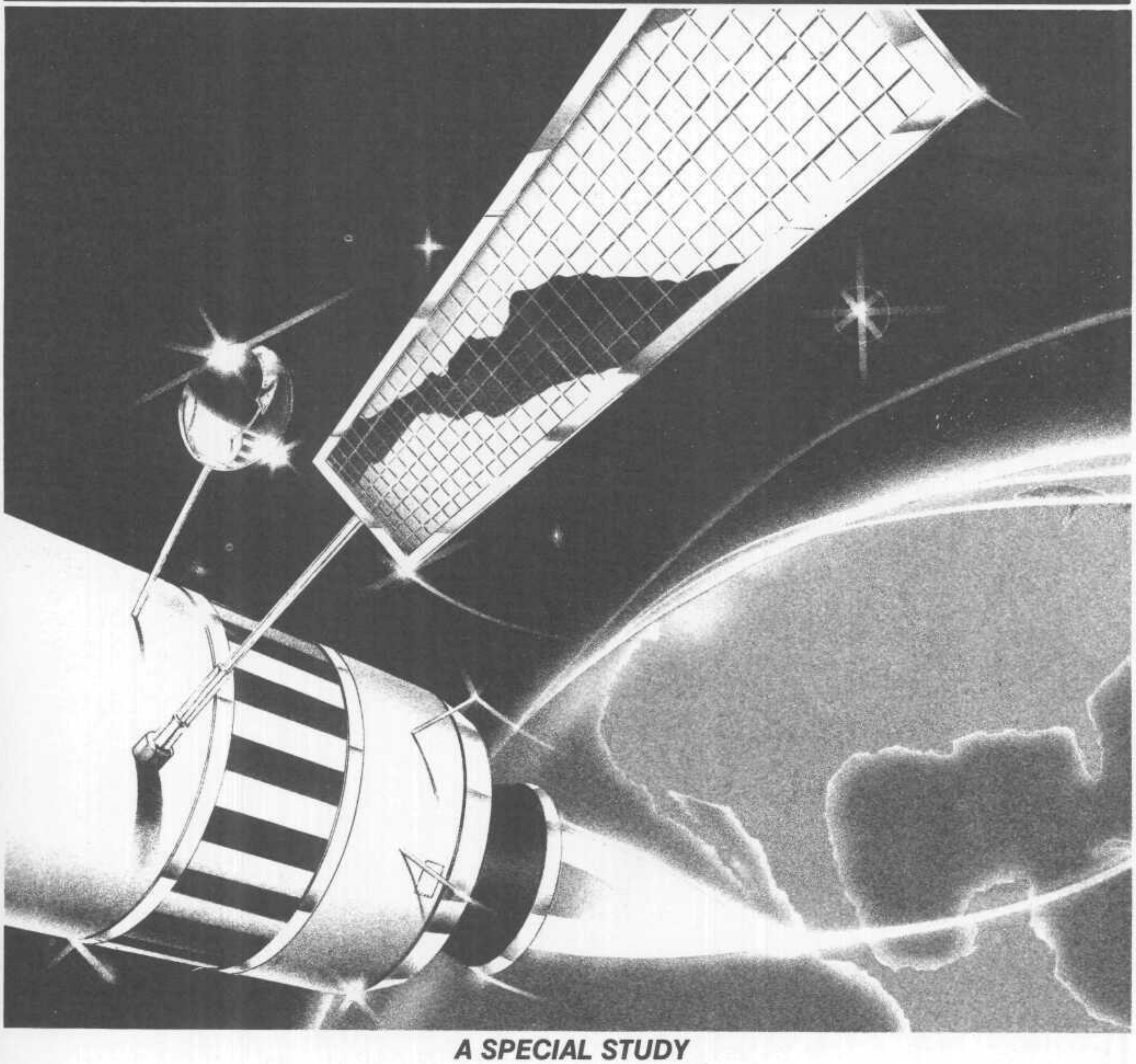
CONGRESS OF THE UNITED STATES
CONGRESSIONAL BUDGET OFFICE

JUNE 1989

Strategic Defenses: Alternative Missions and Their Costs



A SPECIAL STUDY

CBO Publication
#492

S U M M A R Y

June 1989

CBO STUDY ON ALTERNATIVE MISSIONS AND BUDGET FOR STRATEGIC DEFENSES

If total defense budgets continue to be limited, the Congress may consider sharply lowering the Administration's request for Strategic Defense Initiative (SDI) research. This could require a change in mission. A special study by the Congressional Budget Office (CBO), *Strategic Defenses: Alternative Missions and Their Costs*--prepared at the request of Congressman John Spratt, formerly head of the SDI Panel of the House Committee on Armed Services--examines the cost of the Administration's proposal and three alternative missions for research on strategic defenses.

The Bush Administration proposes spending $4.6 billion in 1990, and $31 billion over the next five years, on SDI research and development (costs are in 1990 dollars). These funds would develop an initial system of defenses designed to provide limited protection against a large nuclear attack by the Soviet Union. The Administration estimates that acquisition of this Phase I system would cost $74 billion, most of which would be spent after 1994.

In this study, the least costly alternative to the Administration's proposal--the *hedge mission*--would be limited to guarding against the effects of a possible Soviet deployment of a widespread system of strategic defenses. This mission would involve research on defenses but no deployment. In 1990, costs would range from $1.9 billion to $2.6 billion. Over the next five years, costs for such a mission would range from $11.3 billion to $14.5 billion--between one-third and one-half of the proposed Administration budget.

A second alternative, the *accidental launch protection mission*, would also provide some protection against a small accidental or unauthorized launch of ballistic missiles. It would develop and deploy a small system of defenses intended to be compatible with the ABM Treaty. Costs would amount to $2.6 billion in 1990 and total about $17 billion between 1990 and 1994. Procurement costs would total $4.2 billion, with most spending occurring after 1994.

The third alternative, in addition to providing the capabilities of the other missions, would *protect silo-based ICBMs*, thought to be increasingly vulnerable to Soviet attack. Increasing ICBM survivability by defending ICBMs would not necessarily be more costly than other methods, such as deploying mobile missiles, although mobile missiles would provide more certain protection than defenses. Defending ICBMs would cost $2.7 billion in 1990 and $18.4 billion over the next five years. Costs to complete procurement beyond 1994 would total $10.9 billion.

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Washington, D.C. 20515

STRATEGIC DEFENSES: ALTERNATIVE MISSIONS AND THEIR COSTS

The Congress of the United States
Congressional Budget Office

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

NOTES

All years referred to in this report are fiscal years unless otherwise indicated.

All costs are expressed in fiscal year 1990 dollars of budget authority unless otherwise indicated.

PREFACE

From its inception, the Strategic Defense Initiative (SDI) has been a controversial program. Critics and supporters have argued vehemently over the goals of the program and its chances of success. Under Administration plans, SDI also promises to become increasingly expensive during a period when the total defense budget may grow by little or, perhaps, be further reduced. Thus, the Congress will continue to confront difficult choices: how much to spend on SDI research and, if budgets are to be held down, which of various alternative SDI missions to pursue.

This special study seeks to inform the Congressional debate on the SDI by analyzing four alternative missions, which vary widely in their costs and in the defense capability that would result. In keeping with the mandate of the Congressional Budget Office (CBO) to provide objective analysis, the report does not recommend any particular course of action.

The study was prepared at the request of Congressman John M. Spratt, Jr. At the time the request was made, Mr. Spratt was the Chairman of the SDI Panel of the House Committee on Armed Services

Bonita J. Dombey of CBO's National Security Division wrote the report under the general supervision of Robert F. Hale and John D. Mayer, Jr. The author wishes to acknowledge the valuable assistance of Frances Lussier, Elizabeth Chambers, G. Wayne Glass, Murray Ross, and William P. Myers of CBO. The author also wishes to thank several people outside CBO who provided thoughtful comments on earlier drafts of the study, including Ashton B. Carter, Sidney D. Drell, Sidney N. Graybeal, Thomas H. Johnson, and Cindy Williams. CBO, however, takes full responsibility for the final product. Finally, the author wishes to thank many others within the strategic defense community who gave generously of their time and expertise. Francis S. Pierce edited the manuscript. Nancy H. Brooks provided production support. Rhonda Wright typed the drafts, and Kathryn Quattrone prepared the report for publication.

Robert D. Reischauer
Director

June 1989

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INTRODUCTION AND SUMMARY

To deter nuclear war, the United States today relies almost entirely on the ability of its offensive strategic forces to retaliate against an aggressor. In March 1983, President Reagan initiated a new approach to nuclear deterrence: he stated that the United States would attempt to develop defenses against nuclear weapons that would effectively protect the citizens of the United States and its allies from a large nuclear attack. In so doing, the President hoped to deter potential aggressors by rendering their attacks ineffective rather than by threatening them with retaliation.

To work toward this goal, the Department of Defense established a broad program of research, which it labeled the Strategic Defense Initiative (SDI). From its inception, the SDI has been highly controversial. Many would agree that if a system of strategic defenses could provide effective defense of populations, it would revise the basis of nuclear deterrence in ways that would be reassuring. That the research performed to date has achieved some important technological advances is conceded even by the stoutest critics of SDI. Nevertheless, even ardent SDI advocates agree that major technological problems remain ahead, and that population defense on a large scale is still only a distant possibility. Moreover, if the United States were to deploy any large-scale system of defenses, it would have to renegotiate or abrogate the existing Anti-Ballistic Missile (ABM) Treaty--another drawback in the minds of many critics.

Work on strategic defenses has already been costly, and promises to become even more so. Since 1984, about $17 billion has been spent on SDI research in the Department of Defense, and over the next five years the Bush Administration proposes to spend an additional $31 billion for research and development. (Except where noted, all costs are in 1990 dollars. The commonly quoted five-year budget request of $33 billion includes an allowance for future inflation.) The costs of deploying and operating a large system could amount to tens or hundreds of billions of dollars. Most costs of deployment would occur in the late 1990s and beyond.

FOUR MISSIONS COMPARED

Even in the next few years, the Congress may consider sharply lower spending for research on strategic defenses than the Administration is planning to request--especially if total defense budgets continue to be limited. Major reductions in funding for strategic defenses would probably require altering the mission for the program. To assist the Congress in its deliberations, this paper examines the levels of spending for strategic defenses that would be consistent with four missions of increasing cost and comprehensiveness: a "hedge" mission, an accidental launch protection system, defense of silo-based ICBMs, and the Administration plan. The paper focuses on the costs of the missions but also briefly discusses their advantages and disadvantages.

A Hedge Mission

The least expensive of the four missions examined in this paper would provide the United States a hedge in case the Soviets were to deploy their own widespread system of strategic defenses. This hedge mission would maintain a technology base and develop, but not deploy, some weapons and sensors. The approach would be designed to be consistent with the existing ABM Treaty. In 1990, costs for such a hedge mission could range from $1.9 billion to $2.6 billion depending on the amounts spent on the technology base (see Summary Table). Over the next five years, total spending would range from $11.3 billion to $14.5 billion--between one-third and one-half of what the Bush Administration proposes to spend for research, development, testing, and evaluation (RDT&E) on strategic defenses.

An Accidental Launch Protection System

Under the second mission, the United States could add to the hedge mission by deploying a small system of strategic defenses. Such a limited system could be designed to defend portions of the United States against a small nuclear attack caused by accident or by unauthorized actions. An accidental launch protection system (ALPS) would be intended to be consistent with the ABM Treaty, though there are some potential conflicts. Costs of research and development of an ALPS and of maintaining a hedge technology base might amount to

$2.6 billion in 1990 and could total about $17.0 billion between 1990 and 1994. Costs of procuring the system of limited defenses would mostly be incurred after 1994 and might total about $4.2 billion.

An accidental launch protection system could provide the United States with some experience in developing and deploying a system of strategic defenses. It could also provide insurance against a limited accidental or unauthorized launch of nuclear weapons, which could otherwise cause great destruction. But critics assert that such an event is highly unlikely. Moreover, an accidental launch protection system

SUMMARY TABLE. SUMMARY OF COSTS OF ALTERNATIVE SDI BUDGET MISSIONS (In billions of 1990 dollars of budget authority)

Mission	1990	1991	1992	1993	1994	Total 1990-1994	Costs Beyond 1994 to Complete Acquisition
			Alternative I				
Maintain a Hedge							
Higher Option	2.6	2.7	2.9	3.1	3.4	14.5	n.a.
Lower Option	1.9	2.0	2.3	2.4	2.7	11.3	n.a.
			Alternative II				
Deploy an Accidental Launch Protection System	2.6	3.0	3.4	3.9	4.0	17.0	4.2
			Alternative III				
Deploy a System to Protect Silo-Based ICBMs	2.7	3.2	3.7	4.4	4.5	18.4	10.9
			Alternative IV				
Bush Administration Plan	4.6	5.2	6.0	7.1	8.2	31.1	N.A.

SOURCE: Congressional Budget Office.

NOTE: Numbers may not add to totals because of rounding.
n.a. = not applicable.
N.A. = not available.

designed to be consistent with the existing ABM Treaty could not protect all of the United States against all types of limited attacks.

A System to Protect Silo-Based ICBMs

A larger system of defenses, under the third alternative, could allow the United States to protect some of its land-based missiles (ICBMs) that are now based in silos. In the 1990s, these ICBMs could in theory be destroyed by a Soviet attack. This alternative depends on certain assumptions about arms control constraints. Without constraints on Soviet offensive forces, defending U.S. ICBMs, if feasible, would likely require a system of much broader scope and cost than envisioned in this alternative. Therefore, this study assumes the limits now under negotiation in the Strategic Arms Reduction Talks (START). However, developing and deploying a system to defend U.S. ICBMs would eventually require abrogation of the ABM Treaty. It is unlikely that the Soviets would agree both to the START limits on strategic offensive forces and the absence of limits on strategic defensive forces. It is conceivable, although perhaps not likely, that alternative limits on strategic defenses compatible with this mission could be negotiated.

