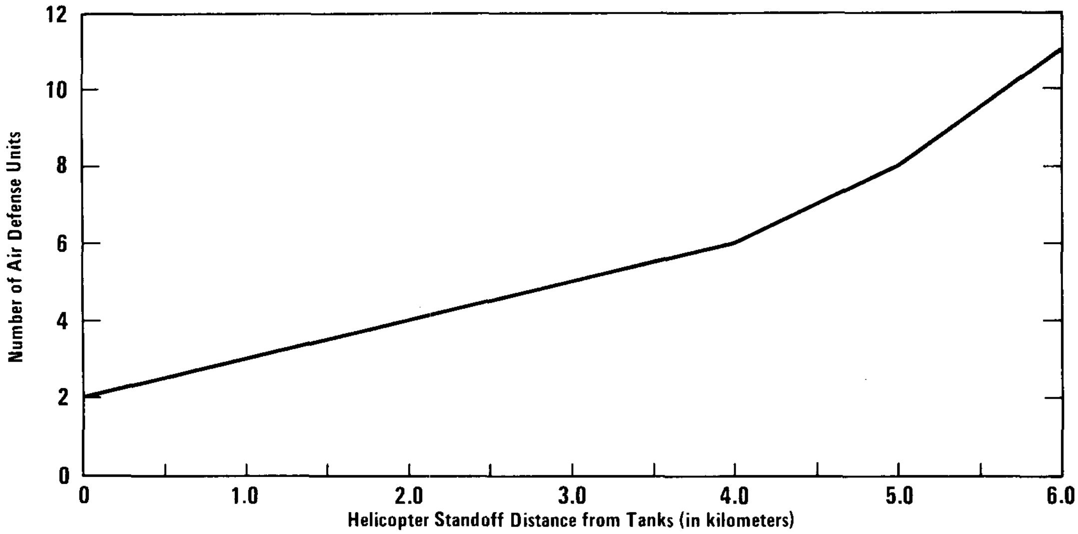
Of course, locating an enemy aircraft would not be all that was required to destroy it. An air defense unit would also have to be able to shoot at, or engage, the attacking helicopter or fighter bomber. Thus, the gun or missile associated with the system would need enough range to engage the enemy aircraft at its operating distances. As discussed previously, the air defense system would have to compensate for both its own position behind the armored forces and the helicopter's standoff range. Thus, air defenses that are set back one km would need an effective range of more than six km in order to defend against a helicopter that could standoff and attack a tank formation from five km.

In order to deter enemy aircraft, air defense units would typically be dispersed along lines roughly parallel to the front. The number of air defense units per kilometer of front can be defined as the air defense density. The density required to defend against a helicopter attack is a function of the helicopter standoff range and the effective range of the air

8. The probability of seeing a helicopter at a given range increases with the helicopter's altitudes. However, the variation in probability is slight within the likely range of altitude (10 to 30m) and is much more dependent on the range to the helicopter. (For example, the probabilities of seeing a helicopter five km away are 23 percent, 27 percent, and 30 percent at 10m, 20m, and 30m altitude, respectively.)

9. The desirability of having two air defenders in position to see each attacking helicopter results from the need to account for redundancy in case one air defense unit is unavailable because of (1) occupation with another target; (2) malfunction of equipment; (3) lack of ammunition; (4) missed detection; or (5) ground attack.

Figure 3.
Number of Air Defense Units Needed to Obtain Two Engagements Against An Enemy Helicopter



SOURCE: Congressional Budget Office.

defense weapon itself. By assuming that air defense units would be dispersed uniformly along a line that is parallel to the front line and one km behind the maneuver elements being attacked, the number of units per kilometer of front, or the needed density, can be calculated for the effective range of a given air defense system (see Figure 4). 10/

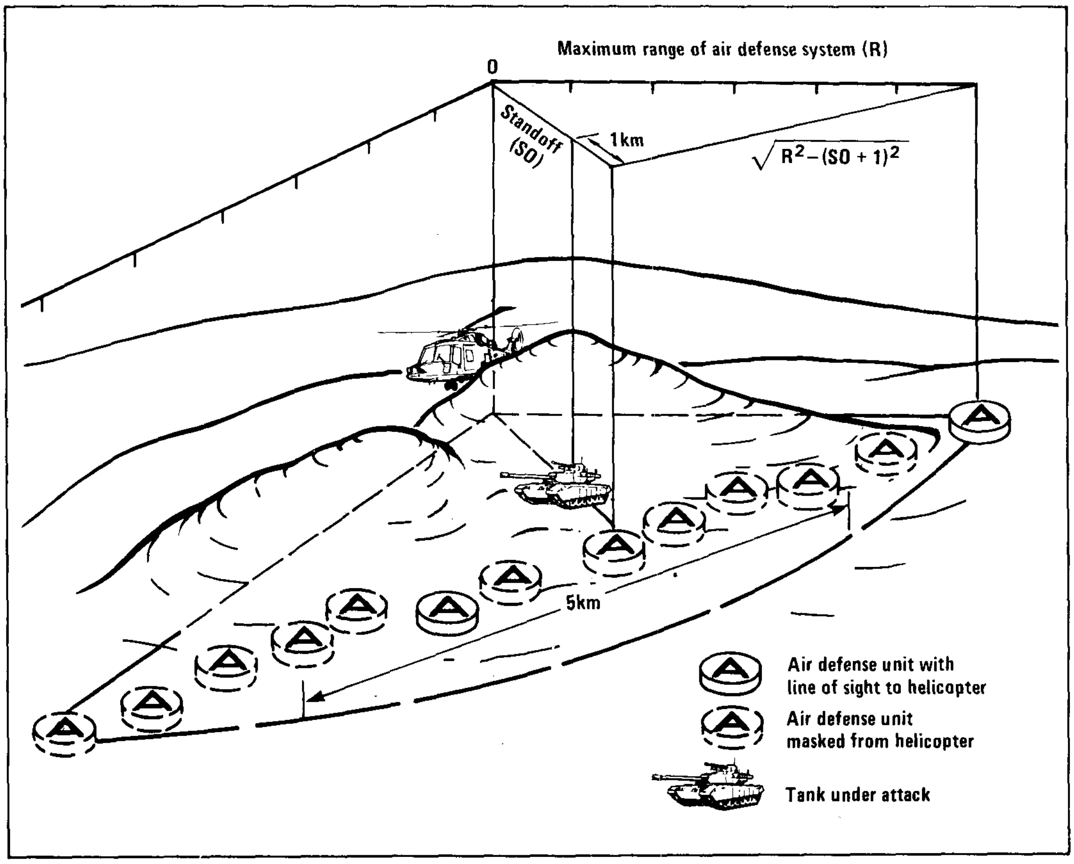
For an air defense weapon with a range of eight km, the density required for two engagements of a helicopter standing off five km is about four per every five km of front, or 0.8 per kilometer. The required density decreases as the range of the air defense system increases because longer-range systems can provide greater lateral coverage and be spread out more (see Figure 5). In order to provide two engagements of a helicopter standing

10. Although this assumption is a simplification of the irregularities of the battlefield, the total number of air defense units needed would not be greatly influenced by changing the actual positioning of specific air defense systems.

off six km away, between seven and eight air defense systems with a maximum effective range of eight km might be needed per every five km of front.

A five km front corresponds to the distance usually defended by a battalion task force. Thus, seven to eight air defense units could be needed

Figure 4.
Method for Determining Required Air Defense Density



SOURCE: Congressional Budget Office.

a. The required air defense density (per five km of front) is determined by the following relationship:

$$D = \frac{5N}{2\sqrt{R^2 - (SO + 1)^2}}$$

Where N is the number of air defense units required to ensure two sightings of a helicopter at a given standoff range;
R is the maximum effective range of the air defense system;
SO is the helicopter standoff range from the tank formations under attack.

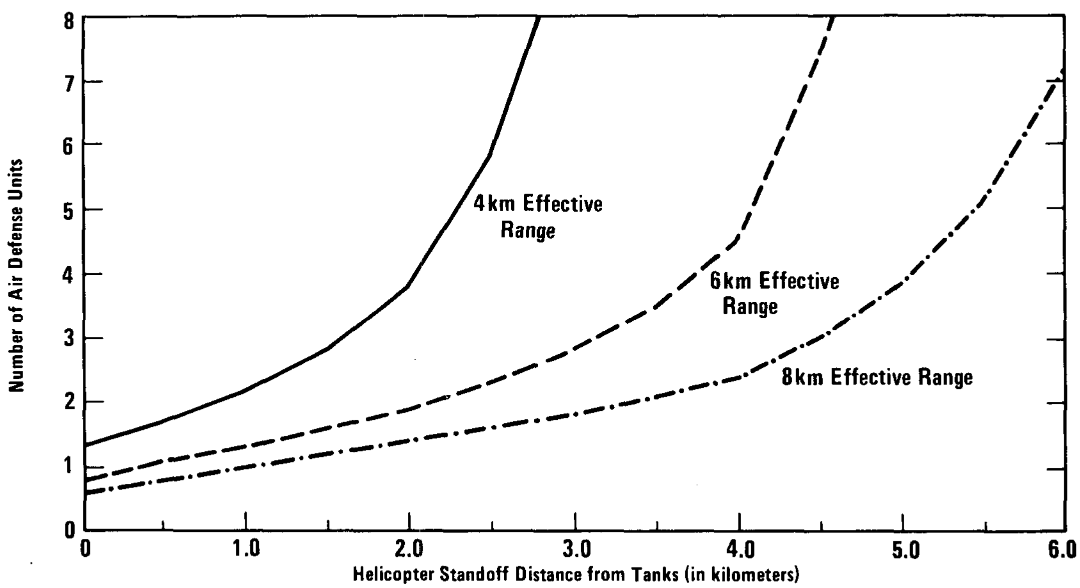
to provide a battalion with enough air defense for two engagements per attacking helicopter. Since each heavy division typically includes 10 battalions, a total of 70 to 80 air defense units could be required to maintain the same level of defense throughout the division. In contrast, a division is currently defended by only 24 Vulcans. Thus, a much higher density of air defense units than that currently deployed would be needed to protect the forward maneuver units from standoff helicopters.

Affordability

The entire DIVAD program, designed to provide 36 DIVAD guns per division or about four guns per battalion, would have purchased a total of 614 air defense units. The total acquisition was estimated to cost over $4 billion, with each fire unit costing an average of $6.4 million. Using the DIVAD program as a precedent, it would be necessary to procure at least 1,200 weapons to provide each division with 70 to 80 air defense weapons.

Figure 5.

Number of Air Defense Units Needed Per Every Five Kilometers of Front



SOURCE: Congressional Budget Office.

Inasmuch as the DIVAD, at over $6 million per unit, was considered too expensive to purchase in quantities of 600 or so (one of the reasons for its cancellation), any weapon system bought in quantities of over 1,000 would have to be less expensive.

One possible source of savings lies in the type of target sensor associated with any potential air defense system. Two types of sensors are commonly used in modern air defense weapons--radars that emit and detect radiation reflected from the target and passive systems such as Forward Looking Infra Red Systems (FLIRs) that do not emit but rely on the visual or thermal signatures of the targets themselves for detection. Radars are, in general, more complicated and expensive than passive systems and often account for a large part of the cost of air defense weapons. In the case of the DIVAD gun, the radar and associated signal processing equipment accounted for 55 percent of the gun's unit cost.

The capability gained by including a radar on each air defense fire unit may not be worth the cost, although radar systems are indeed capable of locating targets at the longest ranges and over the widest area, as well as in the dark and all kinds of weather. While systems such as FLIRs can "see" helicopters or airplanes at longer ranges and in worse weather than the naked or aided eye, they do not have the range of radar nor can they typically cover a full 360° or even 180° sector. All methods currently used for target detection, however, must have a clear line of sight to the target--that is, neither radar nor FLIR nor eyeballs can see through hills, buildings, or, to a great extent, trees. Thus, although a radar could theoretically pick up a helicopter or plane at 10 or 20km, the likelihood that a clear line of sight will exist to low-altitude aircraft at such long ranges is small, particularly in Europe's hilly terrain. Therefore, providing an air defense system with radar might not greatly enhance its capability to detect low-altitude aircraft, at least not in Central Europe.

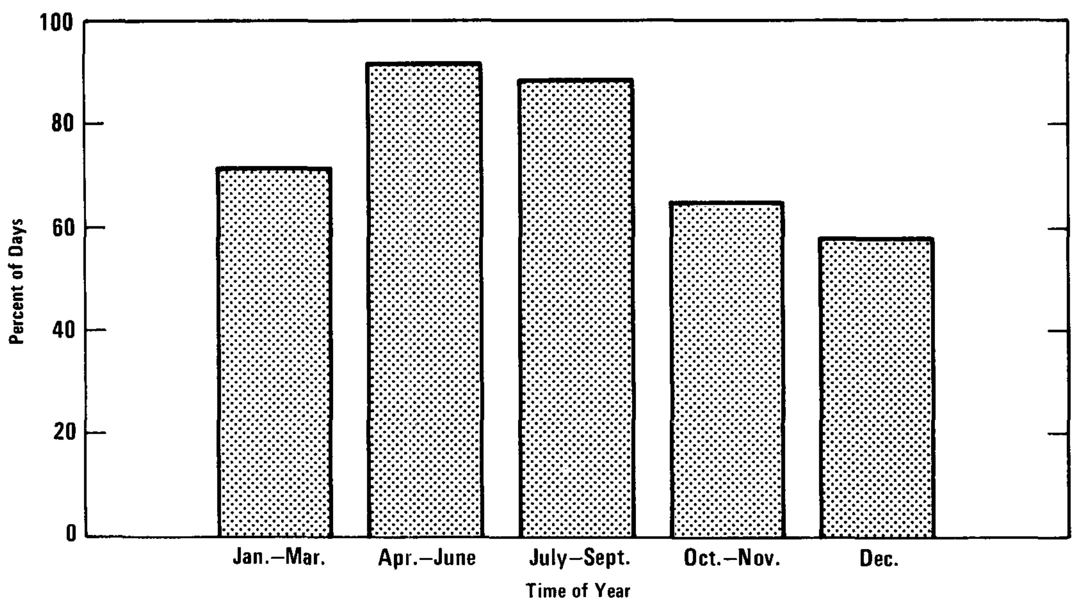
Nor is radar's all-weather capability always useful. Relative to passive systems such as FLIRs and visual systems, radar does work better in bad weather, and the weather in Central Europe, particularly during the winter months, can severely limit visibility (see Figure 6). Adverse weather works to the disadvantage of both attacker and defender, however, making it difficult for both to locate targets. As a result, attacking aircraft, particularly helicopters, might need to decrease their attack range, thus bringing them closer to the targets they are attacking and any air defenses located nearby. Furthermore, FLIRs can offset, to some extent, the effects of limited visibility in bad weather, since infrared light can often penetrate fog and mist that is impermeable to visible light. Finally, aircraft are not likely to fly in the type of weather that would prevent a FLIR from working, further negating radar's all-weather advantage.