In 1990, costs for a system to defend silo-based missiles and to maintain a technology base would be about $2.7 billion, slightly greater than the ALPS alternative. Over the next five years, costs would be somewhat greater than for an ALPS--$18.4 billion. Costs beyond 1994 would be significantly higher--about $10.9 billion.

A system designed to defend ICBMs would be substantially larger than an accidental launch protection system. It could provide the military with more experience in integrating and operating strategic defenses, and industry with more experience in designing and building defensive systems. Such a system would also increase the number of U.S. silo-based missiles likely to survive a Soviet attack. Finally, CBO's analysis suggests that it would not necessarily cost more to increase survivability by defending silo-based missiles than by deploying mobile missiles, which are designed to disperse over wide areas in order to survive an attack.

However, uncertainties would plague a system of silo-based defenses: an attacker might be able to foil the system with countermeasures; a cleverly planned attack might destroy the system without the expenditure of many enemy warheads; and U.S. retaliatory requirements might increase if the Soviets deployed defenses of their own. In view of these uncertainties, other approaches to improving deterrent capability--for example, the addition of mobile missiles--may well be a better way of increasing the numbers of warheads that could survive a Soviet attack.

The Administration Plan

Finally, under the fourth alternative, the Congress could pursue the plan for strategic defenses that was designed by the Reagan Administration and has been modified by the Bush Administration. During the next decade, that plan would develop and begin deployment of a system of strategic defenses designed to destroy a significant portion of an initial Soviet attack. This so-called Phase I system would be followed by subsequent phases providing increased capability. Over the long term it is hoped that the resulting system could effectively defend populations against a large-scale attack. Sometime over the next few years, the United States would have either to withdraw from or renegotiate the ABM Treaty.

To continue its plan, the Bush Administration proposes spending $4.6 billion on strategic defenses in 1990, and a total of about $31 billion over the next five years. According to the Administration, the costs of developing and deploying Phase I would total about $74 billion ($69.1 billion in 1988 dollars), with most of the spending occurring during the latter half of the 1990s. However, the Administration is also exploring the potential of alternative technologies, such as the so-called "Brilliant Pebbles" space-based interceptor concept, in an effort to reduce Phase I costs. The Administration has not estimated the costs of subsequent phases.

(For a comparison of the costs of these four alternative budget missions with SDI costs in the CBO baseline that assumes no real growth in defense expenditures, see Appendix A.)

LIMITATIONS OF THE ANALYSIS

The missions and the budgets presented in this paper are intended to be illustrative, not definitive. In most cases there are other approaches to a particular mission. Costs for the alternative missions are extrapolated from Administration estimates for the costs of systems in Phase I. Administration cost estimates have been refined through many reviews, but are still subject to change as more experience is gained. Costs for the alternatives involve added uncertainties, such as determining how their support costs (command and control, for example) would differ from those of Phase I.

Cost uncertainties also extend to the technology base. For purposes of this study, the technology base includes general research as well as research on specific concepts--up to the point of full-scale development--that are not specifically earmarked for development or deployment in the alternative budget mission. The SDI technology base consists of a large number of research efforts--currently about 340--many of which are interrelated. Hence the cost estimates used in this study for the technology base are inevitably somewhat speculative.

Finally, the alternative missions include systems under development by the Administration for Phase I. There are still many uncertainties as to the capabilities and effectiveness of these systems. Failure to resolve these uncertainties could limit the feasibility of the missions discussed here or affect their costs. In particular, the exoatmospheric missile (called the GBI) under development for Phase I is included in each of the study's alternatives because of the many potential benefits it offers.

These benefits include wide geographic coverage; sufficient time to shoot at a reentry vehicle more than once; immunity to some important countermeasures such as reentry vehicles that can maneuver in the atmosphere and avoid interceptors or frustrate the preferential defense of selected targets; and less concern about reentry vehicles fuzed to detonate on contact with an interceptor, since the resulting nuclear explosions would occur outside the atmosphere. But if an exoatmospheric missile is to function effectively, it must be able to discriminate between reentry vehicles and large numbers of other objects that can be used to foil it. The uncertainties of exoatmospheric discrimination are far from being resolved, and conceivably may never be, since for every technological approach there is likely to be a countermeasure. Depending on the degree of uncertainty and the degree of risk considered acceptable, other systems or approaches may be more appropriate.

CHAPTER I

OFFENSIVE AND DEFENSIVE STRATEGIC FORCES

Any discussion of strategic defenses must begin with a survey of both offensive and defensive forces. The primary mission of U.S. strategic forces has been to deter the Soviet Union (or any other country) from initiating a nuclear war or from using its forces to coerce the United States or its allies. For deterrence, the United States currently relies almost entirely on the threat of retaliation from its offensive strategic forces.

OFFENSIVE STRATEGIC FORCES

Offensive strategic forces are generally those that attack the enemy in its home territory. Should deterrence fail, these offensive forces would be used to persuade the aggressor to cease the attack.

The U.S. strategic offensive arsenal consists of three basic kinds of forces. This "triad" includes:

- Land-based intercontinental ballistic missiles (ICBMs);
- Submarines; and
- Strategic bombers.

Land-based missiles include the older Minuteman II and Minuteman III missiles, and the recently deployed MX missile--all currently deployed in hardened silos that the United States has little confidence would survive a Soviet attack. Submarine-based forces include Poseidon submarines armed with Poseidon (C-3) and (C-4) missiles, and the newer Trident submarines the first eight of which were initially equipped with (C-4) missiles. Strategic bomber forces include older B-52 bombers, which comprise the bulk of the force, along with a small number of FB-111 bombers and the new B-1B bombers. Bombers can carry gravity bombs, short-range attack missiles, and/or longer-range cruise missiles. Cruise missiles can be ground, sea, or air based. Only air-launched cruise missiles carried by strategic bombers, however, are unambiguously considered strategic weapons.

Under current plans for the 1990s, each leg of this triad of offensive forces would continue to be modernized with new systems. The ICBM leg of the triad is to be modernized with missiles on launchers that can move about so as to decrease their vulnerability to attack. With current technology, widely dispersed mobile missiles could be destroyed in an initial attack only by barraging their dispersal area with nuclear warheads in such numbers as to deplete even the Soviet Union's substantial nuclear arsenal. Missiles in silos, by contrast, could be destroyed individually by one or two warheads targeted at each silo.

The bomber leg of the triad is to be modernized with the new B-2 or "Stealth" bomber. The B-2 is designed to evade Soviet radars and so increase the chance of penetrating Soviet air defenses, allowing the bomber to attack targets with gravity bombs or short-range missiles. The bomber force is also being modernized with an advanced "stealth" cruise missile and a new short-range attack missile, the SRAM II. The submarine-based leg of the triad is being modernized with Trident submarines, which are receiving a larger and significantly more accurate missile (the D-5 missile). Eventually all Trident submarines are planned to carry this new missile.

DEFENSIVE STRATEGIC FORCES

With the signing of the ABM Treaty in 1972, the United States greatly reduced its efforts to develop and deploy defenses against strategic weapons. The ABM Treaty allows only a limited deployment of defenses against ballistic missiles. The treaty does not limit defenses against bombers, but the United States chose not to devote many resources to bomber defenses because of the much greater damage that could be inflicted by the Soviet ballistic missile forces.

The current state of affairs is well illustrated by the U.S. military budget. From 1984 through 1988, even with rapid growth in the SDI, the strategic defense budget for the United States--including air defenses against bombers--averaged about $5.6 billion a year. (From

1986 through 1988, SDI research accounted for at least half of that spending, as opposed to spending on defensive forces.) Over the same period, with the United States modernizing its strategic offensive forces, the strategic offense budget totaled about $31 billion a year. (Funding for Command, Control, and Communications is excluded from these calculations.) Clearly, the United States today depends almost entirely on offensive retaliation to deter nuclear war.

The Soviet Union, on the other hand, has always accorded more weight to strategic defenses of all kinds. Indeed, according to the 1987 edition of the Department of Defense's publication *Soviet Military Power*, during the past decade the Soviet Union has consistently spent about equal amounts on strategic offense and defense. A large part of that spending goes to pay for air defenses against the relatively powerful U.S. bomber force.

The Strategic Defense Initiative

In March 1983, President Reagan proposed a new strategy. Rather than rely primarily on the threat of retaliation to deter nuclear attack, he proposed developing defensive forces that would render a nuclear attack ineffective. Indeed, the ultimate goal, which the Bush Administration has not rejected, is to eliminate the threat of offensive forces altogether.

To work toward that goal, the Reagan Administration initiated a broad program of research that it termed the Strategic Defense Initiative (SDI). The SDI focuses entirely on ballistic missiles--that is, on missiles whose warheads or reentry vehicles are lifted into space on rockets and then fall back to earth under the pull of gravitation. Ballistic missiles are considered potential first-strike weapons today because of their speed and accuracy. Eliminating the threat of offensive weapons altogether, however, would also require an effective defense against bombs and missiles carried by ships and aircraft. Defense against these weapons is also very challenging, but would require different approaches. For that reason, the Reagan Administration initiated an Air Defense Initiative (ADI), but so far the ADI has not had the funding or achieved the technological progress of the SDI.

Achievement of an effective defense against ballistic missiles is thought to require a "layered" defense, designed to attack incoming ballistic missiles during several phases of their flight from enemy territory toward the United States. Each phase offers different advantages and disadvantages to a defender.

Phases in a Ballistic Missile's Flight

A ballistic missile's flight is generally divided into four phases: boost, post-boost, midcourse, and terminal.

Boost Phase. In the boost phase, multistage rockets lift a payload of weapons (called warheads or reentry vehicles) through the atmosphere and into space.[1] This phase is completed in three to five minutes, though near-term technologies could shorten the time considerably.

The boost phase is relatively short. Therefore, attacking ICBMs in the boost phase, when they would be far from the defender's territory, would require some space-based components--either the weapons themselves or, perhaps in the future, special mirrors to direct ground-based lasers. There are important advantages to attacking a missile during the boost phase. The missile's hot rocket motors make it very visible to the defender although the hot plume can obscure the body of the missile. It is also accelerating and full of fuel, hence vulnerable. Finally, the missile has not yet dispersed its reentry vehicles (RVs); destroying a multiple-warhead missile means destroying a large number of RVs.

Post-Boost Phase. During the post-boost phase, which currently may last several minutes or more, the post-boost vehicle or "bus" disperses its reentry vehicles. Decoys, and other devices designed to foil defenders and aid RVs in penetrating defenses, may also be dispersed during the post-boost phase. The bus from which they are dispersed uses small rocket motors to drop each RV into its precise trajectory. The bus with its small rocket motors is a much less visible target than the fiery rocket engine used in the boost phase, so the defense requires a differ-

1. A nuclear warhead is the device that explodes and destroys the target. It is encased in the reentry vehicle. Though the terms have technically different meanings, in this study they are used synonymously.

ent sensor to detect it. Destroying a bus in this phase may also result in destroying several RVs.

Midcourse Phase. After the reentry vehicles have been released, they enter the midcourse period of their flight and follow ballistic or freefall trajectories for close to 20 minutes. Much like high-flying baseballs, they climb to the peak of their arc (usually above 1,000 kilometers), then fall back toward Earth and reenter the atmosphere. The midcourse period of flight offers some advantages for a defender. The period is long in duration, and ballistic trajectories are predictable. On the other hand, the defense must identify and track the real RVs, distinguishing them from decoys and other light penetration aids that may far outnumber them. In space there is no atmospheric friction to slow or heat up heavier objects more than the light ones and so help distinguish the RVs. Moreover, they may have to be identified amidst disturbances in the space background caused by nuclear explosions. For all these reasons, finding a practical means of distinguishing RVs from an opponent's countermeasures such as decoys is one of the most difficult technical problems in developing a defense.

Terminal Phase. The terminal phase commences when the RVs reenter the atmosphere at altitudes of about 100 kilometers. The drag of the atmosphere causes them to slow down and heat up. Reentry also destroys all objects not designed to withstand reentry, thus acting as a filter for the defense. But reentry typically lasts only from about half a minute to less than two minutes. The time available to the defender is short, which means that a single interceptor missile can target only a small geographic area and must be very precise in its aim. Sensors and interceptors operating in the terminal phase may also have to cope with the severe physical effects of nearby nuclear detonations from RVs that were not intercepted or that were designed to explode on contact with a defensive interceptor.[2]

Key Systems Discussed in This Paper

Whatever the phase in which it operates, a strategic defense system must have three components. It needs sensors or "eyes" to acquire and

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2. For more information, see Ashton B. Carter and David N. Schwartz, eds., *Ballistic Missile Defense* (Washington, D.C.: The Brookings Institution, 1984).

track potential targets, to discriminate actual targets from other objects, and to assess the damage inflicted by the defense. It must also have weapons that can take information from the sensors and other systems and intercept and destroy the targets. Finally, it must have "brains" to provide real-time information processing, integration, and guidance to all parts of the defense.[3]

This paper discusses a variety of systems, each with its own acronym.[4] Brief descriptions of these systems can best be supplied by defining them in relation to the initial strategic defense architecture envisioned by the Administration. Box 1 summarizes the systems.

The Phase I system approved by the Defense Acquisition Board in October 1988 would provide defenses in the boost, post-boost, and mid-course phases of flight. One system would often operate in more than one phase of a ballistic missile's flight. In the boost phase, the eyes would be provided by the Boost Surveillance and Tracking System (BSTS). BSTS would consist of an array of specially designed satellites in high orbits that would use medium- and short-wave infrared seekers to detect the hot missile launches, acquire and track the missile boosters, and provide an assessment of booster "kills" achieved by defensive interceptors.

A Space-Based Interceptor (SBI) would be used to destroy ballistic missiles during the boost phase. Several SBIs apiece would be carried on satellites orbiting during peacetime. In the event of a nuclear attack, the satellites would fire SBIs that would hit the missile during its boost phase and cause it to explode.

In the post-boost phase, the Space-Based Surveillance and Tracking System (SSTS) would provide the eyes of the system. SSTS is another specially designed array of satellites in a lower orbit than BSTS. During an attack, the SSTS would use long-wavelength infra-

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3. For more information about weapons and sensor technologies, see U.S. Congress, Office of Technology Assessment, Ballistic Missile Defense Technologies, OTA-ISC-254 (U.S. Government Printing Office, September 1985).

4. The word "system" is used on two levels. Some systems, such as sensor systems and weapons systems, are components of an overall strategic defense system or architecture such as the Administration's Phase I system.

BOX 1
STRATEGIC DEFENSE INITIATIVE: KEY ELEMENTS OF PHASE I

System Elements	General Function	Specific Functions	Flight Phase
Boost Surveillance and Tracking System (BSTS)	Sensor	Detect missile launches Acquire and track boosters Assess kills by defense weapons	Boost
Space-Based Surveillance and Tracking System (SSTS)	Sensor	Acquire and track post-boost vehicles, reentry vehicle clusters, satellites, and anti-satellites Assess kills by defense weapons	Post-Boost Midcourse
Ground-Based Surveillance and Tracking System (GSTS)	Sensor	Track reentry vehicles and penetration aids Discriminate reentry vehicles from penetration aids Assess kills by defense weapons	Midcourse
Ground-Based Radar (GBR)	Sensor	Acquire and track reentry vehicles and penetration aids Discriminate reentry vehicles from penetration aids	Late Midcourse (Can operate in the terminal phase)
Space-Based Interceptor (SBI)	Weapon	Destroy boosters, post-boost vehicles, and anti-satellites Destroy reentry vehicles	Boost Post-Boost Early Midcourse
Ground-Based Exoatmospheric Interceptor (GBI)	Weapon	Destroy reentry vehicles	Late Midcourse
Command Center (CC)		Human decisionmaking, communications and guidance for defense system	

SOURCE: Congressional Budget Office, adapted from Department of Defense, Strategic Defense Initiative Organization.

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CHAPTER II

BUDGETING FOR STRATEGIC DEFENSES: STRUCTURE AND HISTORY

In considering alternative approaches to a system of strategic defenses, this study uses the current budget structure of the Strategic Defense Initiative as a basis for estimating their costs. That structure is described in this section. A glance at the history of funding for strategic defenses may also be useful as a guide to evaluating the costs of alternative missions.

STRUCTURE OF THE SDI BUDGET

SDI's current Department of Defense budget structure, first introduced in fiscal year 1985, consists mainly of five funding categories called program elements.[1] (Box 2 summarizes their key aspects.)

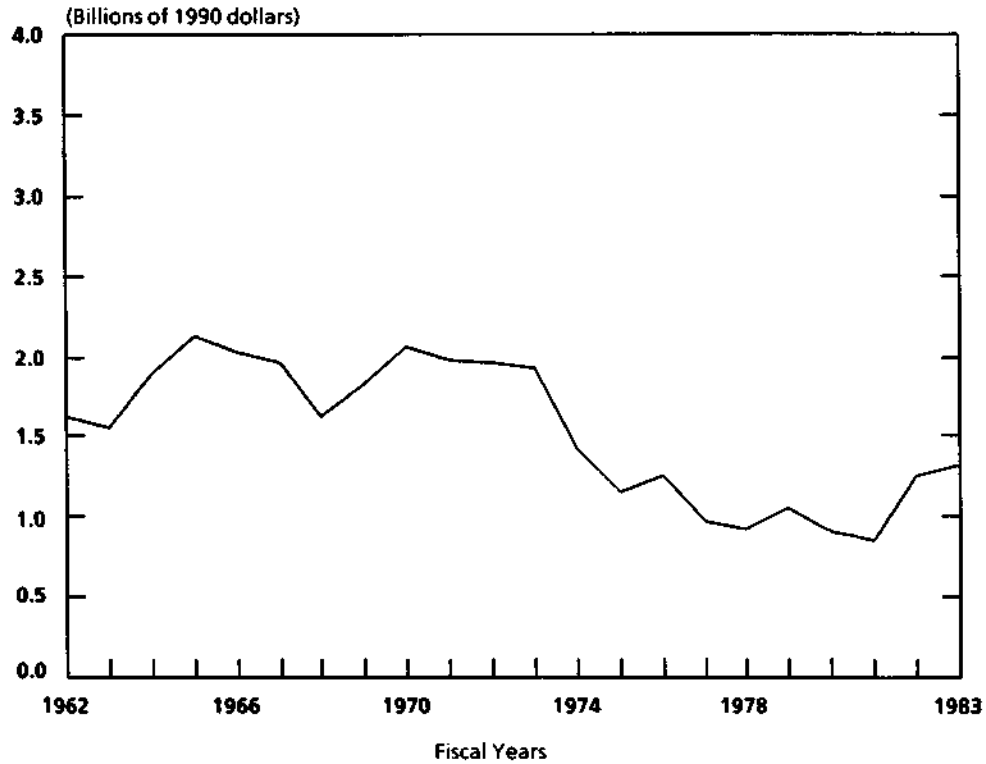
The first two program elements include funds for weapons that would be used to destroy enemy missiles and reentry vehicles:

- Kinetic Energy Weapons (KEW) are those that would destroy an enemy missile by hitting it with another object ("hitting a bullet with a bullet"). Kinetic energy technology is relatively mature, and is the technology planned for use in the system the Administration would deploy in the late 1990s.

- Directed-Energy Weapons (DEW) would destroy an enemy missile with bursts from a laser or particle-beam weapon. Directed-energy technology is generally much less ready for development into weapons than is kinetic energy technology. It would be crucial to maintaining and increasing the capa-

1. There is also a sixth category of funding in the Department of Energy budget for research and development of nuclear-based directed-energy concepts such as the X-ray laser.

Figure 1.
Historical Funding for Ballistic Missile Defense



SOURCE: Congressional Budget Office, adapted from information provided by the Department of Defense to Congressman Dante Fascell and reprinted in the *Congressional Record*, April 4, 1985, pp. E1444-E1446.

missile could survive an enemy attack.[2] This defensive system was not pursued after plans for MX basing were altered.

Announcement of the SDI provided a new basis for funding strategic defenses. The 1984 budget of $1.0 billion ($1.2 billion in 1990 dollars) mostly consolidated funds from existing research efforts. The first formal budget submission for the SDI came with the 1985 request for $1.4 billion ($1.6 billion in 1990 dollars). These amounts were not large compared with the planned funding mentioned above. But now all the funding was aimed at research on a broad system of

2. This document indicates that pre-SDI funding for ballistic missile defense efforts was planned (in current dollars) at about $1.5 billion in 1985, $1.8 billion in 1986, $2.2 billion in 1987, and about $11 billion for the 1985-1989 period.

defenses rather than toward developing a system to protect the MX missile.

From 1984 to 1987, SDI funding grew rapidly, and consumed a sharply growing share of all Defense Department research funds--from about 4 percent in 1984 to about 9 percent in 1987 (see Table 1). The Administration continued to propose increases in SDI funding in 1988 and 1989, but the Congress limited funding so that it remained relatively flat, both in terms of real dollars and relative to all spending for Department of Defense research.

Although SDI's rate of growth has not been unusual for a research and development program, its size and claim on resources within the Department of Defense budget are unusual. In 1989 the SDI received $3.7 billion (in current dollars). The next largest request for research

TABLE 1. TRENDS IN SDI RESEARCH BUDGETS
(In billions of 1990 dollars of budget authority)

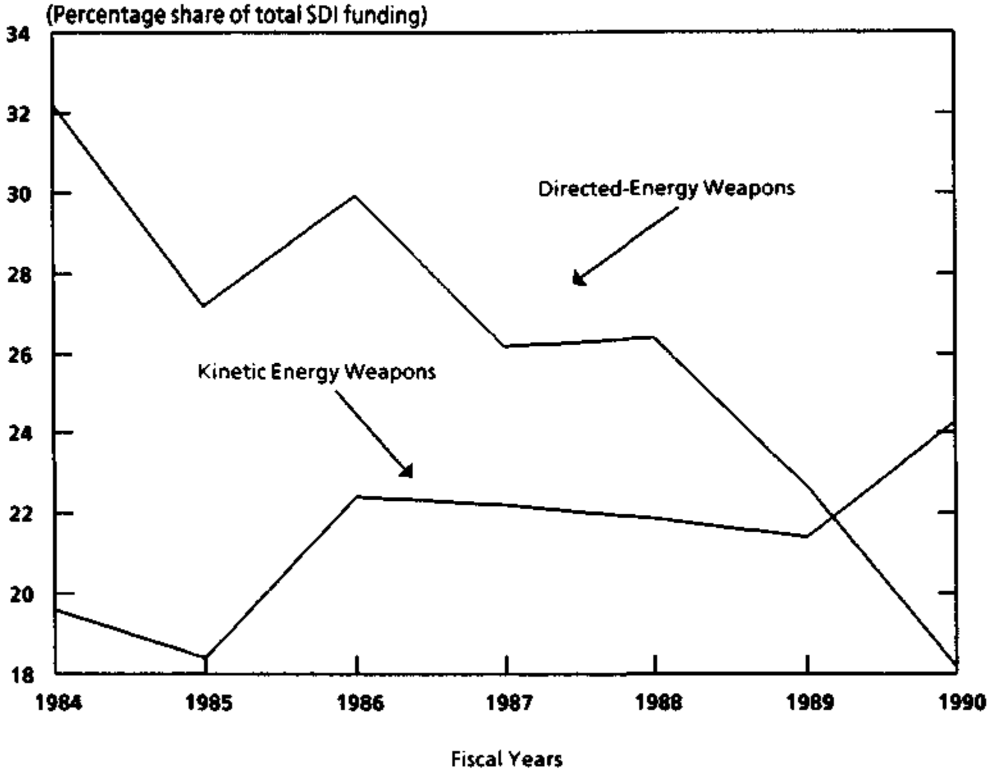
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Defense Department SDI Funds[a]	1.2	1.6	3.1	3.7	3.9	3.8	4.6	5.2	6.0	7.1	8.2
Real Growth (Percent)		33.3	93.8	19.4	5.4	-2.6	21.1	14.0	13.8	19.8	14.8
Total Defense Department Research and Development Funds[b]	32.6	36.8	38.5	39.5	39.1	38.7	39.5	38.4	38.6	38.1	38.4
SDI as a Percentage of Research and Development	3.7	4.3	8.1	9.4	10.0	9.8	11.6	13.7	15.5	18.8	21.4

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

a. Includes funds for the five program elements, headquarters, and military construction.

b. Detail for the Bush Administration plan is not available beyond 1991. These figures assume that the reduction in research and development funds compared with the Reagan plan is proportional to the overall reduction in the defense budget.

Figure 2.
Percentage of Total SDI Funds Devoted to Major Types of Weapons



SOURCE: Congressional Budget Office based on data from the Department of Defense, Strategic Defense Initiative Organization.

NOTE: This figure is based on SDI funds in the Department of Defense budget. The percentages for 1990 are from the Bush Administration budget request.

funding was for the B-2 bomber, which reportedly received $2.2 billion (in current dollars).[3] The next three most expensive R&D programs in 1989 averaged $1.1 billion each (in current dollars).

Funding for SDI has not only varied in total amount; it has also varied in emphasis. For the first few years, funding was much higher for directed-energy programs (see Figure 2 above). These programs are

3. See *Aerospace Daily*, April 4, 1989.

technically risky but in the long run may provide the best chance to achieve a system that provides meaningful population defense.

As has been noted, the Administration currently aims at deploying a Phase I system of defenses that will provide partial defense against an initial Soviet attack as well as experience useful in building a more effective system. To carry out this phased deployment approach, the Strategic Defense Initiative Organization (SDIO) has begun emphasizing technologies that could be used in an initial deployment. Thus kinetic energy weapons have been given greater priority over directed-energy weapons.

FUTURE FUNDING INCREASES

Under plans established by the Bush Administration, total funding for SDI would grow sharply in the early 1990s, though that growth would be less than envisioned by the Reagan Administration in January 1989. In 1990, President Bush proposes to spend $4.6 billion for SDI in the Department of Defense budget, an increase of 21.1 percent in real terms over the 1989 level (see Table 1). By 1994, SDI funding would reach $8.2 billion and could consume about 21.4 percent of all Department of Defense research funds. (The $9 billion budget request includes anticipated inflation.) Total five-year funding would amount to $31 billion ($33 billion including anticipated inflation).[4]

Budget increases could well continue beyond 1994. The Administration has indicated that, as soon as technology permits, it will begin deployment of the initial phase (Phase I) of the strategic defense system--perhaps in the late 1990s. Current SDIO estimates put the deployment cost for this phase at about $74 billion, or about $89 billion if inflation is included. The Administration has not estimated the costs of subsequent phases, but they could be expected to be high.