Another argument against providing each air defense unit with radar is its marginal performance against low-altitude helicopters. The return radar signal from a hovering helicopter is very small. Whatever signal was received would be obscured to some extent by ground clutter--radar reflections from the nearby ground, trees and buildings. Finally, the enemy would attempt to hide aircraft signals further by jamming air defense radars or flooding them with synthetic electrical signals. The combined effect of small radar return, ground clutter, and enemy jamming makes radar detection of helicopters hovering at low altitude difficult.

Since air defense radars must emit radiation to work, they also alert enemy aircraft to the presence of opposing air defenses. Although at-

Figure 6.

Percent of Days in Germany with Visibility of Five Kilometers or Better



SOURCE: Congressional Budget Office from *Close Air Support*, Hearings before the Special Subcommittee on Close Air Support of the Senate Armed Services Committee, 92:1 (1971), p. 78.

tempting to avoid enemy air defenses might reduce the effectiveness of attacking aircraft, it will certainly allow them to survive longer. Passive acquisition systems, such as FLIRs and televisions, on the other hand, do not provide warning to attacking aircraft, and thus afford the air defender an element of surprise and stealth. In conclusion, equipping all individual air defense units with active radar sensors could be an expensive proposition that might provide only limited useful added capability over cheaper passive sensors.

Additional Desirable Characteristics

Both helicopters and fighter bombers attacking armored formations in the extremely hazardous environment of the forward battle area would attempt to minimize their vulnerability to enemy air defenses by employing tactics that would limit the time they were exposed to air defense sensors. Thus, the period available for air defense reaction would be short. As a consequence, whatever munition--be it missile or anti-aircraft round--that is employed to destroy the aircraft would have to traverse the distance from the air defense unit to the target quickly, so that it would arrive before the aircraft has a chance to duck behind hills, buildings, or trees.

Moreover, attacking aircraft would employ maneuvers and use passive and active countermeasures to elude the air defense's systems for locating targets and guiding missiles to their targets. Evasive maneuvers employing rapid, jerky turns are particularly effective against air defense systems with unguided munitions. Dropping infrared flares and suppressing aircraft heat signatures (such as engine exhaust) are common measures employed against infrared sensors and missiles. Thus, the munition might need guidance as it nears its target in order to have a high probability of hitting aircraft that are maneuvering or are a long way from the firing unit. For maximum effectiveness, this "terminal guidance" should not rely solely on either radar or infrared means. Instead, it might use a combination of the two, or rely on commands from the gunner transmitted by wire, radio link, or laser beam.

Although most Soviet helicopters and fighter bombers are not currently capable of operating effectively at night, new systems entering the inventory, such as the Havoc attack helicopter and the Frogfoot close air support aircraft, will probably be equipped with FLIRs and will have some ability to operate in darkness. Therefore, any new U.S. air defense system designed to overcome these new threats must not rely solely on visual means for locating targets, but should also include a sensor capable of detecting aircraft in darkness.

Two final characteristics that are desirable in forward area air defense systems are found in almost all weapons positioned close to the front lines--mobility and light armor protection from small arms fire and artillery fragments. A system providing air defense for the maneuver elements must be able to accompany the vehicles that make up the fighting force. Therefore, it must have mobility and survivability characteristics similar to the weapons that it is protecting.

CHAPTER III

CURRENT U.S. AIR DEFENSE SYSTEMS AND THEIR CAPABILITIES

The Army's heavy divisions currently include many types of weapons, some of which are dedicated solely to the air defense mission. In addition, some of the weapons that are not designed primarily to destroy enemy aircraft could do so under certain circumstances. The ability of a heavy division to protect itself from air attack depends on the total contributions from each of the many different types of weapons within the division.

One means of gauging an Army force's ability to defend itself from air attack would be to count the total number of weapons in that force that could locate and fire upon an attacking enemy aircraft. The supposition is that the more U.S. weapons capable of attacking enemy aircraft, the better. This chapter describes the weapons in a typical heavy division that would make up the forces deployed closest to the front. It also examines and evaluates the ability of each of those weapons to destroy enemy aircraft, particularly standoff helicopters.

CURRENT U.S. SYSTEMS

The Army's armored and mechanized divisions currently include three weapon systems dedicated solely to air defense: Chaparral, Vulcan, and Stinger. The mission of these systems is to protect the forward half of the division (within about 10 kilometers of the front line) from aerial attack. In addition, each division includes many M1 tanks and fighting vehicles. Although these weapons are not specifically designed to engage aircraft, they do have some residual capability against airborne targets, particularly hovering helicopters. A detailed discussion of the characteristics of these various systems follows.

Chaparral

First deployed in 1966, Chaparral is a guided missile system that is effective against both high-speed, fixed-wing aircraft and slower moving or hovering helicopters. Chaparral consists of a launching station and infrared target sensor mounted on a tracked vehicle. Four missiles with infrared seekers and an effective range of about five km can be mounted and carried on the launch rails. Eight more missiles can be carried in the vehicle, providing two reloads. The time needed to mount four new missiles on the rails is about eight minutes.

The original version of Chaparral had no means of detecting targets other than the crew's eyesight, which severely limited the ability of the system to operate at night or in bad weather. In order to remedy this deficiency, the 500 or so Chaparral fire units now in the Army's inventory are being equipped with Forward Looking Infrared Sensors (FLIRs) to provide the gunner with the ability to find targets at night and in adverse weather.

The Chaparral's infrared missile is guided to its target by the heat emitted by the engines of the attacking aircraft. The missile seeker finds and locks-on to its target before it is launched from the Chaparral unit. The maximum range from launcher to target at time of launch is determined by when the missile's seeker can "sense" the heat emanating from its target. This range varies greatly with the position and nature of the target, since it is easier to sense the heat from the engines of a receding high-performance aircraft than it is to detect the heat from those of a face-on hovering helicopter. Thus, the five km range cited by various sources could be reduced somewhat (to about three to four km) against hovering helicopters or increased against departing fighter bombers.

Chaparral was not designed to survive in the extremely hazardous environment of the most forward area of the division. Its mission is limited to defending stationary assets, such as command posts, supply points, and field artillery emplacements--typically located at least five km from the front--because the Army feels that placing Chaparral firing units closer to the front lines and enemy artillery would endanger their survivability. Although Chaparral units are currently being removed from the heavy divisions and placed directly under the control of the corps--the managerial unit directly above the divisions--their primary mission will still be to support the divisions within each corps.

Vulcan

The Vulcan anti-aircraft gun was introduced into the Army's inventory at the same time as Chaparral and, in the heavy divisions, is mounted on a self-propelled vehicle equipped with tracks. Its six-barrel, 20mm gun is a rapid fire "Gatling" type that is effective against both fixed-wing aircraft and helicopters up to ranges of 1,200 meters. Although it is equipped with a night sight, the Vulcan system does not include a FLIR and is, therefore, incapable of operating in adverse weather. Each division currently includes 24 Vulcan guns to be used in support of the maneuver units. An illustrative battalion-sized task force, which might contain 19 tanks and 30 infantry fighting vehicles, would be accompanied by four Vulcans. The Vulcans can move with the units and would be positioned so that two-thirds of their effective range extends in front of the defended force. Vulcan's primary limitation, particularly against standoff helicopters, is its short range.

Stinger

Stinger is a small, portable air defense weapon that fires an infrared missile, similar to Chaparral's, and is launched from a soldier's shoulder. The gunner must detect targets using eyesight only, thus limiting Stinger's usefulness to daytime and good weather. Stinger's maximum range is comparable to that of Chaparral, and could be as much as six km when fired at most fixed-wing aircraft. Its range would be reduced to three to four km against hovering helicopters, however.

Each armored and mechanized division currently includes 60 Stinger teams, each composed of two soldiers equipped with a jeep, six missiles, and communitions equipment. (A typical battalion-sized task force might include four Stinger teams.) Since Stinger is a small, highly mobile system, it can travel with the maneuver units and provide flexible, widely dispersed air defense. Because Stinger cannot be fired from inside a vehicle, the gunner could be exposed to enemy fire whenever he dismounts to fire at approaching enemy aircraft. This liability, and Stinger's limited range against hovering helicopters are its main drawbacks.

The Bradley Fighting Vehicle (BFV) and Improved TOW Vehicle (ITV)

These two lightly armored vehicles provide additional antitank capability to the armored and mechanized divisions. The Improved TOW Vehicle (ITV) is a converted M113 personnel carrier equipped with a TOW antitank missile launcher and its associated optical day and night sights. It is used solely to destroy enemy tanks and does not transport soldiers. The Bradley is a new personnel carrier designed to carry troops onto the battlefield where they can support the more heavily armored main battle tanks. It is also equipped with a TOW missile launcher plus a 25mm cannon.

The TOW missile has a maximum effective range of almost four km. It is guided by commands transmitted from the gunner through a wire that is played out as the missile flies toward its target. It is a rather slow missile, taking 15 seconds to reach its maximum range of 3,750 meters, and must be guided all the way to its target. Because TOW was not designed to attack fast-moving targets, it is ineffective against fixed-wing aircraft or even helicopters traversing at high speed. Against hovering helicopters, however, it could be a formidable weapon, even though it was designed to be and is primarily used as an antitank weapon.

The Bradley also carries a 25mm gun, with an effective range of about two km. Because the Bradley cannot compute appropriate lead angles for moving targets or ranges to any targets, the 25mm gun is not very useful against fast-moving airplanes. Within its range of two km, however, the gun could be used effectively against relatively stationary aircraft, such as hovering helicopters.

Each heavy division includes a total of 376 to 430 Bradleys and ITVs. Although the primary role of these vehicles is not air defense, their weapons could certainly be used in self-defense against an attacking helicopter or against any aircraft that should suddenly come within the weapons' range.

M1 Abrams Tank

Each armored or mechanized division also includes between 290 and 350 M1 tanks. The latest A1 version of the tank includes a 120mm gun with a maximum effective range against ground targets of three km. Against aircraft, the range would probably be diminished somewhat, to two to two and a half km. The tank's fire control system can establish range to the target and compensate for slowly moving targets. It cannot, however, adjust for targets moving up or down. Although designed and used primarily for other purposes, the tank's main gun could be used against hovering helicopters, especially in self-defense.

CAPABILITIES OF CURRENT U.S. SYSTEMS

The characteristics necessary for successful air defense against standoff helicopters were identified and discussed in the previous chapter. Table 2 presents a comparison of the characteristics of the weapon systems currently in the Army's armored and mechanized divisions with those that were determined to be desirable when combatting the Soviet helicopter threat. It can be seen from the table that none of the current systems possesses all the desired characteristics.

Limited range is the main drawback of all current systems. Not one has the seven to eight km effective range needed to engage helicopters standing off at distances that would be expected during a Central European battle. Further, none of the dedicated air defense systems are present in

TABLE 2. CAPABILITIES OF CURRENT U.S. AIR DEFENSE SYSTEMS

	Dedicated Air Defense Systems			Armored Fighting Weapons	
Capability a/	Vulcan	Chaparral	Stinger	TOW b/	Tank
Range 7 to 8km	No	No	No	No	No
Adequate Numbers (70-80 per Division)	No	No	No	Yes	Yes
Inexpensive (Relative to DIVAD)	Yes	Yes	Yes	Yes	Yes
Rapid Destruction Capability (Relative to TOW)	Yes	Yes	Yes	c/	Yes
Guided	No	Yes	Yes	Yes	No
Resistant to Counter Measures	Yes	No d/	No d/	Yes e/	Yes
Night Capability	No	Yes	No	Yes	Yes

SOURCE: Compiled by Congressional Budget Office from various Department of the Army documents including Department of the Army, *United States Army Weapons Systems 1986* (January 1986); and Department of the Army Field Manuals *FM 44-3, 44-18, 77-2J.*

a. Two additional characteristics were identified in the previous chapter: mobility and protection from small arms and artillery. All of the systems listed in the table are mobile. All are also protected, except for Stinger.

b. On Bradley Fighting Vehicles and Improved TOW Vehicles.

c. Not applicable.

d. New versions of the Chaparral and Stinger missiles include improved seekers (Rosette Scan Seeker and the POST seeker, respectively) with increased resistance to countermeasures.

e. The latest version of the TOW missile, TOW II, is relatively resistant to countermeasures such as smoke and flares, but is too slow to follow a rapidly maneuvering aircraft.

the armored or mechanized divisions in sufficient number (70 to 80) to provide an adequate air defense against low-altitude helicopters. The only numerous systems within the armored and mechanized divisions are the TOW missile launchers on the Bradleys and ITVs (376-430) and M1 tanks (290-350) for whom air defense is secondary. Finally, most of the current systems can destroy targets quickly (except for TOW) and some also can operate at night. Only the TOW missile, however, is both guided--and, therefore, able to hit long-range or slowly maneuvering targets--and resistant to countermeasures.