In order to render all strategic offensive forces ineffective, the Administration must develop a system of defenses against aircraft and ships and the weapons they carry, including cruise missiles. Devel-

4. These funding plans do not include requests from the Department of Energy for nuclear-based SDI concepts.

oping and deploying such a system could also be very challenging and expensive. The Administration has begun a modest Air Defense Initiative, but its costs cannot be estimated at this time.

Growth in the projected budgetary requests for the SDI in the early 1990s, coupled with likely limits on defense funding in the 1990s, may cause the Congress to consider alternative levels of funding for SDI. Major decreases in SDI funding would probably also require a change in its mission unless technology yields a lower-cost way to accomplish the current mission. To assist in understanding what funding levels would be consistent with various missions, this paper reviews four broad missions for the SDI and estimates the costs associated with each. Although the paper focuses on costs, it also briefly discusses the advantages and disadvantages of each mission.

CHAPTER III

BUDGET MISSION ONE: A HEDGE AGAINST SOVIET BREAKOUT OR BREAKTHROUGH

At a minimum, the Strategic Defense Initiative could aim at providing a hedge against Soviet actions that would weaken the present system of nuclear deterrence. One such Soviet action might be a "breakout" from the ABM Treaty. In this hypothetical scenario, the Soviets would use their present technology to deploy a system of strategic defenses fairly rapidly. Such a system would be unlikely to negate U.S. retaliatory capability, but it could make that capability less certain and thus reduce confidence in the U.S. ability to deter nuclear attack. In the longer run, the Soviets could conceivably achieve a "breakthrough" by discovering advanced technologies that would permit deployment of an effective system of defenses against U.S. retaliation.[1]

In either event--breakout or breakthrough--the United States would want to be capable of responding with effective defenses of its own or with countermeasures to Soviet defenses. The task of SDI under this mission would be to ensure this capability. The hedge mission would not envision deployment of strategic defenses in the absence of such Soviet actions. Nor would this mission include testing of technology beyond the restrictions of the ABM Treaty.

COSTS OF A HEDGE MISSION

The costs of a hedge mission would depend on what programs were developed and what research was conducted. For illustration, CBO estimated the costs of a sample of specific programs that might rea-

1. The author thanks Sidney N. Graybeal of the System Planning Corporation for this characterization of the near- and long-term threats.

sonably be pursued under such a mission. It also estimated the cost of developing the technology base.[2]

Specific Programs

In this mission, the United States would probably want to be capable of responding relatively rapidly to a Soviet breakout by deploying some defenses of its own. One way to achieve that capability would be to fully develop a sensor system (the "eyes") and a weapons system that could be the basis of a U.S. system of defenses. Thus this option assumes that the United States pursues full-scale development of the Ground-Based Radar (GBR) and the ERIS version of a ground-based interceptor system.[3] (This option also assumes comparable development of the "brains" that would support these systems.) These two systems would not proceed beyond full-scale development into production unless the Soviet Union began deploying a system of defenses in violation of the ABM Treaty.

This action would cut several years off the time required to respond to a Soviet breakout, compared to a program that only funded the technology base. Although producing and fielding a system would also take several years, the same is likely to be true for the Soviets. The lag time for the U.S. response would depend on how early it detected and reacted to a Soviet breakout.

Also included in this mission would be funding for a general countermeasures program. If the Soviet Union were to deploy a defensive system, the United States could respond by deploying offensive countermeasures to foil that system. The United States might, for example, add decoys or other penetration aids such as radar chaff on some or all of its ballistic missiles that would make it difficult for Soviet defenses to pick out the real U.S. reentry vehicles. Many experts have expressed concern that insufficient funding is being dedicated to counter-

2. For an alternative approach to this type of mission, see the Center for International Security and Arms Control, *Strategic Missile Defense: Necessities, Prospects, and Dangers in the Near Term* (Stanford, Calif.: Stanford University, 1985). This is a report of a workshop chaired by Sidney D. Drell and Thomas H. Johnson.

3. The space-based interceptor (SBI) could probably not be taken through full-scale development in compliance with the ABM Treaty.

measures, even though countermeasures might provide a relatively cheap hedge against a Soviet breakout from the ABM Treaty. A program of countermeasures would also contribute to the hedge mission by maintaining a robust technological effort in this field. Finally, a countermeasures program would provide the knowledge needed to ensure that concepts proposed for use in a system of strategic defenses would not be easily foiled by Soviet responses. The program of countermeasures under this hedge mission would be combined with the Air Force's Advanced Strategic Missile Systems (ASMS) program that currently funds work on decoys and penetration aids for U.S. ballistic missile systems. Total annual funding for this combined program is assumed to be $200 million.

Some programs included in the Administration's SDI program would be dropped under this hedge mission. The capabilities of the Boost Surveillance and Tracking System exceed requirements for a system being designed as a hedge. Those needs could be met by current satellites that provide early warning of Soviet missile launches or by upgraded versions of such satellites. Funds to upgrade existing satellites--an action that is likely to be carried out regardless of decisions about funding for strategic defenses--are assumed to be paid from other portions of the Department of Defense budget.

Though the BSTS program would be dropped, most of the technologies for BSTS-type satellites would continue to be pursued under funding discussed below for the technology base. These technologies include focal plane arrays, signal/data processing, and large optics technology.

The Space Surveillance and Tracking System (SSTS) would also be deleted under this mission since its capabilities would not be immediately needed. (A small constellation of these satellites would, however, provide some valuable ability to track objects in space. If this capability is judged worthwhile, it could be funded outside of the SDI program.)

Other programs associated with the Administration's Phase I system, including the Space-Based Interceptor program and the Ground-Based Surveillance and Tracking System, would also cease to exist as separate programs. Technology for these approaches would be developed within funds available for the technology base.

TABLE 2. EXAMPLES OF TECHNOLOGY BASE PROJECTS ELIMINATED OR SHARPLY REDUCED

Directed-Energy Weapons Technology Demonstrations (R)
Kinetic Energy Weapons Space-based Kinetic Kill Vehicle Experiments (R)
Systems Analysis and Battle Management Strategic Defense System Phase I (E)
Systems Analysis and Battle Management Strategic Defense System Engineering and Support (R)
Survivability, Lethality, and Key Technologies Advanced Launch System (E)

SOURCE: Congressional Budget Office.

NOTE: (R) = Sharply reduced

(E) = Eliminated

Technology Base

In addition to specific programs, SDI monies would fund development and testing of a wide array of technologies. It is not feasible to examine each of the myriad efforts that make up the technology base, which currently includes some 340 research efforts.[4] In order to estimate total funding, CBO examined funding for the technology base in the SDI budget approved for 1989. Where it was possible to closely associate an effort with the Administration's proposed Phase I deployment, it was eliminated or sharply reduced because this budget mission does not envision such a deployment. Table 2 above lists examples of programs that were eliminated or sharply reduced under this criterion.

4. In this study, the term "technology base" refers to all funding of research including research on specific concepts through the stages of demonstration and validation, except for specific systems earmarked for further development and funded separately.

The number 340 is based on so-called "work package directives" such as the Exoatmospheric Discrimination Experiment. Work package directives are aggregated into "projects" such as Optical Discrimination and Data Collection.

Under a hedge mission, it may also be reasonable to reduce funds for technology not directly associated with Phase I. The Administration is planning to develop not only the technology supporting Phase I, but also advanced technologies to deploy Phase II and beyond in a timely way. Under this mission, absent Soviet actions there is no commitment to deploy strategic defenses that would drive the pace of technology development. However, a strong research program helps guard against a surprise breakthrough in technology by the Soviets. To illustrate two possible approaches to such reductions, funds for programs other than those directly associated with Phase I were reduced below their 1989 level by either 25 percent in real terms or by 50 percent in real terms (see Tables 3 and 4).[5]

It is not possible to characterize the effects of these overall reductions on specific programs, but their general effects can be described. Research on basic technology is not expensive by the standards of an SDI program. Generally speaking, exploratory technology projects are funded at the level of millions of dollars or tens of millions of dollars. The 50 percent reduction referred to above would provide funding of about $1.3 billion for the technology base in 1990. Thus, even under the reduction of 50 percent, SDI could maintain a broad program of basic and exploratory research.

Costs accumulate, however, as components are built and tested, and grow even more as components are integrated into systems for testing and experimentation. For example, meaningful tests on concepts for directed-energy weapons--lasers, for example--usually require elaborate and expensive facilities and test equipment. Testing in space is also very expensive. For instance, the Delta 181 experiment that gathered data on the appearance and behavior of objects in space under different circumstances cost $261 million (in 1988 dollars). The Zenith Star experiment, which is intended to confirm the system concept for a space-based chemical laser, is expected to cost $1.6 billion (in 1988 dollars).[6] Yet without some realistic testing, including tests in space,

5. The funds shown in Tables 3 and 4 do not represent a straight percentage reduction from the 1989 level, since some technology-base efforts closely associated with Phase I were eliminated or sharply reduced.

6. These examples are used to illustrate the spectrum of costs in a large program such as SDI, from basic research to progressively more integrated and realistic experiments, and are not meant as a comment on the usefulness or validity of these particular experiments.

TABLE 3. COSTS OF MISSION 1: MAINTAINING A HEDGE ASSUMING A 25 PERCENT CUT IN TECHNOLOGY BASE (In millions of 1990 dollars of budget authority)

	1990	1991	1992	1993	1994	Total 1990-1994
Specific Programs						
Complete Full-Scale Development of ERIS	245	275	340	400	520	1,775
Complete Full-Scale Development of GBR	150	165	300	270	345	1,230
CC/SOIF/SE&I[a]	75	125	200	300	400	1,100
Countermeasures Program[b]	100	100	100	100	100	500
Technology Base						
Directed Energy Weapons (DEW)	500	500	500	500	500	2,500
Kinetic Energy Weapons (KEW)	370	370	370	370	370	1,850
Surveillance, etc. (SATKA)	560	560	560	560	560	2,800
Systems Analysis, etc. (SABM)	310	310	310	310	310	1,550
Survivability, etc. (SLKT)	245	245	245	245	245	1,225
Total	2,550	2,650	2,925	3,055	3,350	14,530

SOURCE: Congressional Budget Office.

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

a. Command Center/System Operation and Integration Functions/Systems Engineering and Integration. CC/SOIF includes the command and control center for human decisionmaking, and the information and data processing network connecting the system and executing the plan for the defense.

b. Combines with funding from Advanced Strategic Missile Systems (ASMS) program for annual level of effort of $200 million; takes some penetration aid programs through full-scale development.

TABLE 4. COSTS OF MISSION 1: MAINTAINING A HEDGE ASSUMING A 50 PERCENT CUT IN TECHNOLOGY BASE (In millions of 1990 dollars of budget authority)

	1990	1991	1992	1993	1994	Total 1990-1994
Specific Programs						
Complete Full-Scale Development of ERIS	245	275	340	400	520	1,775
Complete Full-Scale Development of GBR	150	165	300	270	345	1,230
CC/SOIF/SE&I[a]	75	125	200	300	400	1,100
Countermeasures Program[b]	100	100	100	100	100	500
Technology Base						
Directed Energy Weapons (DEW)	340	340	340	340	340	1,700
Kinetic Energy Weapons (KEW)	250	250	250	250	250	1,250
Surveillance, etc. (SATKA)	375	375	375	375	375	1,875
Systems Analysis, etc. (SABM)	210	210	210	210	210	1,050
Survivability, etc. (SLKT)	165	165	165	165	165	825
Total	1,905	2,005	2,280	2,410	2,705	11,305

SOURCE: Congressional Budget Office.

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

a. Command Center/System Operation and Integration Functions/Systems Engineering and Integration. CC/SOIF includes the command and control center for human decisionmaking, and the information and data processing network connecting the system and executing the plan for the defense.

b. Combines with funding from Advanced Strategic Missile Systems (ASMS) program for annual level of effort of $200 million; takes some penetration aid programs through full-scale development.

it is not possible to know if many of the components of a system of strategic defenses would work.

For these reasons, a large reduction in funding for the technology base would probably have its greatest effect on the number and sophistication of experiments. Under the 50 percent cut in particular, more work would have to be concentrated at the component level, and thus less would be learned about the workings of complete systems. Since the "sum" often behaves differently than its "parts," the difference could be important. There would also be fewer realistic tests. Less system-level testing would also mean fewer opportunities to evaluate the promise of one type of technology as against another--a step that is necessary to weed out impractical concepts.

Nonetheless, even a 50 percent cut would leave a substantial program of research that would provide ideas and components for development if the Soviet Union were to deploy a system of defenses that threatened U.S. retaliatory capability.

Budget Effects Through 1994

The hedge mission would result in substantially lower funding than proposed by the Administration and would probably lead to significant restructuring of the SDI budget. Under the assumptions discussed above, including a reduction of 25 percent in the technology budget, the United States would spend about $2.6 billion on SDI in 1990 (see Table 3). This amount is $2.0 billion less than the Bush Administration proposes to spend but still about $1.0 billion higher in constant dollars than the 1985 funding level for SDI, its first formal budget year. Funding would grow to about $3.4 billion by 1994, and over the five years from 1990 through 1994 would total about $14.5 billion--less than half of what President Bush proposes to spend. In addition to developing systems that would provide a capability to respond to potential Soviet actions in the near term, this hedge budget should allow for a robust research program in strategic defenses--including some integrated experiments--that would enable the United States to make informed choices about advanced-technology options for development and deployment in the late 1990s if such a decision was compelled by Soviet actions or appeared compelling from a technology standpoint.

Reductions of 50 percent in the technology base would yield a program of about $1.9 billion in 1990, $2.7 billion below what the Bush Administration proposes to spend and about $300 million more than the 1985 funding level for SDI in 1990 dollars (see Table 4). Funding would grow to about $2.7 billion by 1994 and would total about $11.3 billion over the 1990-1994 period--somewhat over one-third the spending planned by the Bush Administration. As in the case above, this level of spending would develop specific systems that would speed a U.S. response to a Soviet breakout. While it might be sufficient to maintain the technology base, it would clearly not advance it as far as if the reduction were only 25 percent.

This mission is designed to develop technology over the next five years and to provide a hedge against future Soviet actions. CBO did not project budgets for it beyond the next five years since those would depend on the results of research and on Soviet actions.

LOWER BUDGETS

There have been proposals to reduce SDI budgets significantly below those of the hedge budget mission. Most notably, Michael Dukakis argued for SDI budgets of about $1 billion during his presidential campaign in 1988. That level of spending would yield large savings compared with the Administration plan. If one judges that the likelihood of a Soviet breakout or breakthrough is quite small, such a budget level might well seem appropriate in light of overall fiscal constraints.

The current level of the technology base could probably not be sustained at this level of funding, however. Funding of $1 billion would represent a reduction of about 38 percent in real terms from the level in 1985, SDI's first formal budget year. Since 1985, the technology base has grown much larger and more sophisticated. For instance, in 1985 the funding for SDI technologies for the Department of Defense at Lawrence Livermore National Laboratories (LLNL) was about $38 million (in current dollars) and about 145 people (in full-time equivalents) were employed on these efforts. By 1989, that funding amounted to about $112 million and involved about 350 people.[7] Cutting back to budgets of $1 billion would thus require terminating much of the research now under way.

DESIRABILITY OF A HEDGE BUDGET

Whether or not a hedge budget such as the one discussed here is desirable depends in part on one's philosophical conviction. President Reagan argued strongly that he wanted to alter the basis for U.S. deterrence from dependence on offensive retaliation to dependence on defensive systems, and that he wanted to do so as quickly as possible. The pros and cons of his proposal are discussed briefly below in connection with the Administration's approach (Budget Mission Four). But it is clear that a hedge budget would not be directed toward a shift in the basis for strategic deterrence.

The desirability of a hedge budget for SDI may also depend on one's assessment of the likelihood of a Soviet breakout or breakthrough. If one judges the likelihood of the Soviets deploying an effective defense against U.S. retaliatory capability to be high, one would probably want to proceed with development and deployment--perhaps pursuing a phased approach of the sort envisioned by the Administration. At a moderate or low level of likelihood, however, the hedge budget may be a reasonable option. If effective Soviet breakouts or breakthroughs are deemed highly unlikely, budgets even lower than those envisioned in this mission may seem reasonable. One would also have to consider the potential Soviet response to U.S. action or inaction.

How likely is a Soviet breakout or breakthrough? Concerns about this stem from current Soviet activities.[8] Under the ABM Treaty the Soviet Union is allowed one system of defenses, which it has deployed around Moscow. In recent years the Soviet Union has been upgrading the nuclear-interceptor-based Moscow ABM system with new, more

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7. LLNL also does research on nuclear-based SDI concepts for the Department of Energy. In 1985, funding was about $46 million and involved 240 people. In 1989, funding was about $76 million and involved about 415 people.

8. For a more detailed discussion of Soviet activities and their possible implications, see Sayre Stevens, "The Soviet BMD Program," in Ashton B. Carter and David N. Schwartz, eds., *Ballistic Missile Defense* (Washington, D.C.: The Brookings Institution, 1984).

capable missiles. Thus it has open production lines that can produce missiles capable of intercepting incoming reentry vehicles. It is also deploying early warning radars that can detect ballistic missiles; these radars would also be needed for a broad-based system of strategic defenses. When completed, the Soviet network of large phased-array radars (LPAR)--under construction since the 1970s--will provide a nearly complete ring of sophisticated radars capable of detecting ballistic missiles aimed at the Soviet Union. The Krasnoyarsk radar, which the Administration has concluded is located and oriented in a way that violates the ABM treaty, is a component of this network. Indeed, it closes a major gap in the coverage of the LPAR network.

While it is clear that the Soviet Union has an active program in strategic defenses of all types, it is also clear that the system now available for ballistic missile defense is of limited effectiveness. Administration officials have testified that the United States believes it can still penetrate the upgraded Moscow system with a small number of ballistic missiles equipped with highly effective chaff and decoys.[9] As for the Soviet LPAR network, the United States also relies on phased-array radars for detection of and early warning of ballistic missiles aimed at this country, and has been modernizing and upgrading the coverage of its network. But the United States would not rely on such radars as the basis for a nationwide anti-ballistic missile system because of their susceptibility to nuclear effects, such as blackout, and--given their limited numbers and large size--to direct attack.

According to a Defense Department publication, *Soviet Military Power*, the Soviet Union has also tested some components for an ABM system--the "Flat Twin" ABM radar--that could be deployed to a site in a matter of months. And some analysts are concerned that certain missiles the Soviet Union uses for defense against strategic bombers may also have the potential to intercept selected types of ballistic missile warheads. The requirements for intercepting fast-approaching ballistic missile warheads are, however, much more rigorous than those for intercepting bombers or cruise missiles. Therefore, most analysts agree that Soviet air defense systems, even if upgraded, would probably have modest capability against ballistic missiles.

9. Testimony of Lawrence Woodruff, Deputy Undersecretary of Defense, cited in *Defense News*, July 11, 1988, p.27.

Whatever their defensive activities, the Soviets may have strong reasons for abiding by the ABM Treaty. The treaty is a useful weapon in their anti-SDI campaign. Moreover, if the Administration's SDI program forces the United States to abrogate the treaty, this country would bear the adverse political consequences. The Soviets may also genuinely wish to constrain U.S. strategic defense efforts, either because of concern about U.S. technological superiority or simply to avoid the economic burden of having to respond.[10]

In the event of a Soviet breakout from the ABM Treaty--especially if that breakout was accomplished using current systems that have limited capability--the United States would have recourse to measures other than deploying its own defenses. For example, it could add many offensive warheads to its inventory and try to overwhelm the Soviet defense. Through the 1990s, at least, this country is likely to have open production lines for a number of offensive systems that would allow increasing their numbers, though significant increases would require a number of years. Alternatively, the United States might be able to foil Soviet defenses by adding offensive countermeasures, such as penetration aids and decoys, to its ballistic missiles. The appropriate response would depend on the effectiveness of the Soviet system and on how rapidly the United States wanted to respond.

In sum, there seems to be no imminent danger of the Soviet Union deploying a highly effective system of strategic defenses. Even if it developed the technology, it might have to reckon with the sort of budget constraints that have slowed U.S. progress on SDI. And the Soviets may have strong reasons to want to maintain the ABM treaty.

Nevertheless, the Soviet program of research and deployment argues for a continued U.S. program. Such a program could be funded by a hedge budget of the sort just described. Alternatively, if the United States wanted to do more than develop a hedge but also wanted to avoid the high costs associated with deploying a large system, it could consider the deployment of a limited system of strategic defenses.

10. See the remarks of Sidney N. Graybeal, *SDI and the ABM Treaty*, American Association for the Advancement of Science, Occasional Paper No. 88-14 (1988).

CHAPTER IV

BUDGET MISSION TWO: DEPLOY AN ACCIDENTAL LAUNCH PROTECTION SYSTEM

This budget mission would provide funds to deploy an accidental launch protection system (ALPS). The ALPS would be designed to protect portions of the United States against a small nuclear attack. The occasion could be an accidental or unauthorized attack from a country like the Soviet Union, or a deliberate attack by a country with a small arsenal of nuclear weapons. The ALPS concept was suggested by Senator Nunn, chairman of the Senate Armed Services Committee, who felt that it should be analyzed as a potentially useful mission for a strategic defense system.

Under this budget mission, the ALPS would consist of a maximum of 100 interceptor missiles deployed in the silos already in place at the site of the abandoned Safeguard ABM system in Grand Forks, North Dakota. The particular example discussed in this section is based on a design by the Lockheed Corporation and would use that company's ERIS interceptor missile.[1]

This budget mission would also develop technology both to evaluate its potential and to provide a hedge against a Soviet deployment of an effective system of defenses. Thus it would provide funding for the technology base at a level equal to the higher-cost option under Budget Mission One.

The ALPS funded under this budget mission would be intended to be compatible with the existing ABM Treaty between the United States and the Soviet Union. There are, however, some gray areas that would have to be resolved. The treaty (see Appendix B) has many prohibitions, including a ban on the use of space-based or mobile components in any ABM system, and limits ABM systems based on "other physical principles" including components that can substitute for per-

1. For more details on technical parameters and capabilities of an ALPs, see the Office of Technology Assessment Staff Paper, *A Treaty-Compliant Accidental Launch Protection System* (April 1988).

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mitted ABM systems such as interceptors or radars.[2] The Ground-Based Surveillance and Tracking System (GSTS) consists of ground-based sensor probes that are launched into space in the face of an attack to provide an enhanced "view" of the attacking reentry vehicles. The GSTS could be regarded as mobile and substituting for an ABM radar and so be inconsistent with the existing ABM Treaty. On the other hand, if the GSTS was deployed in the silos at Grand Forks and considered an adjunct to the Ground-Based Radar, it might be compatible with the treaty. The GSTS may be needed to provide high confidence that an ALPS would be effective. Some question whether a "hit-to-kill" kinetic energy interceptor like the ERIS is based on a new physical principle compared with an interceptor that uses a nuclear explosion as its kill mechanism. Finally, some analysts have expressed concern that tying the ballistic missile early warning radars (BMEWS) to an ALPS system would not be compatible with the treaty. Compliance would likely depend on the quality of information provided by these radars and the use to which the information was put. Some feel that the U.S. would be unwise to constrain itself in areas such as this that are difficult to verify because they feel the Soviet Union would not constrain itself.

To comply with the treaty, the ALPS must clearly have no more than 100 interceptors. But that means the system could not defend the entire United States against certain attacks. For example, with this system, the coastal zones of the country would not be protected from ballistic missiles launched from a submarine in routine patrol zones off the U.S. coast. Protecting the entire United States would require more interceptors; some of the interceptors would also have to be located at sites other than the one at Grand Forks, which would clearly violate the existing ABM Treaty.

COSTS OF THE SYSTEM

Budget Mission Two, like Budget Mission One, would provide a specified level of funding for the technology base and for full-scale develop-

2. For an extensive discussion of the ABM Treaty and related issues, see George Schneiter, "The ABM Treaty Today," in Ashton B. Carter and David N. Schwartz, eds., *Ballistic Missile Defense* (Washington, D.C.: The Brookings Institution, 1984).

ment of specific programs. In addition, Budget Mission Two would produce and deploy several types of systems.

Elements of the ALPS Budget

Budget Mission Two would provide the same funding for the technology base as was provided under the more generous of the two versions of Budget Mission One--that is, under the version that reduced funding by 25 percent below the 1989 level. Like Budget Mission One, this mission would also provide funds to complete full-scale development of the Ground-Based Radar (to provide eyes for the ALPS) and for the ERIS version of the ground-based interceptor missile (which would be used to destroy incoming reentry vehicles).

In addition, Budget Mission Two would provide funds for the development of the Ground-Based Surveillance and Tracking System (GSTS) to provide additional sensor capability, especially during the later portion of the midcourse phase of flight. According to Lockheed's concept for an accidental launch protection system, upgrades of the ballistic missile early warning radar (BMEWS) at Clear, Alaska, would also be undertaken.[3] A similar upgrade has already been completed at the radar in Thule, Greenland, and is scheduled to be completed in 1991 for the radar at Fylingdales Moor, United Kingdom. (Costs for upgrading the Alaska radar have not been included in this alternative, but have been roughly estimated by the Air Force to be $320 million in current dollars.)

Finally, unlike Mission One, Mission Two would not stop at development. It envisions replacing the current radar at Grand Forks with the more capable Ground-Based Radar (GBR) planned for the Administration's Phase I program. The planned GBR has only one face. Based on information from early warning satellites and radars, the radar would slew to the direction of the incoming ballistic missiles. One radar could not handle ballistic missiles simultaneously approaching from different directions, but such is not likely to be the case for a

3. These radar upgrades have also been a subject of controversy with respect to the ABM Treaty, since the radars are not located on the periphery of the United States and facing outward as specified in the treaty. The United States maintains that the radars were in place before the ABM Treaty, and that these are allowable upgrades.

limited accidental or unauthorized launch. (Such a constraint on ALPS may differentiate it from a system that would have a significant military capability and thus be less provocative to the Soviets.) The mission also envisions deployment of four of the GSTS (plus two spares to permit peacetime maintenance without reducing the capability of the system) and 100 of the ERIS interceptor missiles (plus 100 test missiles). If the GSTS were deployed in the silos, then only 96 of the ERIS missiles would actually be deployed. In addition, a system to trigger and coordinate defenses against a limited attack would have to be developed and deployed (to provide the "brains" for the system).

Cost Estimates

Mission Two would require that the United States spend about $2.6 billion on strategic defenses in 1990 (see Table 5). Spending would rise to $4.0 billion in 1994. Over the next five years these numbers would be somewhat higher than those under Mission One. Costs would be higher over the next five years because of funding required to develop the GSTS, and because of larger funding requirements to develop the "brains" of the system.

In this mission, furthermore, these systems would proceed into limited production, resulting in production costs that would occur mostly in years beyond 1994. Costs to complete their acquisition would total roughly $4.2 billion (see Table 5). Estimates of acquisition costs are based largely on data supplied by the Administration in connection with its planned Phase I deployment, adjusted for the very limited numbers of systems that would be procured. Also, under this ALPS mission, the ERIS interceptor missile would not be as small and sophisticated as the ground-based interceptor (GBI) required to meet the needs of the Administration's planned Phase I system.