Measuring Total Air Defense Capability

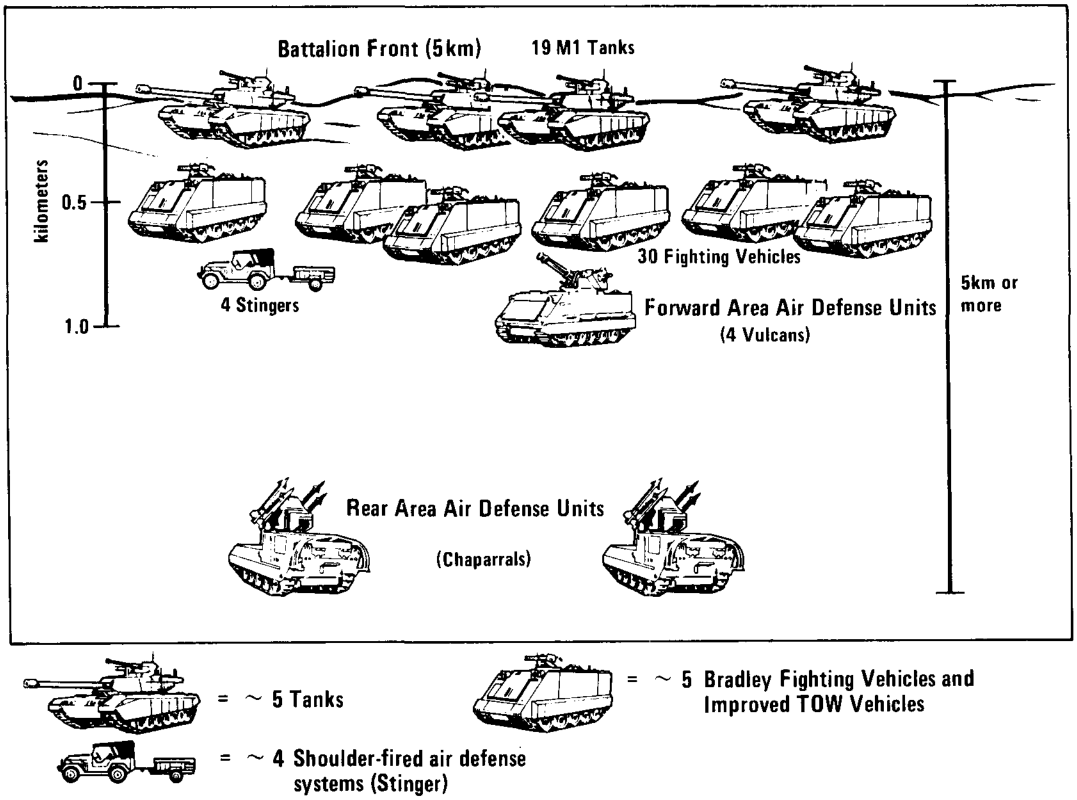
Although an Army unit is made up of individual weapons, the total capability of the entire unit acting in concert is not necessarily equal to the sum of all the individual capabilities. The total impact of the force might be less, because of overlap or redundancy of the individual systems, or more, because of synergistic effects. Furthermore, the contribution of each individual system could be affected by its placement on the battlefield or its ability to communicate with other systems. For this reason, a measure is needed of the effectiveness of an entire Army unit to defend itself from air attack while engaged in battle in Central Europe.

One measure that can be used to gauge the relative air defense potential of various forces or collections of weapon systems is the total number of potential engagements that a force might have against aircraft attacking the forward maneuver elements. The discussion of the air threat in Chapter II pointed out the altitude and standoff advantage that helicopters have over fixed-wing aircraft when attacking armored targets. Thus, the measure used in this study emphasizes the ability to defend against standoff helicopters.

Potential Engagements

Specifically, this study calculates the number of engagements that a battalion-sized task force could expect to complete against helicopters hovering at various ranges. The task force was assumed to be deployed in central Germany on typically hilly terrain. The tanks in the force were assumed to be the most forward element, and were dispersed uniformly along the front. The fighting vehicles, including Bradleys and ITVs, were assumed to be deployed uniformly along a line parallel to and 0.5 km behind the front. Shoulder-fired air defenses, such as Stingers, were deployed uniformly at the same depth as the Bradleys. The forward air defense units (Vulcan guns, for example) were assumed to be deployed uniformly along a line one km behind the tanks. Chaparral units were positioned at least five

Figure 7.
Typical Weapon System Deployment for Battalion-Sized Force



SOURCE: Congressional Budget Office, based on scenario used in Department of the Army, TRADOC Studies and Analysis Agency (TRASANA) Sgt York Alternatives Analysis (October 1985).

km to the rear of the tanks (see Figure 7). 1/ The total frontage of the battalion was assumed to be five km. Obviously these assumptions--as with many other in this analysis--will not predict or represent all of the characteristics of a specific battlefield. They are, however, reasonable simplifications.

1. The placement of weapons on the battlefield is representative of Army practices as outlined in Field Manuals FM 44-3, 44-18, and 71-2J. The impact of an altered weapons placement on the ultimate measured capability would not be significant.

Enemy helicopters were assumed to attack the center of the battalion from various standoff ranges (as measured from the tanks) and to fire their weapons while hovering at 20m altitude. The number of each type of weapon within range of each hovering helicopter was then calculated, taking into account the maximum range capability of each of the weapon systems. Assuming clear weather conditions with a visibility of seven km, the number of those weapon systems within range and with at least a 50 percent probability of line of sight to the helicopter was then determined (for example, the number of Bradleys within range of the helicopters multiplied by the probability of line of sight to helicopters five and one-half km away). The total number of potential engagements by the battalion task force against helicopters at varying standoff ranges was then determined by summing up the engagements by each of the various types of weapons. This defined the total potential engagements.

By measuring the total potential engagements, the maximum air defense capability of a battalion task force can be evaluated and used to compare the air defense potential of differing combinations of weapons. The possible contribution of all weapons is taken into account, as well as the effects of terrain and the relative positioning of the various types of weapons dictated by survivability constraints.

Because of all the assumptions necessary to simplify the actual conditions that might exist on a battlefield, however, this measure cannot be viewed as an absolute one--that is, the measure used in this study cannot be used to predict the outcome of an actual U.S.-Soviet confrontation in Central Europe. Rather, the measure should be used to compare the relative performance of various weapons combinations against standoff helicopters.

Limitations of the Measurement Analysis

While the measurement of total potential engagements provides a very useful evaluation of air defense capability, it does omit some pertinent factors. These include target detection ability, reaction time, and target destruction; the possible development of an air defense system that would not require line-of-sight target acquisition; and lack of engagement analysis against fixed-wing aircraft.

System Detection Capability, Reaction Time, Destructiveness. Several factors that could affect the ultimate air defense capability of an armored force are not captured by measuring total potential engagements. The ability of an individual weapon unit to convert potential engagements to aircraft destruction is assumed to be the same for all weapon systems. This assumption ignores the several steps that must be accomplished from establishing line of sight to an attacking helicopter to destroying it. First, the air defense gunner must detect the helicopter--that is, distinguish the attacking helicopter from its background. Most modern air defense systems include some kind of sensor--radar, infrared or magnified visual--to help the gunner spot attacking aircraft. Radar systems are for the most part the most efficient since they can easily and quickly scan the total 360° surrounding the unit (for example, the DIVAD radar made a complete 360° scan every two seconds). Furthermore, radar return signals are processed electronically for any reflections that might represent targets. Detection of a target by radar is, therefore, automatic and does not require human interpretation to distinguish a target from the background.

On the other hand, infrared and optical systems--known as passive systems--are typically limited to viewing a small sector (45°, for example) at a time, and generally do not scan the entire 360°. Furthermore, signals are not processed electronically, nor targets identified automatically. Rather, an image like a television picture is produced, and a crew member must constantly watch the screen to see if a target appears. Thus, should a target appear somewhere besides where the sensor is looking, or should a target appear on the screen and the crew member not recognize it as such, a helicopter could go undetected.

A partial solution to the limitations of passive systems--limited coverage and nonautomated target recognition--would be to provide information on target presence and general location to the air defense units equipped with passive sensors. In this way, the passive sensors could be pointed in the correct direction and crew members alerted to the presence of a target. This process, called "cueing" or "alerting," obviously requires input from some system that can automatically detect targets appearing anywhere within 360°. One approach would be to deploy a small number of radars with a much greater number of air defense units (for example, eight radars per 36 or 72 air defense units) to alert the air defense weapons when an air attack commenced.

With cueing, passive systems should be able to respond to an air attack as reliably and quickly as those equipped with radar, although the cost of providing cueing radars would also have to be taken into account. Therefore, the ability of different weapon systems, which rely variously upon radar, FLIRs, optical systems, or unaided eyesight, to detect low-altitude helicopters out to ranges of seven km was assumed to be roughly equal.

Second, air defense missiles or anti-aircraft rounds must reach the helicopter before it completes its task and remasks. The time needed to react to a detected helicopter, pull the trigger, and fly the missile or bullet to the helicopter, was assumed to be about the same for all systems considered. Furthermore, all systems were assumed to react quickly enough to engage all potential targets.

Finally, the bullet or missile must arrive at the target and explode, causing lethal damage. This analysis assumed that, given an engagement opportunity within a system's effective range, all the systems studied had a roughly equivalent likelihood of destroying the target.

The total number of engagements is still a useful measure even if all these assumptions are not strictly valid. Differences in detection capability, reaction time, and munition effectiveness do, of course, exist among specific weapons systems. These differences, however, would be of no consequence if the weapon were not in position to detect and engage the attacker in the first place. Further, since the measure defined here is used only to establish relative performance of various force mixes, small differences among specific systems would not affect the respective rankings.

Non-Line-of-Sight Air Defense Systems. The measure of effectiveness used in this analysis assumes that an enemy helicopter must see its target in order to attack it and, conversely, that the air defender must see the helicopter to engage it. This measure obviously would not be appropriate for an air defense system that did not have to see its target (helicopter or fighter bomber) in order to engage it. Although the Army does not currently have such a system in its inventory, it does have prototypes of a missile capable of attacking targets behind hills or trees. While such a "non-line-of-sight" (NLOS) air defense system might be readily available within the next five to ten years, it probably would not be able to contribute significantly to air defense capabilities during the more immediate period that is the focus of this study.

Another factor arguing against the relevance of a NLOS air defense system to this study is the absence of a Soviet weapon that a helicopter or fighter bomber could deliver without the attacking aircraft's exposing itself. In other words, current Soviet antiarmor munitions require the attacking aircraft to see its target before launching its weapon. Indeed, in the case of the AT-6 antitank missile currently used by Soviet helicopters, the helicopter must guide the missile all the way to impact. This requires that the helicopter maintain line of sight to the target throughout the entire missile flight. Although a missile has been postulated for enemy helicopters that would allow the launching aircraft to remain hidden behind hills while lobbing its missiles at a target designated by some other enemy platform, no mention has been made in unclassified literature of such weapons in the Soviet inventory to date. It is, therefore, unlikely that such a threat would materialize in any significant way before the mid-1990s.

A final facet of NLOS air defense systems that raises questions concerning their utility and places them outside the scope of this study is their need for general target-location information that would have to be furnished by a source other than the weapon system itself. 2/ The NLOS systems typically envisioned (and currently under study by the Army) would include a missile with some sort of seeker in its nose. The missile would be launched to the general vicinity of the target, where its integral seeker--radar or television, for example--would locate the target and guide the missile to impact.

In order to place the missile in the vicinity of the target, however, some general knowledge of the target's location would be needed. Therefore, some other sensor (an airborne radar is the one most commonly mentioned) would be required to support the NLOS air defense weapon system by initially locating the attacking aircraft. Furthermore, the information concerning the target's presence and location would have to be transmitted from the sensor to the NLOS air defense system in a timely manner. Thus, an efficient command and control system linking the sensor and air defense unit would also be required. The additional sensor and command and control network that would be required to make such a NLOS system feasible would provide the enemy with many opportunities for countering the system, such as destroying or "spoofing" the sensor or jamming communications links.

Capability Against Fixed-Wing Aircraft. Measuring potential engagements against hovering helicopters does nothing to evaluate a force's capability against fixed-wing aircraft. As previously stated, however, the Soviet Union--like the United States--seems to be increasing its attack helicopter inventories but not those of its ground-attack fighter bombers. In addition

2. An exception to this would be when attacking a helicopter that exposes itself for a short time and then remasks before the air defense weapon can respond. Alternative air defense solutions to remasking helicopters are shorter reaction times and faster missiles.

TABLE 3. EFFECTIVE RANGES OF CURRENT WEAPON SYSTEMS

System	Number in Task Force a/	Maximum Effective Range Against Hovering Helicopter (in kilometers)	Assumed Distance from Front Line (in kilometers)
M1 Tank	19	2-2.5	0.5
Bradley and ITV	30	3.75 (TOW)	1.0
Stinger	4	3-4	1.0
Vulcan	4	1.2	1.5
Scout Helicopter	5	None	0-0.5

SOURCE: Compiled by the Congressional Budget Office from Army data contained in various sources (see source for Table 2 on p. 25).

a. Based on the scenario used in the recent Army analysis of DIVAD alternatives, TRASANA, *Sgt. York Comparative Analysis* (October 1985).

to growing numbers, hovering standoff helicopters hold the tactical advantage over fighter bombers when attacking armored units near the front lines. Therefore, quantitative comparisons of various air defense forces based on antihelicopter capability are adequate if augmented with qualitative comparisons of effectiveness against fixed-wing aircraft.

Capability of Battalion-Sized Forces

A typical front-line, battalion-sized unit would be composed of a maneuver element containing tanks and fighting vehicles supplemented by some air defense and helicopter assets. Such a combat unit, known as a battalion task force, today might include, among other weapons, 19 M1 tanks, and 30 Bradleys and ITVs, as well as four Vulcans and four Stingers for air defense and five scout helicopters. 3/ The maximum range capability of these weapons against hovering helicopters is tabulated in Table 3.