ADVANTAGES AND DISADVANTAGES

A limited protection system would offer several potential advantages. It would provide insurance against a small launch of ballistic missiles caused either by accident or by unauthorized action. Currently, the United States has no protection against such an attack, which could

TABLE 5. COSTS OF MISSION 2: DEPLOYING AN ACCIDENTAL LAUNCH PROTECTION SYSTEM (In millions of 1990 dollars of budget authority)

	1990	1991	1992	1993	1994	Total 1990-1994	Costs Beyond 1994 to Complete Acquisition[a]
			Specific Programs				
Develop and Deploy ERIS	245	275	340	400	520	1,775	1,075
Develop and Deploy GSTS	40	105	125	435	490	1,195	935
Develop and Deploy GBR	150	165	300	270	345	1,230	1,140
CC/SOIF/SE&I[b]	125	350	550	730	600	2,355	1,025
Countermeasures Program[c]	100	100	100	100	100	500	n.a.
Subtotal	655	995	1,415	1,935	2,055	7,055	4,170
			Technology Base				
Directed Energy Weapons (DEW)	500	500	500	500	500	2,500	n.a.
Kinetic Energy Weapons (KEW)	370	370	370	370	370	1,850	n.a.
Surveillance, etc. (SATKA)	560	560	560	560	560	2,800	n.a.
Systems Analysis, etc. (SABM)	310	310	310	310	310	1,550	n.a.
Survivability, etc. (SLKT)	245	245	245	245	245	1,225	n.a.
Total	2,640	2,980	3,400	3,920	4,040	16,980	n.a.

SOURCE: Congressional Budget Office.

NOTE: Numbers may not add to totals because of rounding.
n.a. = not applicable.

a. These are rough extrapolations based on Administration estimates for Phase I.

b. Command Center/System Operation and Integration Functions/Systems Engineering and Integration. CC/SOIF includes the command and control center for human decisionmaking, and the information and data processing network connecting the system and executing the plan for the defense.

c. Combines with funding from Advanced Strategic Missile Systems (ASMS) program for annual level of effort of $200 million; takes some penetration aid programs through full-scale development.

result in great destruction. An accidental launch protection system might also reduce the chance of a nuclear war by rendering ineffective a limited attack. An enemy might be less likely to initiate a nuclear war if a meaningful attack could be achieved only with a large launch of ballistic missiles (although other types of weapons could also be used for a limited attack). The ERIS interceptor missile deployed with this system might also be capable of destroying enemy satellites. The United States currently has no antisatellite capability.

Deployment of an accidental launch protection system would also provide the United States with some experience in deploying and operating a system of strategic defenses. Although production lines would probably not be opened, manufacturers would learn to produce small numbers of these systems. The military would learn to operate a system and to integrate it with other systems that provide wartime command and control. That experience could be valuable if this country eventually decided to deploy a larger system of defenses.

These various advantages might be achieved without abrogating the ABM Treaty--and without providing incentives to the Soviets to deploy countermeasures to overwhelm the system--assuming that the gray areas mentioned at the beginning of this chapter were cleared up in a manner consistent with the treaty. The accidental launch protection system might thus avoid one major criticism of most plans to deploy strategic defenses--the need to abrogate the ABM Treaty, which some view as a key to preventing a major new arms race in defensive weapons.

On the other hand, the system outlined in this section would cost a substantial sum. Many analysts feel that it would protect against contingencies that are highly unlikely. Few countries have the capability to launch nuclear weapons on ballistic missiles that can reach the United States. Most that do are either U.S. allies or have rigid controls that make accidental or unauthorized launches highly unlikely. Indeed, no such launches have occurred during the roughly 30 years that ballistic missiles have existed. Moreover, in order to have any chance of complying with the existing ABM Treaty, the system could not be designed to protect all of the United States from all types of attacks.

Nor is it clear, as some proponents have argued, that an accidental launch protection system would offer protection against what may be a more likely contingency--deliberate attack with chemical or biological weapons by Third World countries. (Iraq used chemical weapons in its recent war with Iran.) Biological agents launched on ballistic missiles, even if intercepted outside the atmosphere, could potentially still penetrate and cause some destruction. More important, a Third World country intent on attacking the United States might well choose a less sophisticated means of delivery--such as aircraft or human agents.

CHAPTER V

BUDGET MISSION THREE: DEPLOY DEFENSES TO PROTECT SILO-BASED ICBMs

The United States could decide that an accidental launch protection system by itself would offer too few benefits. At the same time, the country might want to gain the experience of deploying a system of strategic defenses without committing the resources required to deploy the Administration's proposed system. In that case, the United States could consider deploying a system of defenses to protect its land-based missiles (ICBMs). Such a system should also be able to defend against small accidental or unauthorized launches.[1]

Why defend these missiles? Today they are protected by silos located in the central portion of the United States. These silos are hardened to withstand the threat posed by Soviet ballistic missiles in years past. But Soviet missiles are becoming more accurate, and by the 1990s most analysts agree that United States would not be able to absorb a Soviet attack on its ICBMs and be confident of having many of them left to retaliate. Their vulnerability would put a President in the position of having to make a rapid decision to "use or lose" these valuable forces, perhaps before complete information was available. He would also not have the option of using a portion of the force for an initial response without accepting destruction of the remainder.

A system of defenses for silo-based missiles could take many forms. This analysis assumes that it would consist of exoatmospheric ground-based interceptor (GBI) missiles deployed to protect existing Minuteman III missiles. As it did for the preceding two budget missions, the study examines the costs of such a system as well as some of its advantages and disadvantages.

1. If the United States deployed a system to defend ICBMs, the Soviets would be much more likely to deploy widescale countermeasures than if the United States deployed an ALPS. However, if the system has any meaningful effectiveness for the defense of ICBMs, then it surely would be effective against a small accidental or unauthorized launch.

Defense of silo-based ICBMs is amenable to a different sort of analysis than could be provided for other budget missions. Missiles are defended to permit a certain number to survive a Soviet attack, thus ensuring retaliation and enhancing deterrence. This goal could be achieved by defending silo-based missiles, or it could be achieved by deploying more ICBMs on mobile launchers. These mobile missiles would be able to disperse over a wide area and so could survive a Soviet attack without a separate system of defenses.

CBO was asked to examine alternative approaches to increasing the survivability of ICBMs and to compare those alternatives with the mission of defending silo-based ICBMs. Such an evaluation has to be made in terms of goals for surviving ICBM warheads, the potential Soviet threat to U.S. ICBMs, and U.S. force structure options. The remainder of this chapter first describes the system assumed in this study for defense of silo-based ICBMs, its costs, and some of its advantages and disadvantages. It then sets forth the bases for the assumptions used and provides a comparative analysis of approaches to increasing ICBM survivability.

THE SYSTEM FOR DEFENDING SILO-BASED MISSILES

The analysis in this paper assumes that a U.S. system of defenses for silo-based missiles would consist of 2,200 exoatmospheric ground-based interceptor (GBI) missiles. These interceptors would be deployed to protect 527 of the Minuteman III missiles currently in silos.

This system might well use a so-called "preferential defense." ICBM silos are spaced miles apart, and--because they are hardened to withstand nuclear effects--an attacking warhead must be aimed with great accuracy. This permits the defender to determine which attacking warheads are directed against particular silos.[2] Long-range interceptor missiles, such as the GBI, could gain an advantage by attacking only those incoming warheads aimed at a subset of silos, without revealing which silos are being defended. Such a preferential defense

2. Maneuvering reentry vehicles (MARVs) pose a potential problem since, from one trajectory, they could potentially attack any one of several silos. By defending clusters of silos, an exoatmospheric defense can protect all silos within the potential "footprint" of the MARV. The reentry vehicle cannot actually maneuver until it is within the atmosphere.

would force the attacker to target all silos as if they were equally defended.

The defender could also design his silo-based missile system to increase his advantage by deploying missiles in as many silos as possible so the enemy could not destroy the ICBM force by concentrating his attack.[3] Also, the defender could deploy his missiles so that each silo had equal value to the attacker (that is, the same number of warheads per missile) so the attacker would gain no advantage from targeting some silos more heavily than others.

This alternative assumes limits on offensive forces now being discussed in the START negotiations. Without constraints on offensive forces, the Soviets could expand their strategic arsenal--consisting mostly of ballistic missiles--from about 12,000 or 13,000 warheads by 1990, to between 16,000 and 21,000 warheads by the mid-1990s with a robust but not maximum effort.[4] Defending U.S. ICBMs in that case, if feasible, would likely require a system of much broader scope and cost than envisioned in this alternative.

It is unlikely, however, that the Soviets would agree to START limits on offensive forces without some limits on defensive forces. Deploying the system described in this option to defend silo-based ICBMs would not be compatible with the ABM Treaty, although development and testing might be done within treaty limits for a while longer. Although not now the focus of negotiations, it is conceivable that a framework for limits on defensive forces compatible with this alternative could be negotiated.

COSTS OF DEFENDING SILO-BASED MISSILES

Over the next five years, the costs under Budget Mission Three would be somewhat greater than those incurred for the accidental launch protection system described in the preceding chapter because the

3. Under START constraints this would lead to fewer, not more, warheads per missile. At some point, even if the United States were to deploy all single-warhead missiles, the 1,600 Strategic Nuclear Delivery Vehicle or "platform" sublimits could also become constraining.

4. Robert M. Gates and Lawrence K. Gershwin, Central Intelligence Agency, in testimony before the House Committee on Armed Services, June 5, 1986.

requirements for the supporting "brains" and system integration would be greater. Spending on defenses would rise from $2.7 billion in 1990 to $4.5 billion in 1994 (see Table 6). These funds would pay for full-scale development of the GBI missiles plus two sensor systems--the Ground-Based Surveillance and Tracking System (GSTS) and the Ground-Based Radar (GBR) currently designed to be rail-mobile. In addition, costs over the next five years would finance continued research to develop the technology base.

Most of the costs of procuring the components of the defensive system would be incurred in the years beyond 1994. These components are assumed to include 3 of the Ground-Based Radars (plus 1 spare for a maintenance pipeline) and 20 of the Ground-Based Surveillance and Tracking Systems (plus 4 spares). The estimate also assumes that the United States buys 2,600 of the ERIS interceptor missiles (2,200 operational missiles plus 400 missiles for operational testing). Total costs beyond 1994 would amount to about $10.9 billion. Including all years beyond 1989, total costs for developing and procuring this system of defenses would amount to about $18.9 billion (this figure excludes spending on the technology base and on countermeasures). These cost estimates, which are at best rough approximations, are extrapolated from data supplied by the Administration in connection with its currently planned Phase I deployment.

Costs might be higher or lower if new or revised systems had to be developed in order to field a system that could effectively defend silo-based missiles. A number of technical problems could demand such changes. For example, GBI missiles would attack enemy reentry vehicles outside the Earth's atmosphere. Exoatmospheric interceptors might have to contend with decoys and penetration aids that could raise the "effective" number of objects against which they would have to defend unless they had adequate discrimination capabilities. To combat Soviet countermeasures, an effective system might have to deploy more sophisticated sensors, or combine exoatmospheric attackers with endoatmospheric interceptors that would attack incoming reentry vehicles within the atmosphere after it had "filtered out" lighter decoys and penetration aids. In all cases, the defense would have to be based so as not to expose the interceptors or radars to easy attack.

TABLE 6. COSTS OF MISSION 3: DEPLOYING A SYSTEM TO PROTECT SILO-BASED ICBMs (In millions of 1990 dollars of budget authority)

	1990	1991	1992	1993	1994	Total 1990-1994	Costs Beyond 1994 to Complete Acquisition[a]
				Specific Programs			
Develop and Deploy GBI	245	275	340	400	520	1,775	4,700
Develop and Deploy GSTS	40	105	125	435	490	1,195	1,900
Develop and Deploy GBR	150	165	300	270	345	1,230	2,700
CC/SOIF/SE&I[b]	200	525	875	1,175	1,025	3,800	1,600
Countermeasures Program[c]	100	100	100	100	100	500	n.a.
Subtotal	730	1,170	1,740	2,380	2,480	8,500	10,900
				Technology Base			
Directed Energy Weapons (DEW)	500	500	500	500	500	2,500	n.a.
Kinetic Energy Weapons (KEW)	370	370	370	370	370	1,850	n.a.
Surveillance, etc. (SATKA)	560	560	560	560	560	2,800	n.a.
Systems Analysis, etc. (SABM)	310	310	310	310	310	1,550	n.a.
Survivability, etc. (SLKT)	245	245	245	245	245	1,225	n.a.
Total	2,715	3,155	3,725	4,365	4,465	18,425	n.a.

SOURCE: Congressional Budget Office.

NOTE: Numbers may not add to totals because of rounding.
n.a. = not applicable.

a. These are rough extrapolations based on Administration estimates for Phase I.

b. Command Center/System Operation and Integration Functions/Systems Engineering and Integration. CC/SOIF includes the command and control center for human decisionmaking, and the information and data processing network connecting the system and executing the plan for the defense.

c. Combines with funding from Advanced Strategic Missile Systems (ASMS) program for annual level of effort of $200 million; takes some penetration aid programs through full-scale development.