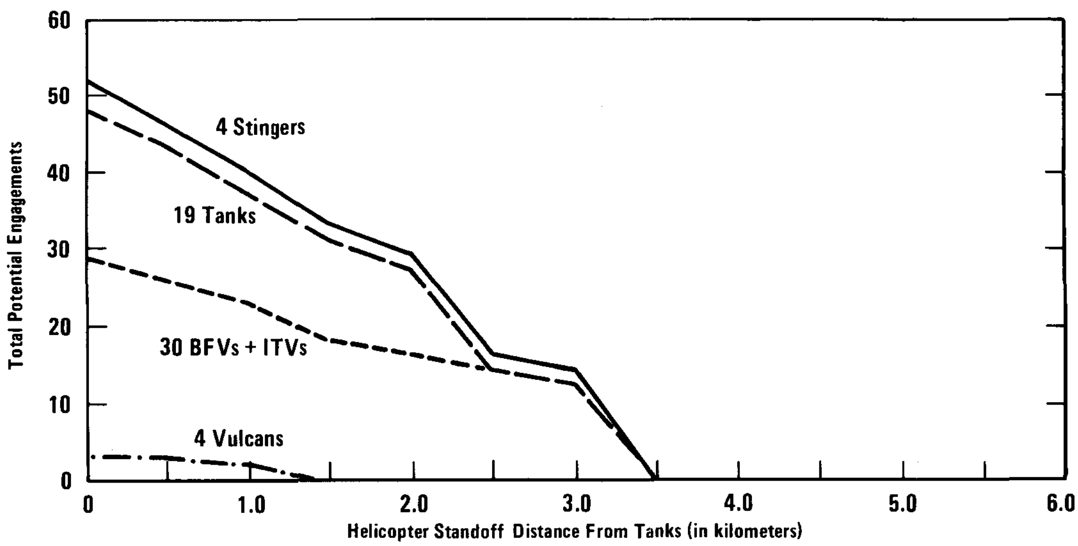
The total number of engagements that a task force composed of these weapons might have against helicopters hovering at an altitude of 20m rapidly diminishes as the standoff range of the helicopter increases (see Figure 8). With no standoff distance--that is, with the helicopter hovering directly over the target tanks--almost all of today's weapons with some air

3. Based on the battalion task force used in the Army analysis of DIVAD as reported in Department of the Army, Tradoc Studies and Analysis Agency (TRASANA), *Sgt York Comparative Analysis* (October 1985).

defense capability theoretically could engage an attacking helicopter. Under the assumptions used in this study, this would lead to a total of 52 potential engagements. As the attacking helicopters move off, however, the proportion of deployed weapons that would have line-of-sight to the aircraft, and, therefore, have a chance to see them, rapidly diminishes. Indeed, at a standoff range of one km, helicopters could be engaged by only 40 out of the total 57 weapons included in the task force. As the helicopters increased their standoff range to three km, they would be outside the reach of both the Vulcan and the tanks' guns, thus reducing the total potential engagements to 14. If enemy helicopters could standoff at ranges greater than three km and continue to attack tank formations, none of today's weapons would be able to engage them. The limited ranges of Stinger and Vulcan, in particular, in combination with the requirement that they be situated behind the most forward armor elements for their own protection,

Figure 8.

Potential Engagements of Hovering Helicopters with Current U.S. Weapons



SOURCE: Congressional Budget Office.

NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

would afford enemy helicopters an operational sanctuary at ranges between three and six km from the armored formations they would be attacking. 4/

Although not captured in the measure used here, the performance of current U.S. air defense systems, particularly Stinger and Chaparral, against fighter bombers would be much better. These two missile systems could provide a more effective defense against fighter bombers because they have a greater effective range against fixed-wing aircraft than hovering helicopters and because high-speed fighter bombers with today's weapons must come within one to two km of the armored targets they are attacking. While this is an important qualitative capability of today's systems, helicopters currently pose the greater threat.

Indeed, it was partly DIVAD's inability to defend U.S. assets from standoff helicopter attack that resulted in its demise. The need for a weapon system or systems to counter this challenging threat still exists. The next chapter examines several alternatives for improving the Army's ability to defend against standoff helicopter attack.

4. Chaparral would be situated too far to the rear to be able to engage enemy helicopters operating from their side of the front line.

CHAPTER IV

AIR DEFENSE ALTERNATIVES FOR THE MANEUVER ELEMENTS

In the previous chapter, the Army's current air defense systems were found to be deficient in defending against potential attacks by enemy helicopters armed with long-range missiles. This deficiency can be explained in part by the reliance on 20-year-old, limited range systems like Vulcan and Chaparral for air defense. The Army's modernization program, which planned to replace Vulcan with the new longer-range DIVAD gun, was seriously derailed by DIVAD's cancellation in August 1985. The Army believes, therefore, that the need for improved air defense is urgent. In light of this perceived need, this study considers only those systems that are currently available or might be available within five years. This time constraint limits candidate systems to those already in service with other nations, or at least in prototype stage.

CANDIDATES FOR DEDICATED AIR DEFENSE

Candidate systems capable of providing air defense for the maneuver units within the next five years can be divided into three general categories: anti-aircraft guns, missile systems, and hybrids. All would be dedicated solely to the air defense mission.

Guns

Anti-aircraft gun systems typically are equipped with one or two guns whose barrels have an inner diameter of 30 to 40 mm. They also usually include an acquisition and tracking radar to enable the gun to be aimed accurately at long-range or fast moving targets. Anti-aircraft guns are usually mounted on a chassis with tracks rather than wheels to facilitate movement over rough terrain. Besides the cancelled DIVAD, other modern versions include the 35mm Gepard (developed in Switzerland and in service with West German forces), and two guns not yet in service--the 30mm Wildcat (developed in West Germany) and the 40mm Trinity (developed by Bofors, a Swedish firm). The maximum effective ranges attributed to these weapons are generally four kilometers. Their costs would most likely be similar to that of the DIVAD gun, so that buying them in large numbers would require a large investment.

Missiles

Several air defense missile systems are either in service with other nations (for example, Roland with West German forces and Rapier with the British) or exist as prototypes (such as ADATS developed by a Swiss firm). These systems typically include a radar for target detection, optical or radar systems to track targets once detected, and various means for guiding the missile to the target. 1/ Most of these missile systems have sufficient range to destroy helicopters that must see their target to attack it. Furthermore, none of these systems rely upon the target's heat emissions for guidance and are, therefore, more resistant to countermeasures than Chaparral or Stinger.

All missile systems, however, require time after they have been launched to stabilize and come up to speed. Thus, they have a minimum effective range within which they cannot engage aircraft, otherwise known as a "dead zone." This might or might not be a significant problem when defending against standoff helicopters. When the cost of the accompanying missiles is taken into account, missile systems are at least as expensive as large, self-propelled, radar equipped anti-aircraft guns, requiring the same large investment for the purchase and deployment of large numbers.

Hybrids

Hybrid systems attempt to combine the advantages of gun systems and missile systems in one unit. They typically combine a small caliber gun (20 to 25mm) or hypervelocity rockets (unguided rockets capable of speeds in excess of 1,500 meters per second) with a simple missile, such as Stinger, or a small laser beam rider (for example, the Saber missile developed by Ford or the Bofors RBS-70 in use with the Swedish Army). In this way, the gun or rockets can cover the missile's inner dead zone, and the missiles can extend the range of the system beyond the gun's capability. Furthermore, systems such as General Electric's Blazer and Boeing's Avenger (which are two

1. The Roland and the Rapier missiles are like the previously described Soviet AT-6 antitank missile, in that they are directed to their targets by commands from the gunner to the missile transmitted by a radio link. ADATS is directed to its target by a laser beam shone on the target by the gunner in the fire unit. Rather than home in on laser light reflected from the target, these missiles, known as "laser beam riders," have laser detectors on their tails that can tell the missile if it is in the center of the laser beam. If not, the missile corrects itself by moving back into the middle of the beam and, thus, heads in the direction of the target.

TABLE 4. CAPABILITIES OF CANDIDATE AIR DEFENSE SYSTEMS

Capability b/	Guns (Trinity, Gepard, Wildcat)	Missiles (ADATS, Rapier, Roland)	Hybrids a/ (Blazer)
Sufficient Range (7 to 8km)	No	Yes	Yes
Cheap and Capable of Being Fielded in Large Numbers (Relative to DIVAD)	No	No	Yes
Rapid Destruction Capability	Yes	Yes	Yes
Guided to Target	No	Yes	Yes
Resistent to Counter Measures	Yes	Yes	Yes (w/missile other than Stinger)
Night Capability	Yes	Yes	Yes

SOURCE: Congressional Budget Office.

a. Mounted on a lightly armored chassis similar to the Bradley.

b. All systems are mobile and protected from small arms fire and artillery fragments.

prototype hybrid systems) generally rely on passive means for target acquisition, thus avoiding the cost of a radar. 2/ As a result they could be relatively cheap ($1.5 million to $2 million each), compared with DIVAD's $6.4 million unit price tag and a minimum of $4 million for most other gun or missile systems. Thus, it could be more feasible to buy them in large numbers.

Assessment of Candidate Air Defense Systems

When measured against the eight critieria identified in Chapter II--sufficient range, ability to field in large numbers (thus low cost), rapid destruction capability, guidance to target, resistance to countermeasures, nighttime capability, mobility, and light armor protection--air defense guns that might be available within five years fail to meet three out of eight (see Table 4). The primary shortcomings of anti-aircraft guns are their limited

2. Passive means for detecting targets include infrared sensors such as FLIRs, television cameras, and magnified optics.

range and high cost. The misssile systems have sufficient range, accuracy, and night capability and are relatively resistent to countermeasures. They too are very costly, however, and would be expensive to deploy in large numbers.

If a hybrid system were equipped with a missile that did not rely on infrared guidance (for example, a laser beam rider or one with a fiber optic command link) to avoid the possibility of infrared decoys or signature suppression, it could theoretically meet all of the outlined criteria. 3/ Although typically not equipped with radars, the individual firing units do include passive sensors such as FLIRs. When cued and alerted by early warning radars included in the divisions, even without radars, hybrid firing units should be able to detect most targets. 4/

The advantages of a hybrid system appear to be minimal for three reasons. First, the armored and mechanized divisions already include over 300 25mm guns on Bradley Fighting Vehicles. Although each individual Bradley might not be very effective against attacking helicopters, the combined impact of 300 guns would probably be more intimidating than that of the guns included on the smaller number of hybrids that would ultimately be included with each division. Secondly, the range or dead zone within which most missile systems are ineffective is at most one km. This is also the range in which a 20 or 25mm gun is most effective. It is unlikely, however, that attack helicopters would approach so closely to air defenses that are set back at least one km from the maneuver units. Furthermore, opportunities to engage attacking aircraft would occur before the aircraft approached to such short ranges. Thus, the synergistic effect of combining a gun and a missile on the same platform might be small. Lastly, the addition of a gun and its associated ammunition to a weapon system would add, unnecessarily perhaps, to the complexity and cost of that weapon. These factors, in turn, could add to the cost of purchasing and deploying sufficient numbers of a hybrid system.

IMPROVING THE AIR DEFENSE CAPABILITIES OF SYSTEMS WITH OTHER PRIMARY MISSIONS

The candidates discussed above were all dedicated to the air defense mission. Increasing the antihelicopter effectiveness of weapons with other

3. This analysis assumes that the hybrid system would not include Stinger.

4. Army divisions currently include eight Forward Area Alerting Radars (FAARs) for detecting attacking aircraft.

primary missions is another means of upgrading a division's capability to counter attack helicopters. As outlined previously, several of the systems included in a heavy division's inventory, although not designed to attack helicopters, could do so. Some rather simple modifications to the division's tanks, fighting vehicles, and scout helicopters could enhance their effectiveness against enemy helicopters without significantly degrading their ability to perform their primary mission.

Tanks

The ammunition used by main battle tanks is designed for maximum effectiveness against enemy tanks and fortified positions. As a rule, it must strike an object before detonating or causing any damage. Most munitions designed for use against aircraft include fuzes that cause the warhead to detonate if it comes close enough to sense the aircraft's presence.

Equipping tanks with some ammunition armed with proximity fuzes would improve their ability to destroy hovering helicopters at longer ranges without having to improve the accuracy of the gun itself. 5/ Because tank rounds designed for use against helicopters would not be very effective against armored vehicles, the majority of a tank's standard load would continue to be the type of ammunition currently used. Furthermore, because of the inherent inaccuracy of a tank's main gun, its ability to destroy helicopters, even with a special round, would probably not extend beyond three km; thus, tanks alone could not totally negate the projected standoff capability of Soviet helicopters.

Bradley Fighting Vehicles and Improved TOW Vehicles

The TOW antitank missile on both the Bradley Fighting Vehicle (BFV) and older Improved TOW Vehicle (ITV) is potentially a very effective weapon against hovering helicopters. Because the TOW receives commands from a wire attached to its tail and connected to the launching vehicle, however, both its range and speed are limited by the amount of wire that can be stored within the missile and the rate at which it can be played out. Removing this limitation by converting the missile's guidance to one that relies upon either a laser beam or radio frequency command link could increase the missile's range to at least seven km and its speed to Mach 2.

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5. The Army is investigating a new tank round that would be effective against both helicopters and tanks. However, this round is still under development and is not likely to be available in large numbers in the next five years.

Equipped with such a missile, the BFV and ITV would be able to negate the standoff capabilty of any Soviet helicopters likely to be deployed during the next decade.

Of course, without a specialized sensor, each individual fighting vehicle's ability to detect aircraft might be limited. Nevertheless, replacing the current TOW missile entirely with a new longer-range, faster missile would provide each fighting vehicle with an impressive self-defense capability against attacking helicopters.

Scout Helicopters

Each heavy division currently includes 44 scout helicopters whose missions are to assist the division's 36 attack helicopters by locating targets and to provide target acquisition and fire direction for the division's field artillery. The scouts attempt to operate close to or forward of the friendly forces closest to the front. Because of their position on the battlefield and elevation above the terrain, scout helicopters would be in a good position to see enemy helicopters when they attack. In fact, by hovering at an altitude of 20 meters, scout helicopters close to the front would have a 26 percent better chance to see a hovering helicopter six km away than would ground air defenses (see Figure 9).

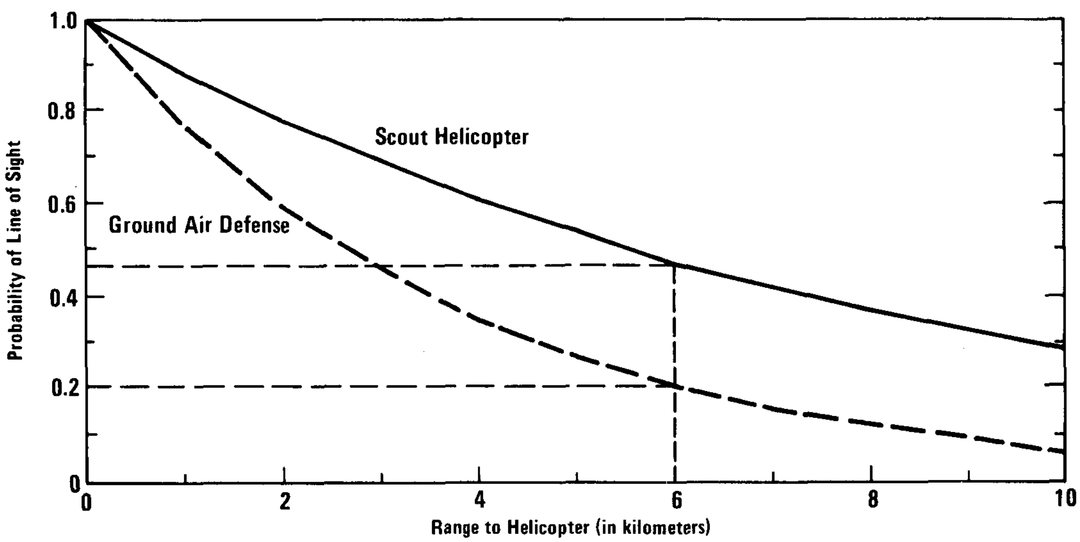
Equipping scout helicopters with air-to-air missiles would enable them to attack enemy helicopters they encounter. Furthermore, because the Soviets are equipping their helicopters with air-to-air missiles, it would also provide U.S. helicopters with the ability to defend themselves. As was the case for ground-based air defense missiles, however, the missile added to the scouts should not be susceptible to countermeasures and should have a six to seven km range against hovering helicopters. These requirements would tend to argue against an infrared missile such as Stinger and for one relying on a laser beam or other means of guidance that is relatively resistant to countermeasures.

AIR DEFENSE ALTERNATIVES

Army Plans

The Army, recognizing the need to remedy the sparcity of air defenses against enemy standoff helicopters, has earmarked funds and begun a five-part program to improve its air defense, and in particular its antihelicopter capability. (See the appendix for a detailed discussion of these plans.) One part of the Army's improvement plan for air defense would modify its scout helicopters so that they could launch air-to-air missiles. The costs of this program--which would provide only launchers for 720 scouts, and not the accompanying missiles--over five years would be $163 million. The second part, the so-called "Air Defense System, Heavy" (ADS, H) program, is also designed to improve air defense for the Army's maneuver elements. The purpose of the ADS, H program is to field, as soon as possible, a system to perform the mission for which the DIVAD was intended--that is, successfully destroy hovering enemy helicopters at their operating ranges. The Army has allocated almost $1.4 billion over the fiscal years 1987-1991 period for this program. The Army has not, however, decided what specific system to procure to fulfill the ADS, H role, or how many of these systems it wishes to buy. Thus, it is impossible to determine now whether the funds the Army has allocated for this program could provide enough capable systems to protect the forward maneuver elements.

Figure 9.
Probability of Unobstructed View of Hovering Helicopter at Altitude of 20 Meters



SOURCES: Congressional Budget Office from data contained in U.S. Army Material Systems Analysis Activity (AMSAA), *Air Defense Air-to-Ground Engagement (ADAGE) Simulation* (May 1978); and Department of the Army, TRADOC Studies and Analysis Agency (TRASANA) *Advanced Optical Study* (June 1982).

The total amount allocated for these two programs in the President's budget for fiscal year 1987 was $1.5 billion (in fiscal year 1987 dollars) over the 1987-1991 period. This represents about 1.5 percent of the funds included in the President's budget for total Army procurement for the same five-year period (see Table 5).

CBO Alternatives

CBO examined four alternative ways of combining the weapon system candidates to improve the Army's forward air defense capability. This list is by no means exhaustive. Rather, the alternatives were choosen to illuminate four decidedly different ways of improving, within five to ten years, the Army's ability to protect maneuver units from airborne attack.

The four alternatives and their main characteristics are summarized in Table 6. They run the gamut from retaining improved versions of today's

TABLE 5. FUNDS PROJECTED BY THE ARMY FOR AIR DEFENSE AND TOTAL ARMY PROCUREMENT (By fiscal year, in millions of fiscal year 1987 dollars of budget authority)

	1987	1988	1989	1990	1991	Total 1987-1991
Helicopter Air-to-Air Capability	29	42	48	45	0	163
Air Defense System, Heavy	9	63	298	516	486	1,372
Total, Air Defense	38	105	346	561	486	1,535
Total Army Procurement	18,600	20,400	20,300	20,600	21,500	101,400
Air Defense Funds as Percent of Total Army Procurement	0.2	0.5	1.7	2.7	2.3	1.5

SOURCE: Compiled by the Congressional Budget Office from Army data.
NOTE: Numbers may not add to totals because of rounding.

systems (Alternative I) to placing the responsibility for air defense of the maneuver elements totally upon systems with other primary missions supplemented by small shoulder-fired systems similar to the current Stinger (Alternative IV). Alternatives II and III would take more orthodox approaches by replacing existing dedicated systems with new ones. Alternative II would replace the current Vulcan systems with three times as many chassis-mounted simple missile systems (CMMSs) or hybrid systems. Alternative III would replace Vulcan with a new, sophisticated, more capable missile system. All four alternatives would equip the Army's scout helicopters with air-to-air missiles capable of destroying enemy helicopters at long range since this appears to be a desirable addition under all approaches. The following sections provide a detailed discussion of the benefits of each alternative, in terms of increased battalion-level helicopter engagements, and the associated costs. 6/

Alternative I--Improve the Capability of Current Systems

The main shortcoming of the air defense systems currently included in the Army's heavy divisions is their limited range against hovering helicopters. As was pointed out earlier in the chapter, none of the weapons likely to be included today in a battalion task force has the ability to engage enemy helicopters attacking U.S. tank formations from ranges greater than three km. Although some of the range limitations are inherent to the weapon systems themselves (for example, Vulcan) and cannot be easily remedied, some improvement to the battalion's overall capability is possible at modest cost.

Description. Several modifications for Vulcan have been proposed by the Army in its Product Improved Vulcan Air Defense System (PIVADS) program. These include providing the system with an infrared sight (thereby enabling it to operate at night), upgrading Vulcan's fire control computer, and replacing the current ammunition with a new, improved 20mm round. Such modifications could extend the range of the system from its current 1.2km to as much as 1.75km. This, of course, would still be insufficient to counter enemy helicopters standing off from the armor formations at ranges greater than 0.75 km.

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6. The costs provided for each of the alternatives are presented merely for comparative purposes. Since most of the systems included in the alternatives are not currently being purchased by the U.S. government, it is impossible to determine their exact cost. The unit procurement costs used to estimate the total cost associated with each alternative were based on the cost of surrogate systems or contractor estimates.

Another simple modification to present systems--which the Army has proposed in its five-year plan--would be to equip the division's scout helicopters with air-to-air (AA) missiles. The required range of such missiles would be about six to seven km against hovering helicopters, which would exceed Stinger's maximum range. The Army would, therefore, need to acquire a new missile for this role. Small missiles employing some guidance other than infrared--such as the RBS-70 or Saber laser beam rider missiles--have been developed and could be adapted for use on helicopters. Long-range versions of the Saber or the RBS-70 could have a range of about five to seven km against hovering helicopters and could also be used against

TABLE 6. SUMMARY OF AIR DEFENSE ALTERNATIVES

	Systems Per Division a/		
Description	Area Rear	Area Forward	Air Defenses Shoulder-Fired
Alternative I-- Improve Current Systems	24 Chaparral	24 PIVADS b/	60 Stinger
Alternative II-- Deploy Many Simple Systems	18 Chaparral	72 CMMS c/ 8 Alerting Radars	None
Alternative III-- Deploy Fewer New Sophisticated Systems	24 Chaparral	36 Missile Systems with Radar	None
Alternative IV-- Provide Tanks and Fighting Vehicles with Air Defense Capability	24 Chaparral	New Tank Round, New Missile for BFV and ITV d/ 8 Alerting Radars	60 New Missile Teams

SOURCE: Congressional Budget Office.

a. Each alternative also includes 44 scout helicopters with air-to-air missiles.
b. PIVADS = Product Improved Vulcan Air Defense System.
c. CMMS = Chassis-mounted simple missile system.
d. BFV = Bradley Fighting Vehicle; ITV = Improved TOW Vehicle.

fixed-wing aircraft; however, the feasibility of using a helicopter-mounted missile to engage fixed-wing aircraft is unknown.

This alternative would also retain 24 Chaparral units per division for rear area defense of supply and command posts and 60 Stinger teams for protection against fighter bomber attacks. This option could require about 150 more soldiers than the 626 personnel that the Army now plans for the air defense battalion included in each of the heavy divisions.

Capability. Alternative I would result in a modest increase in the battalion task force's total number of potential engagements of an enemy helicopter. When compared with the current capability versus helicopters with one to three km standoff ranges, implementing the alternative could add three to four potential engagements for a relative increase of 10 percent to 25 percent. Perhaps more important, at ranges beyond three and one-half km--where there is essentially no current capability at all--this alternative would provide the modest ability for three potential engagements (see Figures 10 and 11).

No established criterion exists to determine how many potential engagements are needed in order to have a reasonable level of confidence in the level of air defense provided by a battalion task force. The greater the number of potential engagements, however, the less chance an attacking helicopter has of destroying its target. Furthermore, the measure in this study examines only **potential** engagements. Some might not be realized because a number of air defense units might be busy engaging other targets; other opportunities would be missed because of an air defense unit's failure to detect an attacker in the cluttered and confusing battlefield. Thus, the potential for three engagements, while certainly better than nothing, is not reassuringly large.

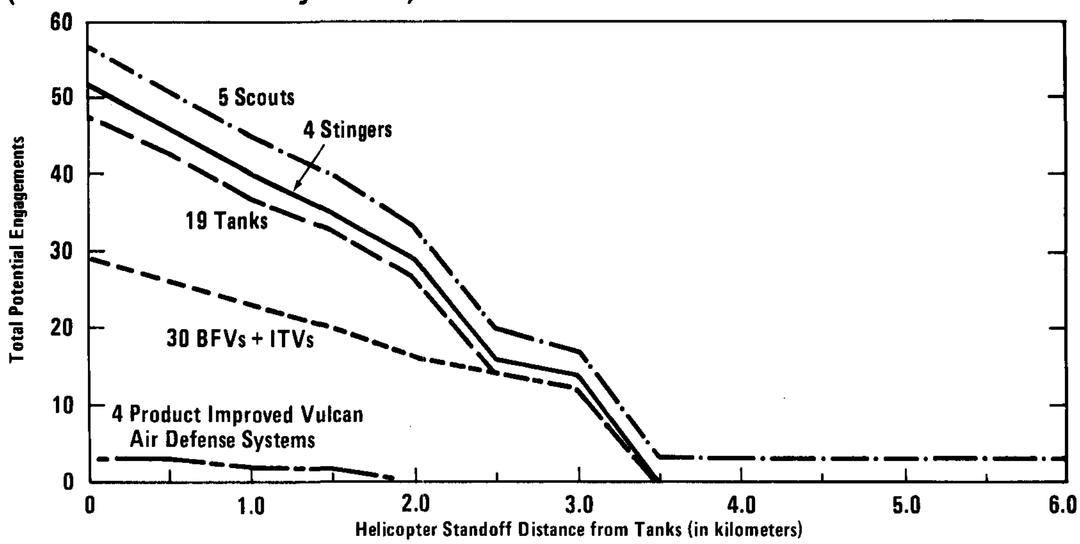
All the added capabilty for this alternative would result from providing air defense capability to the scout helicopters. Chaparral would be stationed too far back to engage attacking helicopters. Vulcan, Stinger, the fighting vehicles, and the tanks would still, as is the case today, have insufficient range to engage helicopters beyond three km.

While the increased capability under this option is modest, Army analyses have shown that, in the absence of any other air defense improvements, equipping U.S. scout helicopters with air-to-air missiles could significantly reduce U.S. losses to enemy helicopter attack. 7/ In

7. U.S. Army TRADOC Studies and Analysis Agency (TRASANA), *Sgt York Alternatives Analysis* (October 1985).

Figure 10.