One option that might be relatively less expensive would be to deploy only endoatmospheric interceptors with very low-yield nuclear warheads. Such an interceptor need not actually hit an incoming RV in order to destroy it, and might thus be more effective than non-nuclear endoatmospheric interceptors against maneuvering reentry vehicles. However, preferential defense of a subset of silos might not be feasible because the shorter-range missiles would have to be deployed relatively close to the ICBMs they were defending, possible revealing to the attacker which silos were being preferentially defended. This option might also encounter political resistance to the deployment of nuclear-tipped interceptors.

ADVANTAGES AND DISADVANTAGES OF DEFENDING SILO-BASED MISSILES

The mission of defending ICBMs would provide the United States much experience with a system of strategic defenses. Because it would be substantially larger than an accidental launch protection system, a system of defenses for silo-based missiles would provide the military more experience in deploying and operating strategic defenses. Deployment would also provide manufacturers with more experience in developing and building strategic defenses. Such experience could be valuable, especially if the United States were eventually to deploy a large system of strategic defenses aimed at protecting whole populations against attack.

Silo-based defenses would also add to the number of U.S. warheads that would be likely to survive a Soviet attack and so could improve deterrence. Without defenses, few of the U.S. missiles based in silos would be expected to survive a dedicated attack. A system of defenses such as the one outlined above might allow many more U.S. warheads to survive an attack.

Defending silo-based missiles would not necessarily be more costly than other methods of adding to surviving warheads. CBO calculated the costs of buying and operating for 10 years the silo-based missiles and defenses in the system outlined above. The cost per surviving warhead in this force would be about $38 million. The cost per surviving warhead achieved by deploying a force that included 500 2-RV small mobile ICBMs (SICBMs) would be about $39 million. (The bases for these costs are detailed in the following section.)

But there are important disadvantages to deploying a system of defenses for silo-based missiles, especially when compared with the option of deploying mobile missiles. Silo-based missiles that are defended would have less certainty of surviving a Soviet attack than would mobile missiles. Many tactics and countermeasures are available to an attacker attempting to foil a system of defenses. For example, the attacker could develop warheads that maneuver, or it could deploy decoys and penetration aids. Some of these tactics would be costly, but not necessarily more costly than the defense against them, and the attacker might consider the benefits worth the cost. The efficacy of such countermeasures would depend on the strengths and weaknesses of the defensive systems. One difficulty could lie in determining the opponent's tactics and capabilities. Decoys, for example, could possibly be deployed surreptitiously, although if they were fully tested the United States might gain some information about them. Even so, the United States might lack full confidence in its system of defenses, and find it necessary to continue spending in order to upgrade its capabilities against suspected threats.

Silo-based ICBMs could only be defended against an initial attack. Once the interceptors had been used, the offense could know their location and which silos were being defended. This might permit the Soviet Union to mount a clever attack at a low price. For instance, it could first attack every silo with one warhead. Using the information gained from this, it could try to target the interceptors themselves and the remaining silo-based missiles in a second attack. To foil such a tactic, the silo-based missiles would have to be launched after the initial attack.

Mobile missiles, on the other hand, would not suffer from these drawbacks. They could survive in large numbers unless the Soviet Union developed the ability to determine their individual locations in a wartime situation which would require a breakthrough in technology not foreseeable at this time. (The United States, it is true, believes it can use penetrating bombers to locate and destroy the Soviet Union's mobile missiles. If successful, this tactic might erode the ability of mobile missiles to survive for extended periods after an initial attack. But bombers take many hours to reach their targets. Furthermore, even though the United States has devoted many billions to its strategic bomber fleet and continues to do so, this "search and destroy" mission would be most challenging for the U.S. fleet, while the Soviet Union has a much smaller and less capable bomber force.)

Deploying a system of defenses for silo-based missiles also poses a clear risk that the Soviet Union would deploy its own system of defenses. If it did, it would be able to destroy reentry vehicles, which could increase U.S. requirements for retaliatory offensive warheads simply to enable the same number of warheads to reach Soviet targets. In other words, Soviet defenses could reduce or even negate the initial advantage afforded by U.S. defenses. Mobile missiles, on the other hand, could be deployed without abrogating the ABM Treaty and its prohibition on strategic defenses.

In sum, if the principal U.S. goal is to gain experience with a system of strategic defenses--along with an ALPS capability--then defending silo-based missiles has some merit. It would provide this experience while also adding to the number of U.S. warheads likely to survive a Soviet attack. If, however, the principal U.S. goal is to add surviving ICBM warheads, then deployment of a system of mobile missiles could meet that goal with greater assurance that warheads would survive an attack and less chance that added expenditures would be needed to offset Soviet countermeasures.

ANALYSIS OF ALTERNATIVE MIXES OF FORCES

The preceding section noted the cost of a surviving warhead for a silo-based missile defense as compared with small mobile ICBMs. To determine those costs, and the relative merits of different ICBM options, CBO examined three mixes of offensive forces. Each of these three mixes--or "force structures"--is designed to be consistent with the proposed START treaty. Achieving consistency with START requires assumptions about all three parts of the U.S. triad of strategic offensive forces; these assumptions are detailed in Appendix C. For the sake of comparability, each force structure contains the same total number of ICBM warheads--1,581. (Actually, because there are multiple warhead missiles in each force, the numbers range from 1,580 to 1,582.)

The first of the three force structures examined by CBO illustrates one of several possible compromises between the Congress and the Administration over the contentious issue of how to modernize ICBM forces. This first force structure includes 50 of the large 10-warhead MX missiles based on rail cars (rail-MX) and 300 of the small mobile ICBMs (SICBMs)--a smaller missile deployed on trucklike vehicles hardened to some degree against nuclear attack.[5] In this force structure each SICBM is assumed to carry one warhead. Both the rail-MX and the SICBM are mobile missiles that can be dispersed over wide areas to survive a Soviet attack. This first force structure also contains 260 of the silo-based Minuteman III missiles--each of which carries three warheads--for a total of 1,580 warheads.

The second force structure is designed to be the most mobile among the three in this analysis. It contains 500 SICBMs deployed with two warheads apiece.[6] It also contains 194 Minuteman III missiles in silos.

The third force structure is the least mobile force in this analysis. It consists of 527 Minuteman III missiles in silos, and no mobile missiles.

The remainder of this section analyzes these three force structures and explores the potential for deploying defenses with some of these forces. The analysis depends on assumptions about the threat posed by the Soviet Union to the ICBM force. It also requires a notion of how many survivable ICBM warheads are required for U.S. retaliatory plans.

5. The rail-based 10-warhead MX would be deployed aboard special railroad cars. In peacetime, they would be kept in garrison on Air Force bases, where they could be vulnerable to attack since their locations would be known. In a crisis, they would move randomly about the commercial rail lines, designed to look like other trains. The SICBM would have one or two warheads and would be deployed in a mobile launcher hardened to some degree to withstand nuclear effects. In this analysis, SICBMs are assumed to be deployed at three Minuteman wings in the northern states where they could be dispersed over more than 25,000 square miles within the 25 or so minutes of notice that an attack by the Soviet Union was actually under way. In contrast, rail-based MX missiles would require about six hours of advance warning to be dispersed sufficiently to achieve the same level of survivability as SICBMs at Minuteman bases. If survivability considerations warranted it, SICBMs could be dispersed even further by being based in the Southwest. Without a change in its configuration, however, the two-warhead SICBM would not have the range to reach some important targets in the Soviet Union if based in the Southwest.

6. The 2-RV version of the SICBM would require $15 million in research and development funds, and $300 million in production funds (in current dollars). It would also require additional Department of Energy funds for procuring the extra warheads.

The Assumed Soviet Threat

This analysis assumes that the proposed START treaty is accepted by the United States and the Soviet Union. The proposed treaty would limit each side to no more than 6,000 total strategic warheads. As part of the negotiations, the United States has proposed a sublimit of 3,300 on ICBM warheads. This analysis assumes that the sublimit is accepted and that the Soviet Union maintains the allowed maximum of 3,300 warheads.

In carrying out a nuclear attack, the Soviet Union would have to allocate its warheads among a wide range of U.S. targets: ICBM silos, bomber bases, submarine bases, military command centers, industrial targets, and others. Because the issue in this paper is the ability of U.S. ICBMs to survive, the analysis assumes that the Soviet Union makes this allocation in a way that poses a severe threat to U.S. ICBMs. Thus, of its 3,300 ICBM warheads, the Soviet Union is assumed to dedicate about 2,100 to attacking the U.S. ICBM force. (See Appendix C for details.)

U.S. Goal for Surviving Warheads

The desired nature of U.S. forces depends in part on how many warheads are judged necessary to ensure retaliation and deterrence. The Defense Department makes these judgements, but they are not routinely disclosed to the public. When the concept for deceptive basing of the MX missile was first introduced by the Carter Administration, however, the goal was to assure that 1,000 ICBM warheads would survive a Soviet attack. In testimony before the Congress in 1986, General Larry D. Welch, then Commander-in-Chief of the Strategic Air Command, and now Chief of Staff of the Air Force, testified that the United States needed 1,500 accurate, survivable ICBM warheads.[7]

Under the mutual force reductions of a START agreement, which are assumed under this option, those goals would likely be reduced. A START treaty could reduce total warheads on each side by 30 percent or more, but the goal for surviving land-based warheads might not be

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7. Testimony of General Larry D. Welch before the Senate Committee on Armed Services, *Department of Defense Authorization for Appropriations for 1987*, 99:2 (1986) pt. 4, pp. 1569-1602.

reduced proportionately. In assessing the effectiveness of alternative force structures, this paper assumes that the United States judges that it requires between 500 and 750 surviving warheads from its ICBM forces.

Ability to Survive Without Defenses

In the absence of any strategic defenses, how well would the three alternative force structures postulated above survive a nuclear attack by the Soviet Union? Figure 3 depicts the number of warheads that the United States might have available with which to retaliate against the Soviet Union after absorbing a Soviet attack consisting of about 2,100 warheads. The number depends upon the force structure and, in one case, on the amount of warning time that the United States has before the attack occurs.

Regardless of warning time, in the third force structure, which consists entirely of Minuteman III missiles based in silos, only about 2 percent or about 32 of the warheads survive.[8] This force structure falls far short of the goal of having 500 to 750 surviving ICBM warheads. The silos housing the Minuteman III missiles are expected to be vulnerable to a Soviet missile attack and most are assumed to be destroyed. (Of course, the United States would have thousands of warheads on submarines and bombers many of which could be expected to survive a Soviet attack.)

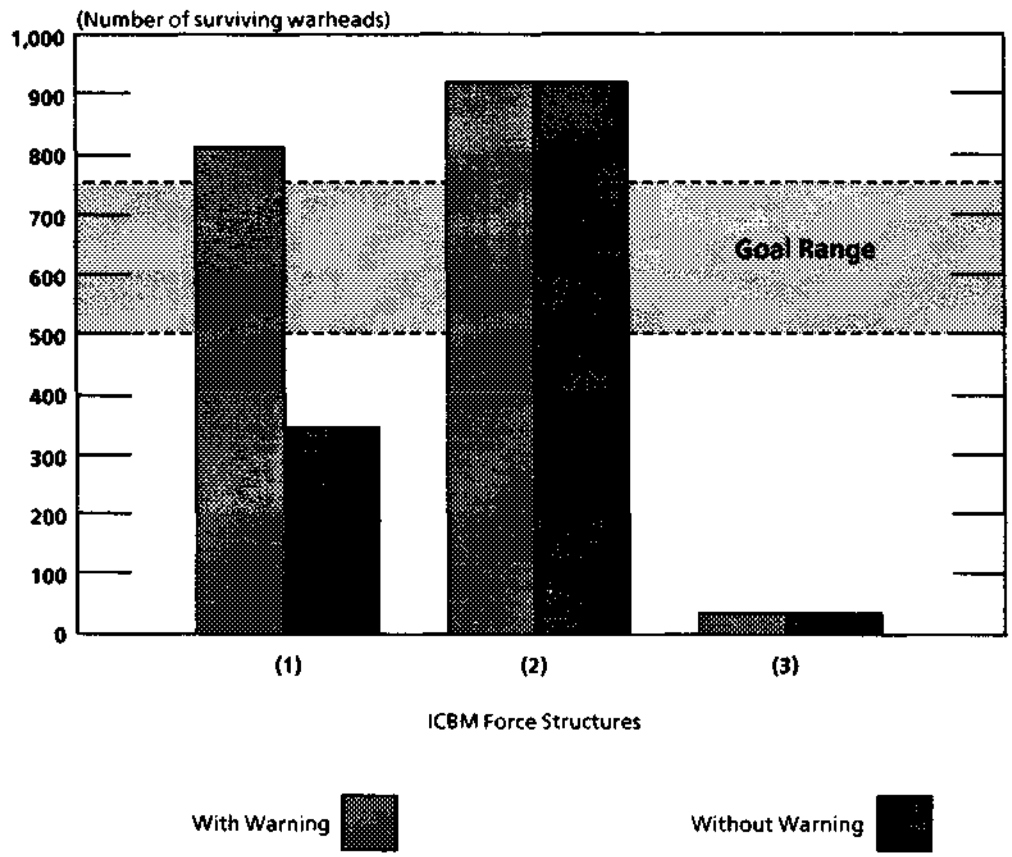
On the other hand, about 58 percent of the warheads in the second force structure would survive, again whether or not there was advance warning of a Soviet attack. Here the goal of 500 to 750 surviving warheads is met and exceeded. This second force structure consists mainly of SICBMs along with some Minuteman III missiles. SICBMs can be

8. This percentage is particularly small because an attack of this size would result in about four Soviet warheads being allocated per silo. It is doubtful whether an attack of such large size and complexity could ever work as well as analysis suggests, so the actual number of surviving warheads might well be larger; however, the United States could not expect that the number would be larger.