Potential Engagements of Hovering Helicopters Under Alternative I (Enhance Current Systems)

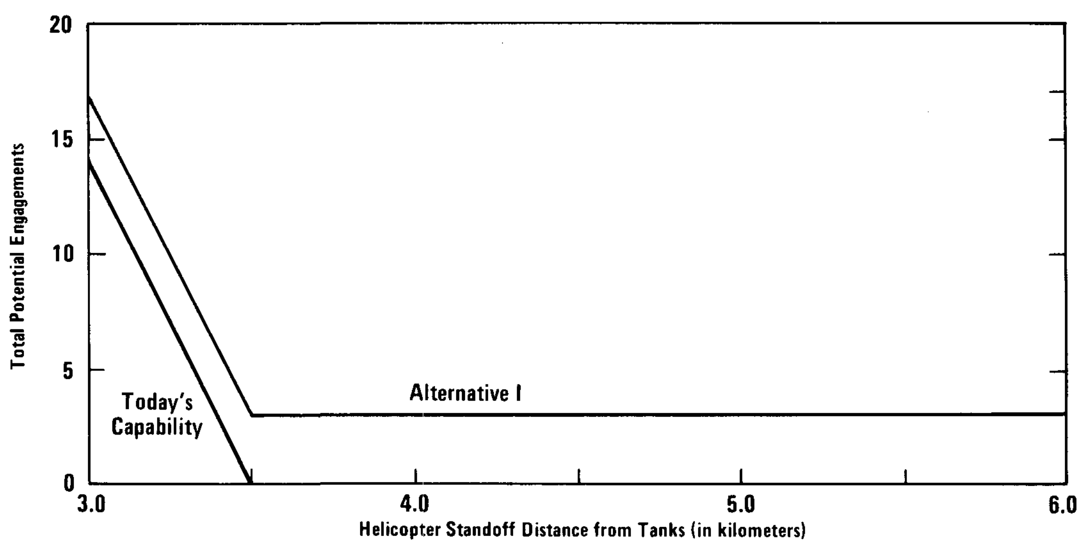


SOURCE: Congressional Budget Office.

NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

Figure 11.

Comparison of Potential Engagements of Hovering Helicopters with Today's Systems and Those Included in Alternative I



SOURCE: Congressional Budget Office.

NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

addition, although not quantified in this analysis, the four Stinger missile teams included in the battalion task force should provide adequate air defense against attacking fighter bombers.

Cost. This option has the additional advantage of modest cost. Total investment cost would amount to $430 million (in 1987 dollars of budget authority). Most of this cost would arise from equipping scout helicopters with air-to-air missiles, estimated to be about $380 million. The remaining cost would be associated with the PIVADS program to improve Vulcan's performance. There could also be modest increases in operating costs. The alternative would require 150 additional personnel for each heavy division's air defense battalion, or 1,500 for the Army as a whole. As a result, annual operating costs could increase by $26 million.

Some of these costs are already included in the Army's budget. For example, the Army plans to modify its scout helicopters as proposed in this option (see Table 5). Furthermore, the cost to improve Vulcan is less than that currently programmed for the Army's ADS, H program. As a result, adoption of this alternative could result in a net savings of $1.1 billion in the Army's planned air defense spending over the next five years (see Table 7). (All dollars amounts are in 1987 dollars of budget authority.)

Drawbacks. Despite its modest cost, this option has two key drawbacks. Under this option, the only system capable of engaging attacking helicopters standing off at ranges over three km would be the scout helicopters whose primary mission is **not** air defense. It may make sense to give the scouts some air defense capability, as the Army is planning to do, because they are in a good position to see enemy helicopters. But an option that relied solely on scout helicopters for its long-range air defense would risk problems if the scouts were occupied in their primary mission of identifying targets for U.S. attack helicopters and field artillery. Second, two 20-year-old systems, Vulcan and Chaparral, would be retained. Both require relatively large crews (four and five, respectively) and Vulcan is of questionable utility because of its limited range.

Alternative II--Deploy Large Numbers of Simple Air Defense Systems

Given the age of its current short-range air defense systems, the Army will undoubtedly wish to replace them with modern systems, despite the cost. Any new systems fielded by the Army will be designed to have an effective range that is sufficient to destroy standoff helicopters. The second requirement for achieving an effective air defense--as discussed in the second chapter--calls for large numbers of dispersed systems. This

TABLE 7. COST OF ALTERNATIVE I COMPARED WITH CURRENT ARMY FIVE-YEAR PLAN (By fiscal year in millions of fiscal year 1987 dollars of budget authority)

	1987	1988	1989	1990	1991	Total 1987-1991	To Complete	Total Cost
Army's Plan a/	38	105	346	561	486	1,535	b/	b/
Alternative I	33	104	117	119	58	430	0	430
Change from Army plan	-5	-1	-229	-442	-428	-1,105	b/	b/

SOURCE: Congressional Budget Office.

NOTE: Numbers may not add to totals because of rounding.

a. Includes the Army's program to add air-to-air missiles to 720 scout helicopters and the new Air Defense System, Heavy program--essentially a replacement for DIVAD.

b. These numbers cannot be calculated since a specific Air Defense System, Heavy weapon has not yet been selected.

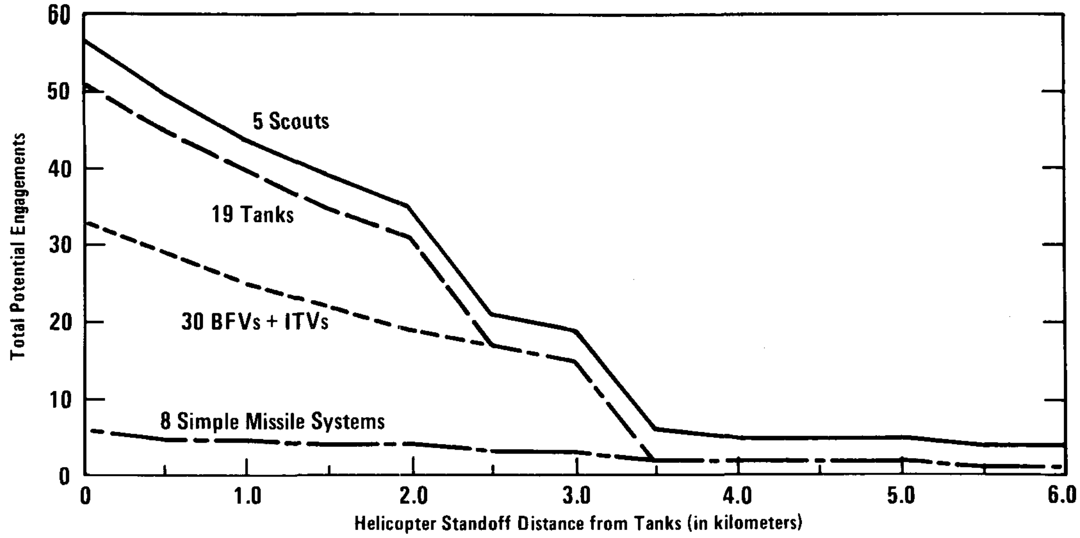
alternative seeks to fill this requirement at reasonable cost by equipping each division with a large number of relatively simple missile systems. These systems would then be able to complement the air defense contribution made by the scout helicopters equipped with AA missiles that are also included in this option.

Description. This alternative would replace the 24 Vulcan anti-aircraft guns currently assigned to each armored and mechanized division with three times as many simple air defense systems to be used for air defense of the forward area. The simple systems envisioned would not use radars but would incorporate passive sensors (such as FLIRs) to acquire targets. New alerting radars, based on the Army's current TPQ-36 counter mortar radar, would be deployed, eight per division, to notify the air defenses of impending attack. The main armament of the system would be a missile--not Stinger or any other missile with infrared guidance--that would have at least a seven km range against hovering helicopters. It would rely on a fiber optic cable or laser beam for transmission of guidance signals to the missile and, thus, be relatively resistant to countermeasures. The system could also include a small caliber gun or hypervelocity rockets, if they could be incorporated into the system cheaply. Finally, the weapon would be mounted on a lightly armored chassis--such as the Bradley--with tracks, rather than wheels, to provide it with more mobility and some protection in the forward area where it will operate. These systems, referred to as "chassis-mounted missile systems" (CMMS) in this study, could be a hybrid of developed or existing systems. A combination of the RBS-70 or Saber missiles, the Bradley Fighting Vehicle chassis, and the 25mm GAU-12 Gatling gun currently on the Marine's Harrier aircraft is an example of a typical hybrid. The inclusion of 72 CMMSs within each division would enable eight air defense units to accompany each battalion task force.

This option, like the first alternative, would equip scout helicopters with air-to-air missiles and retain Chaparral in the division for protection of rear area command posts and other stationary assets, although it would provide just 18 per division rather than the 24 included in the other three options. Unlike the previous option, this alternative would include no shoulder-fired air defenses, such as Stinger. (See Table 6 for a summary of the characteristics of the options.)

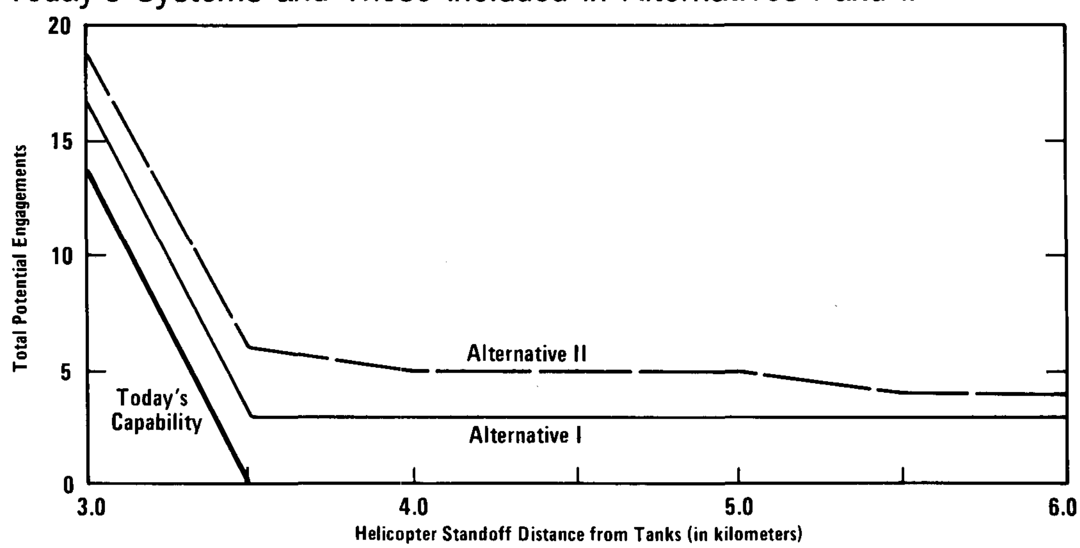
Capability. The addition to each heavy division of 72 air defense weapons capable of engaging hovering helicopters out to ranges of seven km would greatly increase the engagement potential of a battalion task force (see Figure 12). The improvement over today's capability at ranges from one to three km could be two to three more potential engagements, an increase of

Figure 12.
Potential Engagements of Hovering Helicopters Under Alternative II (Deploy Large Numbers of Simple Systems)



SOURCE: Congressional Budget Office.
NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

Figure 13.
Comparison of Potential Engagements of Hovering Helicopters with Today's Systems and Those Included in Alternatives I and II



SOURCE: Congressional Budget Office.
NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

20 percent to 40 percent. More significantly, the combination of scout helicopters and CMMSs could yield as many as four or five engagements of helicopters attacking from ranges of four to six km. This is four or five more than is currently possible and one-third to one-half more engagements than in Alternative I (see Figure 13). Furthermore, two different systems--the CMMSs and scout helicopters--would be capable of engaging helicopters attacking from ranges greater than three km. This combination would greatly complicate the enemy helicopter's mission and attempts to survive. With respect to the threat from fixed-wing aircraft, the combination of Chaparral and another missile system should be able to provide adequate defense against fighter bombers.

Cost. The total investment cost to implement this alternative could be $3.2 billion, with $2.2 billion required during the period from 1987 through 1991, and $1 billion more in the years thereafter. The largest portion of the investment funds would be required to procure sufficient numbers of chassis-mounted missile fire units and missiles ($2.5 billion). Some additional cost ($0.7 billion) would be associated with providing scout helicopters with air-to-air missiles and each division with eight new alerting radars. Since it is unlikely that the large number of systems needed to implement this alternative could be produced by 1991, the program to acquire new CMMS systems probably would not be completed until the mid 1990s. Thus, the accompanying costs would be spread out over this longer period (see Table 8).

The costs for this alternative would exceed by $836 million the funds allocated by the Army over the next five years for those programs most directly related to forward area air defense (see Table 8). This would represent a 41 percent increase in the level of the Army's effort for forward area air defense, but only about a 0.8 percent increase in the Army's total procurement budget for the fiscal year 1987-1991 period. Additional funds totaling almost $1 billion would be required after fiscal year 1991; the Army has not yet identified funds for forward area air defense beyond 1991. (All dollar amounts are in 1987 dollars of budget authority.)

Operation costs should not change significantly under this option. Elimination of 60 shoulder-fired (Stinger) air defense teams from each division would provide the additional personnel required for the 72 CMMSs without increasing the size of the division's air defense battalion. Indeed, a savings of about 90 personnel per division, or 900 people Army-wide, could be realized, for a small yearly savings of $15 million.

Drawbacks. The air defense capability provided by this option would be an improvement over that currently available in the forward area of the Army's

TABLE 8. COST OF ALTERNATIVES I AND II COMPARED WITH CURRENT ARMY FIVE-YEAR PLAN (By fiscal year, in millions of fiscal year 1987 dollars of budget authority)

	1987	1988	1989	1990	1991	Total 1987-1991	To Complete	Total Cost
Army's Plan a/	38	105	346	561	486	1,535	b/	b/
Alternative I	33	104	117	119	58	430	0	430
Change from Army plan	-5	-1	-229	-442	-428	-1,105	b/	b/
Alternative II	65	241	417	779	680	2,171	985	3,156
Change from Army plan	+61	+136	+71	+216	+194	+836	b/	b/

SOURCE: Congressional Budget Office.

NOTE: Numbers may not add to totals because of rounding.

a. Includes the Army's program to add air-to-air missiles to 720 scout helicopters and the new Air Defense System, Heavy program--essentially a replacement for DIVAD.

b. These numbers cannot be calculated since a specific Air Defense System, Heavy weapon has not yet been selected.

divisions, especially at long ranges, and also over the capability provided by Alternative I. On the other hand, the costs associated with achieving the capability in this alternative would be four to five times those required for Alternative I.

Alternative III--Deploy Small Numbers of a New and Sophisticated Forward Air Defense System as a Replacement for Vulcan

As mentioned previously, the Army is currently relying on two 20-year-old systems to provide a large part of the air defense for its heavy divisions. This alternative would modernize the heavy division's air defenses by replacing the Vulcan anti-aircraft gun. The new system would have an effective range of seven to eight km against hovering helicopters, thus extending air defense coverage out six to seven km beyond the front line. In addition, each Vulcan would be replaced by 1.5 new systems, raising the total number of forward area air defense systems in each division from 24 to 36 (excluding Stinger teams).

This option would not provide the large numbers of systems that Chapter II argued are important for an effective air defense. It would, however, provide systems that are highly capable individually, and, thus, would be effective against helicopters at greater ranges. Of the four options in this study, this one most closely follows the approach of the Army's DIVAD program.

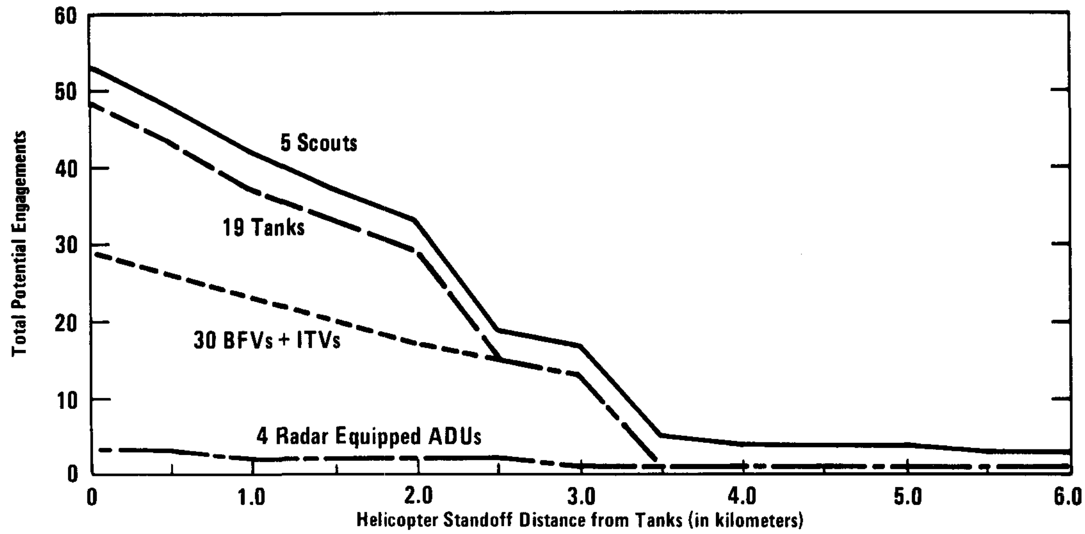
Description. Specifically, this alternative would replace the 24 Vulcans currently assigned to each heavy division with 36 forward area missile systems equipped with acquisition radars, mounted on lightly armored vehicles with tracks, and capable of long-range helicopter engagements (for example, systems like Rapier, Roland, or ADATS). Scout helicopters would, as in the other alternatives, carry air-to-air missiles. No shoulder-fired missile systems would be included in this alternative.

Capability. This alternative could add three to four total potential engagements to today's capability at ranges from four to six km. The added capability would come from the scout helicopters and radar-equipped forward missile systems.

When compared with the air defense capability provided in previous alternatives, however, this one would fall below Alternative II (see Figures 14 and 15). This shortcoming would occur because Alternative II includes twice as many ground-based air defenses as this alternative. This result does not automatically mean that this approach would be less effective than

Figure 14.

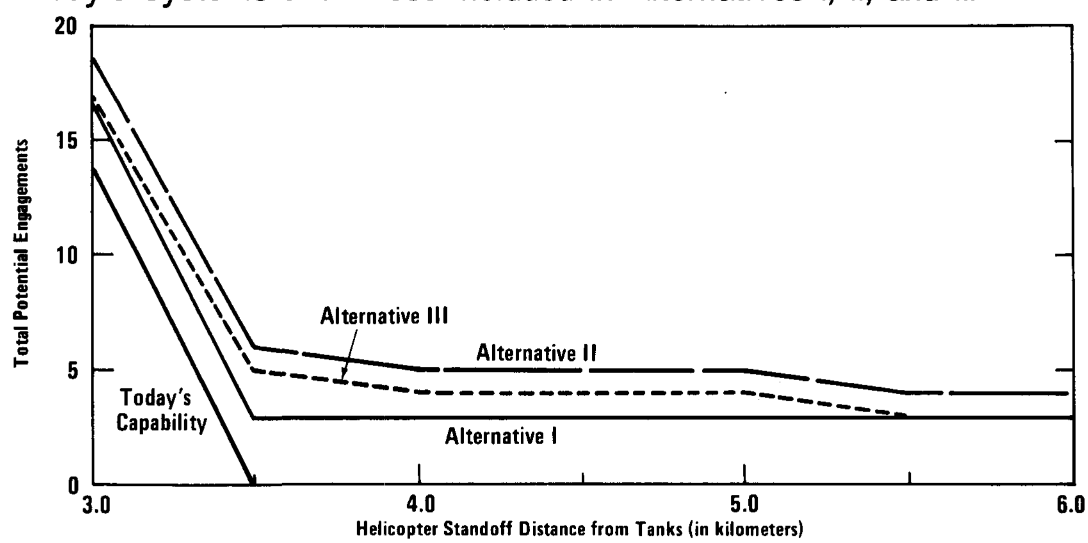
Potential Engagements of Hovering Helicopters Under Alternative III (Deploy Small Numbers of Sophisticated Systems)



SOURCE: Congressional Budget Office.
NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

Figure 15.

Comparison of Potential Engagements of Hovering Helicopters with Today's Systems and Those Included in Alternatives I, II, and III



SOURCE: Congressional Budget Office.
NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

Alternative II with its many simple systems. None of those simple systems included a radar, which would enable automatic detection of targets at long ranges, over a wide sector, and in adverse weather. Coupled with the powerful missile provided by this approach, a radar could allow earlier engagement of attacking high-speed, fixed-wing aircraft than systems contained in other options. The Army has repeatedly stated that it needs this capability to meet the assumed threat. 8/

These advantages, however, might be of secondary importance. The radar's ability to operate in all types of weather might add little extra capability because enemy aircraft might not fly in bad weather or might be forced to use extremely disadvantageous tactics (such as flying higher or coming very close to their targets). Furthermore, the hilly terrain in Central Europe limits the ability of radar to detect low-altitude targets at long range. Finally, this option's increased capability against fixed-wing aircraft, while important, is less compelling because helicopters appear to pose the most demanding potential threat.

Cost. Moreover, the total investment cost required to implement this alternative could be more than $4 billion, with $3.2 billion needed during the next five years (see Table 9). The bulk of this amount would be spent to purchase the radar-equipped forward air defense units and associated missiles ($3.9 billion), with $0.4 billion more to provide air-to-air capability and missiles for the scout helicopters. No additional manpower would be required to implement this option; indeed, as in the last option, about 100 fewer people per division--or 1,000 throughout the Army--would be needed. Thus, an annual operating savings of $17 million could be realized.

As with the previous alternative, implementation of and funding for this alternative would stretch beyond 1991 (see Table 9). Furthermore, funds above those allocated by the Army to forward area air defense would be required--$1.7 billion during the fiscal years 1987-1991 period. This would represent more than a doubling of the funds currently earmarked for air defense and about a 1.7 percent increase to the Army's total procurement budget for 1987-1991. In addition, slightly over $1 billion

8. Statement of Lt. Gen. Donald R. Keith, USA, to the Senate Armed Services Committee, 97:1, March 5, 1981, pp. 1298, 1380, 1422; Statement of Maj. Gen. Louis G. Menetrey, USA, to the Senate Armed Services Committee, 97:2, March 3, 1982, p. 2125; Statement of Dr. Jay R. Sculley, accompanied by Lt. Gen. James H. Merryman, to the Senate Armed Services Committee, 98:1, March 10, 1983, pp. 1899, 1937, 1939, 1940; and Statement of Lt. Gen. Louis C. Wagner, Jr., USA, to House Armed Services Committee, 99:1, March 7, 1985, pp. 397, 398, 466.

TABLE 9. COST OF CBO ALTERNATIVES I, II, AND III COMPARED WITH CURRENT ARMY FIVE-YEAR PLAN (By fiscal year, in millions of fiscal year 1987 dollars of budget authority)

	1987	1988	1989	1990	1991	Total 1987-1991	To Complete	Total Cost
Army's Plan a/	38	105	346	561	486	1,535	b/	b/
Alternative I	33	104	117	119	58	430	0	430
Change from Army plan	-5	-1	-229	-442	-428	-1,105	b/	b/
Alternative II	65	241	417	779	680	2,171	985	3,156
Change from Army plan	+61	+136	+71	+216	+194	+836	b/	b/
Alternative III	29	419	735	1,050	989	3,221	1,055	4,276
Change from Army plan	-9	+314	+389	+489	+503	+1,686	b/	b/

SOURCE: Congressionnal Budget Office.

NOTE: Numbers may not add to totals because of rounding.

a. Includes the Army's program to add air-to-air missiles to 720 scout helicopters and the new Air Defense System, Heavy program--essentially a replacement for DIVAD.

b. These numbers cannot be calculated since a specific Air Defense System, Heavy weapon has not yet been selected.

would be required after 1991 to complete the program. (All dollar figures are in 1987 dollars of budget authority.)

Drawbacks. The obvious drawback associated with this alternative is its low return for a relatively large investment cost. Although it would cost more, the total number of air defense systems fielded under this approach would actually be less than under Alternative II, and even Alternative II did not provide a reassuringly large number of engagements against each attacker.

Alternative IV--Improve the Air Defense Capability of Systems with Other Primary Missions

This alternative takes a different approach to improving the forward air defense. Rather than fielding any new vehicle-mounted system dedicated solely to air defense, this option would improve the air defense potential of the more than 700 fighting vehicles already within the heavy divisions. These weapons are primarily intended to attack ground targets. By equipping each weapon within a maneuver element with some capability for self-defense from air attack, however, this approach would create a force with the potential for a large number of engagements.

Description. To give the Bradley and Improved TOW Vehicles the ability to engage hovering helicopters out to six to seven km, a longer-range antitank missile would replace the TOW missile that is currently part of the fighting vehicles' armament. A missile designed primarily to defeat armor, but using a different means of guidance or command transmission, should also be able to destroy hovering helicopters at this longer range. Similarly, this alternative would provide the tanks within the division with ammunition designed to be effective against helicopters. As in Alternative II, eight new alerting radars would be included in each division to provide warning and cueing to the tanks and fighting vehicles. Twenty-four Chaparral units would be retained per division to provide air defense for the rear area of the forward portion of the division. A new man-portable missile, with a six to seven km range against hovering helicopters, would replace Stinger. Each of the 60 new missile teams per division would be provided with an infrared sensor for finding targets at night. Finally, as in the three other alternatives, the scout helicopters would be given an air-to-air missile capability.

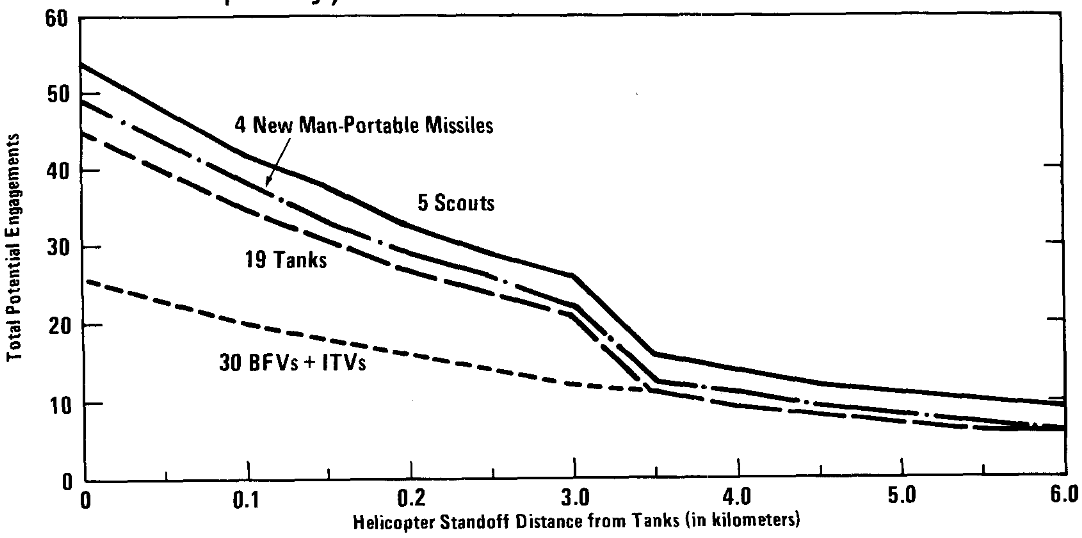
Capability. This alternative could theoretically create as many as 16 potential engagements against hovering helicopters at three and one-half km and nine engagements at six km; no capability exists today at these ranges. Moreover, none of the other options in this study would provide such a large number of potential engagements against attackers beyond three km. Thus, this approach should provide the greatest confidence that, even during a major air attack and amidst all the distractions and demands of the battlefield, most or all attackers could be engaged. Since few new systems would be added to the division's air defenses under this approach and some would actually be removed (that is, the Vulcan guns) very little improvement would be realized at ranges from one to three km. Today's capability at these ranges is already impressive, however.

The vast bulk of the improvement at long ranges would result from providing the Bradleys and ITVs with long-range missiles. Equipping the Army's tanks with an antihelicopter round might increase the tank's ability to engage helicopters somewhat, but it is unlikely that it would enable even the Army's latest tank, the M1, to engage hovering helicopters at ranges much greater than three km. The new man-portable, shoulder-fired missile, capable of engaging hovering helicopters out to six to seven km, would add only another one or two potential engagements to the battalion task force's total. Giving each Bradley and ITV a six to seven km antihelicopter ability, however, could add six to eleven engagements to a battalion task force's total potential engagements at ranges of three and one-half to six km (see Figure 16).

The potential for 9 to 16 engagements per attacker at three and one-half to six km assumes that all the tanks and fighting vehicles would devote their efforts to air defense. It is likely that, when under helicopter attack, a fighting vehicle's primary concern would be self-defense. Thus, this assumption might be reasonable. On the other hand, responsibilities within a task force could be divided so that a given percentage of fighting vehicles, such as 50 percent, would assume an active, though part-time, air defense role, with the remaining fighting vehicles concentrating solely on the ground battle, which is, after all, their primary mission.

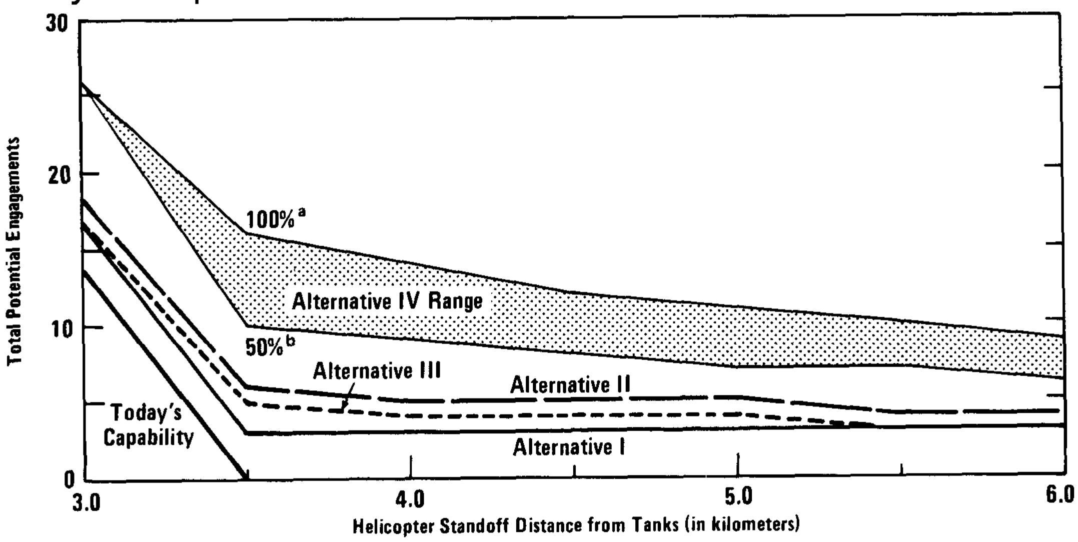
Even with only 50 percent of a battalion's fighting vehicles participating in air defense, the potential helicopter engagements resulting from pursuing Alternative IV are at least 50 percent higher than those attributable to any of the three other alternatives, with six to ten engagements at ranges from three and one-half to six km, where today there are none (see Figure 17). Indeed, if as few as 25 percent of the fighting vehicles participate in air defense, as many engagements as those achieved with Alternative II would be possible. If all the fighting vehicles were provided with improved missiles and took advantage of an antihelicopter opportunity when presented with one, the number of possible engagements would rise to 9 to 16 at ranges from three and one-half to six km.

Figure 16.
Potential Engagements of Hovering Helicopters Under Alternative IV (Providing Tanks and Fighting Vehicles with Improved Air Defense Capability)



SOURCE: Congressional Budget Office.
NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

Figure 17.
Comparison of Potential Engagements of Hovering Helicopters with Today's Weapons and Those Included in Alternatives I, II, III, and IV



SOURCE: Congressional Budget Office.
NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.
[a] All weapons engage helicopters.
[b] One-half of tanks and fighting vehicles engage helicopters.

Cost. The investment cost of achieving such a widespread air defense capability within the Army's maneuver forces could be significant, totaling almost $4 billion with most of the funds required in the next five years and only $0.5 billion required after 1991 (see Table 10). Most of the costs would pay for the purchase of new missiles for the Bradleys and ITVs and for modifying these fighting vehicles to launch the missiles ($2.6 billion). Costs for providing all of the shoulder-fired missile teams with infrared sights could run to $0.7 billion, with another $0.4 billion required to provide the scout helicopters with air-to-air missiles and $0.3 billion for alerting radars. No additional manpower would be needed, however, to implement this alternative; indeed, a savings of about 75 people per division, or 750 people Army-wide, could be realized. Thus, annual operating costs could be reduced by about $13 million.

This alternative would require about $1.9 billion in addition to what the Army has allocated to forward area air defense over the next five years (see Table 10). As in the previous alternative, this amount would represent a doubling in the Army's forward area air defense program, and a 1.9 percent increase in the total Army procurement budget over the next five years. Very little in terms of additional funding--$0.5 billion--would be required beyond 1991, however. (All dollar amounts are in 1987 dollars of budget authority.)

Drawbacks. In this alternative, a task force's ability to defend itself against fixed-wing aircraft would rest solely in the man-portable missile teams and the Chaparral units that would be deployed several kilometers to the rear. This option includes no new dedicated air defense systems, and the tanks and fighting vehicles would probably not be able to attack fast-moving targets.

Furthermore, the same man-portable missile teams provide the only forward area **dedicated** air defense against helicopters. This limitation could result in a lack of forward air defense if battlefield conditions--such as heavy shelling or the use of nuclear or chemical weapons--prevented the unprotected missile teams from performing their mission.

Assigning part of the air defense mission to the fighting vehicles and main battle tanks--a departure from their traditional assignments--could also cause unforeseen problems in training personnel and in command and control. Crews on tanks and fighting vehicles would have to be trained in air defense as well as ground-attack roles. Furthermore, commanders would have to coordinate the air defense activities of some 50 to 60 weapons (rather than the 5 to 13 air defense weapons contained in the battalion today and in other options). The Army's own plans, however, include upgrading the

TABLE 10. COST OF CBO ALTERNATIVES I, II, III, AND IV COMPARED WITH CURRENT ARMY FIVE-YEAR PLAN (By fiscal year, in millions of fiscal year 1987 dollars of budget authority)

	1987	1988	1989	1990	1991	Total 1987-1991	To Complete	Total Cost
Army's Plan a/	38	105	346	561	486	1,535	b/	b/
Alternative I	33	104	117	119	58	430	0	430
Change from Army plan	-5	-1	-229	-442	-428	-1,105	b/	b/
Alternative II	65	241	417	779	680	2,171	985	3,156
Change from Army plan	+61	+136	+71	+216	+194	+836	b/	b/
Alternative III	29	419	735	1,050	989	3,221	1,055	4,276
Change from Army plan	-9	+314	+389	+489	+503	+1,686	b/	b/
Alternative IV	198	552	860	1,002	865	3,468	480	3,948
Change from Army plan	+160	+447	+514	+431	+379	+1,930	b/	b/

SOURCE: Congressional Budget Office.
NOTE: Numbers may not add to totals because of rounding.

a. Includes the Army's program to add air-to-air missiles to 720 scout helicopters and the new Air Defense System, Heavy program--essentially a replacement for DIVAD.

b. These numbers cannot be calculated since a specific Air Defense System, Heavy weapon has not yet been selected.

air defense capabilities of its tanks and fighting vehicles, although probably not on as many vehicles as under this option. 9/ It is possible, therefore, to assume that the Army believes it can surmount whatever organizational or training problems might accompany an increased air defense role for the infantry and amored assets in the divison. Aside from these important but unquantifiable drawbacks, this alternative would provide the air defense posture with the greatest potential.

CONCLUSIONS

The various alternatives considered in this chapter would provide varying improvements to the Army's forward air defense at varying costs (see Table 11). The option that upgrades existing systems (Alternative I) would provide the least improvement at the least cost. Alternatives III, II, and IV would provide air defense systems of decreasing sophistication and individual capability but in increasing quantities. Alternative III would equip each division with 36 very capable air defense systems. The result would be slightly greater overall air defense capability than the first alternative, but at the highest investment cost of all the options considered. Alternative II would provide twice as many simpler air defense weapons to each divison. Although individually these simple air defense systems would not be as capable as the systems included in Alternative III, the overall air defense capability of a battalion task force would be greater. Furthermore, the costs associated with Alternative II would be less than those of Alternative III.

Finally, Alternative IV would equip every tank and fighting vehicle within a battalion task force with some ability to defend itself from helicopter attack. The resulting tanks and fighting vehicles would individually be less effective air defense weapons than the systems in Alternative II and III. They would, however, be present in much higher numbers than in any of the other options. As a result, this last alternative would provide the greatest number of potential engagements. The cost for attaining such a widespread capability would fall somewhere between those of Alternatives II and III.

9. See the appendix which outlines the Army's plan to upgrade its forward area air defenses.

TABLE 11. PERFORMANCE AND COST OF FOUR ALTERNATIVES

Alternatives	Potential Engagements a/ 1km	Potential Engagements a/ 5km	Air Defense Units b/ Sophistication	Air Defense Units b/ Number Per Division	Investment Cost (In billions of 1987 dollars of budget authority)
Today's Capability	40	0	Low	24	N.A.
Improve Current Systems (Alternative I)	45	3	Low	24	0.4
Deploy Many Simple Systems (Alternative II)	44	5	Moderate	72	3.2
Deploy Fewer New Sophisticated Systems (Alternative III)	42	4	High	36	4.3
Provide Tanks and Fighting Vehicles with Air Defense Capability (Alternative IV)	42	7-11	Low	About 700	3.9

SOURCE: Congressional Budget Office.

NOTE: Numbers may not add to totals because of rounding.

a. At specified helicopter standoff range.

b. Forward Ground-Based Systems Excluding shoulder-fired (man-portable) missiles.

APPENDIX

APPENDIX

THE ARMY'S PLAN FOR FORWARD AREA AIR DEFENSE

In the wake of the DIVAD cancellation in August 1985, the Army initiated a study to determine the best way to improve the air defense of the forward areas of its divisions. As a result of the insights gained from the study, the Army has developed a five-part plan to provide the requisite air defense. The plan includes (1) improving the command and control of the various air defense assets within the division; (2) developing and fielding a missile system that can destroy enemy aircraft that are hidden by trees, hills, or buildings (a Non-Line-of-Sight System); (3) fielding a new air defense system for the rear half of the forward area, about 5 to 15 km from the front line; (4) fielding a new air defense system for protection of the manuever elements (a DIVAD replacement); and (5) upgrading the air defense capability of the tanks and fighting vehicles within the division.

Improved Communication. Communication among various air defense assets in the division is now very poor. The first item of the plan is designed to improve information sharing among the division's various air defense assets. In this way, all air defense systems could be alerted to the presence of air attackers earlier than is currently possible. A possible component of this part of the overall plan would be development and deployment of new early warning sensors, both airborne and ground-based. The total estimated cost in current dollars of this portion of the plan, as presented in hearings before Congress, is $2.5 billion, $0.7 billion of which is for development. The program, as defined now, would provide each of the Army's 18 active divisions with six early warning sensors.

Non-Line-of-Sight System. Helicopters that can attack targets without allowing themselves to be seen by the target may be a significant threat in the future. This portion of the plan would develop and field a system capable of attacking aircraft that it cannot see. It would, therefore, be dependent to some extent on execution of the first part of the overall plan, since any weapon system designed to attack a target that it cannot see must have a general idea of the target's location. Thus, some other system, such as the airborne sensor mentioned above, would be needed to find the target in the first place. Assuming that some means is available for determining general target location, this non-line-of-sight system is designed to fly to the general area of the target and then by means of a sensor (TV or radar) in the missile's nose, find the target and destroy it. The

Army's current candidate for this mission is a fiber optically guided missile (FOG-M) with a TV in its nose that broadcasts what it sees back to the launching platform through a fiber optic cable. The funding currently planned over the next five years for this program is $0.8 billion in current dollars ($0.7 billion in fiscal year 1987 dollars). The Army admits, however, that this is not enough to procure the 18 units per division that the Army ultimately plans to field.

Rear Area System. Army units not immediately on the front line also need defense against air attack. The third part of the program will develop and field a Stinger missile launcher mounted on a truck as a replacement for Chaparral. Because Pedestal Mounted Stinger (PMS), as this system is called, is not sturdy enough to be deployed close to the front, it will remain in the rear half of the forward area. The Army plans to spend slightly over $4.8 billion in current dollars to procure enough PMS vehicles to field 36 per heavy division and to buy the accompanying Stinger missiles.

Forward Area System. Defense of units along the front, the ones most exposed to enemy air attack, is a major goal of the Army's air defense plan. The program for the forward area system, referred to as "Air Defense System, Heavy," (ADS, H) most closely corresponds to the former DIVAD program. It is designed to field quickly 36 air defense systems per division for protection of the maneuver elements. Although the Army has not yet decided on a specific system, it has outlined general requirements for the system, such as initial deliveries in 1989, range sufficient to counter the standoff helicopter threat (about eight km), and a mixture of guns and missiles. This last requirement is not specific as to whether guns and missiles must be on the same platform, a combination of platforms, or in conjunction with the guns on the tanks and fighting vehicles. The Army has $1.5 billion in current dollars--$1.4 billion in fiscal year 1987 dollars--earmarked as part of a program to field a new system to defend the maneuver elements of the heavy divisions.

Upgrade Division Tanks, Fighting Vehicles, and Scout Helicopters. Finally, the Army's program would improve the air defense capability of some of the other systems within the division. This upgrading is desirable because they form the bulk of the weapons in the division. Prime candidates for such improvements would be the M1 tank, by developing an antihelicopter round and the Bradley Fighting Vehicle, by modifying its fire control system to accommodate aerial targets.