Some might also argue that a purely silo-based force would be launched on warning from U.S. sensors that an attack was under way. The period of time for such a decision would be small, however, and the risk of error immeasurable. Indeed, former Secretary of Defense Harold Brown has said that there is a tremendous difference to a President between having the option to launch forces on warning of attack and being required to launch them under those conditions or have them destroyed.

widely dispersed in the relatively short period of time between notification that the Soviets have actually launched an attack and detonation of arriving warheads. Because a barrage attack on the SICBM dispersal area would require many Soviet warheads, a wide dispersal guarantees that many SICBMs would survive, especially under the total warhead limits of a START treaty. If based at Minuteman missile sites, about 89 percent of them would survive with or without advance warning of a Soviet attack. That guarantees high surviv-

Figure 3.
Survivability of ICBM Force Structures Without Defenses



SOURCE: Congressional Budget Office.

ability for this second force structure even though most of its silo-based Minuteman III missiles are assumed to be destroyed.

The fate of the first force structure depends on whether or not advance warning is available and is acted upon. This force structure consists of two types of mobile missiles--300 SICBMs and 50 rail-MX--along with 260 Minuteman III missiles in silos. In peacetime, the rail-MX missiles are based on military reservations and would be destroyed by a Soviet attack. In order to survive an attack in large numbers, rail-MX missiles must be ordered to disperse about six hours before the attack. If the United States had that much warning of an attack, and acted on it, about 52 percent of the warheads in this first force structure would survive. This would exceed the goal of 500 to 750 surviving warheads. If there was little or no warning, only about 22 percent of the warheads would survive--not enough to meet the goal.

It is difficult to know how much effective warning time would be available. An attack that was preceded by tensions and hostilities during which U.S. forces could be brought to a wartime posture is considered more likely than a so-called "bolt-out-of-the-blue" attack. Tensions and hostilities, however, can take many forms and occur over extended periods. Maintaining nuclear forces on a wartime footing over a prolonged period is difficult. Also, diplomatic efforts could be under way, making nuclear escalation seem much less likely than might be the case. History has many examples of strategic warning indicators being misinterpreted, of policy makers being reluctant to act on them, or of warnings being truncated somewhere in the chain of command.

Survival of Silo-Based Missiles With Defenses

Defense of silo-based missiles offers promise. As the preceding analysis showed, few of these missiles would be expected to survive a Soviet attack in the absence of defenses. Moreover, as was noted above, the hardness and wide spacing of silo-based missiles would offer the defender some advantages, such as being able to preferentially defend a subset of silos.

What system of defenses would ensure that at least 500 U.S. warheads--the minimum goal assumed in this exercise--would survive a

Soviet attack? No system can guarantee survival of a specific number of warheads. The Soviets could control the number of warheads used to attack U.S. land-based missiles. This analysis assumes a large attack, but no one can be certain of how many warheads the Soviets would use. Moreover, the tactics of each side could affect the number of surviving warheads. For instance, the Soviets could target the same number of warheads on each silo. If they devoted 2,100 warheads to attacking Minuteman III silos, as this paper assumes, then a uniform attack would direct about four warheads at each U.S. silo. Alternatively, the Soviets could try to "exhaust" the U.S. defenses by targeting a larger number of warheads on some silos, and leaving other silos untouched. The defense could attempt a so-called "shoot-look-shoot" strategy by targeting a Soviet reentry vehicle, using sensors to determine if it had been destroyed, and then targeting it again if it survived. These examples indicate the uncertainties that each side would face in structuring its defense or offense and assessing its effectiveness.

Despite the uncertainties, analysis can provide some information about the number of U.S. warheads likely to survive. With a system of 1,500 ground-based interceptors defending the 527 Minuteman III silos in force structure three, and a Soviet attack consisting of 2,100 warheads, analysis of several tactics suggests that at least 500 U.S. warheads would survive. For example, a model developed by the Los Alamos National Laboratory and used in a study by the Institute for Defense Analyses, which allows a preferential defense by the United States, suggests this result.[9] (See Appendix D for the model.) This analysis assumes that the defenses work well (achieving a probability of kill of about 80 percent) and that the defense can discriminate among reentry vehicles and penetration aids. A model consulted by the Strategic Defense Command and others in the Department of Defense also suggests this result. This model incorporates a shoot-look-shoot strategy by the defense. A simpler analysis, which assumes that the Soviets employ an exhaustion attack while the United States

9. Jerome Bracken, *MX Missile Basing and ABM Defenses*, Institute for Defense Analyses Paper P-1655 (April 1982).

conducts a preferential defense, also suggests that at least 500 warheads would survive.[10]

The next section examines the cost per surviving warhead of the different force structures, including silo-based missiles with defenses. The defense system assumed in that section, as well as in the initial budget mission for defending silo-based ICBMs, is a larger system than the one described just above. The system described above is the smallest system that meets the goal of providing at least 500 surviving warheads. CBO's analysis, however, indicates that a larger defense system (consisting of 2,200 interceptors to provide about the same number of surviving warheads as provided by the 500 2-RV SICBM force structure) would have a lower cost per surviving warhead than the smaller defense system (with 1,500 interceptors).

Cost per Surviving Warhead

This section calculates the likely cost per surviving warhead for each of the three alternative force structures and for the silo-based missiles coupled with a system of defenses. To provide a comprehensive estimate of costs, the estimates include not only the cost to develop and deploy the system, but also the cost to operate the system for 10 years. These 10-year life-cycle costs are very similar--around $35 billion--except for costs of the third force structure consisting of silo-based ICBMs without defenses at about $11 billion (see Table 7).

10. The analysis runs as follows. Assume that the United States preferentially defends 250 silos with six interceptors each, more than the number of Soviet reentry vehicles that could be allocated in a uniform attack. Guessing or obtaining information about this strategy, but not knowing which silos are defended, the Soviets conduct an exhaustion attack with one more ICBM RV--or seven--per silo. Because they have one more attacking warhead than the United States has interceptors, the Soviets destroy most of the 300 silos (2,100 attacking warheads divided by seven) that they attack. But 227 silos are not attacked at all in this case, providing significantly more than 500 surviving warheads.

    Alternatively, if the Soviets attack all the silos with one RV having a high probability of kill (using 527 RVs), and conduct an exhaustion attack against as many silos as they can (1,573 remaining RVs divided by six for 262 silos attacked), then fewer RVs survive, but still more than 500. (Some of those silos attacked in the "exhaustion phase" will already have been destroyed by the initial RV because they were not defended.)

    If the Soviets choose to conduct a uniform attack by allocating about four warheads to each of the silos, the number of silos surviving would be more directly associated with the interceptor capability (probability of kill) of the defense. Estimates about such capability may figure into the Soviet choice of strategy.

Table 7 also shows how many warheads would survive a Soviet attack both with advance warning and without advance warning. The number of surviving warheads varies from a low of 32 warheads for silo-based missiles without defenses to a high of 930 warheads for silo-based missiles with a defense system that includes 2,200 exoatmospheric interceptors.

Combining costs with numbers of surviving warheads shows that the cost per surviving warhead is very similar--in the range of $40 million--for the three force structures in the cases where both the rail-MX and the SICBM are fully dispersed, and the silo-based missiles are defended. If the rail-MX missiles are not dispersed, the cost per surviving warhead in that force structure rises dramatically to about $103 million. If the silo-based missiles are not defended, the cost per surviving warhead is about $344 million.

TABLE 7. COSTS PER SURVIVING WARHEAD FOR THREE DIFFERENT ICBM FORCE STRUCTURES
(Costs in billions of 1990 dollars of budget authority)

Force Structures	10-year Life Cycle Cost	Surviving Warheads		Cost per Surviving Warhead	
		With Warning	Without Warning	With Warning	Without Warning
(1) 50 RAIL MX 300 1-RV SICBM 260 MM III	36	814	346	.044	.103
(2) 500 2-RV SICBM 194 MM III	36	920	920	.039	.039
(3) a. 527 MM III no defenses	11	32	32	.344	.344
b. 527 MM III with defenses	35	930	930	.038	.038

SOURCE: Congressional Budget Office. Surviving warheads for the silo-based force with defenses is based on a model developed by the Los Alamos National Laboratory.

Using Defenses with Mobile Missiles

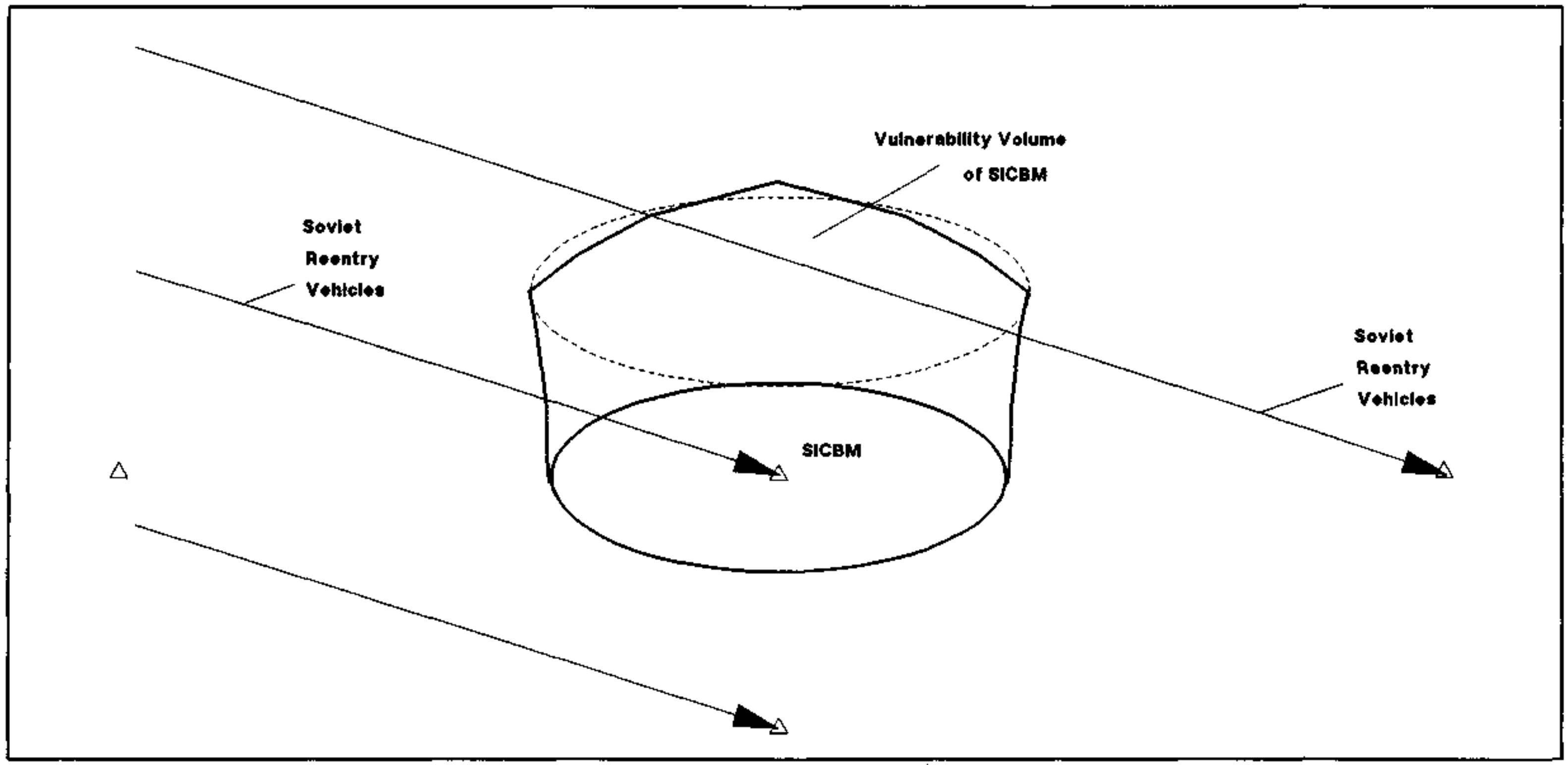
Some analysts have suggested that a system of strategic defenses could be used to defend mobile missiles such as the SICBM. The prospects for success in this venture do not seem promising. As a preceding section noted, SICBM force survivability without defenses is very high. Thus the defense at best can save only a limited number of SICBMs. Nonetheless, for the sake of completeness, this section performs the analysis necessary to ascertain the relevant costs per surviving warhead.

The Soviet Union would probably choose to attack a dispersed system of mobile missiles by blanketing as much of the dispersal area as it could with the lethal effects of its reentry vehicles. (Since such an attack would exact a high price in terms of attacking RVs for those "killed," the Soviets might choose not to attack at all. In this case, of course, defenses would add nothing.) In contrast to the situation when defending silos, if the defense tried to preferentially defend certain SICBMs, it would suffer from some uncertainty in determining which attacking RVs were targeted on a particular SICBM. Figures 4 and 5 illustrate why. They show a simplified example of the region around a SICBM within which the detonation of an RV of the type the Soviets could use to attack the SICBM (the large SS-18 missile) would destroy the SICBM. Any RV passing through this region is a potential killer of the SICBM that the defense wants to protect, so all of them would have to be intercepted by the defense. Depending on the SICBM's location in relation to the aimpoints of the attacking RVs, a barrage attack by the Soviet Union would cause at least two and as many as five RVs to pass through this area of vulnerability.[11] Roughly speaking then, even if the defense worked perfectly, the United States would have to purchase an average of 3.5 interceptors (the average of two and five) for each SICBM that was saved from destruction.

For instance, in the force that contained 500 2-RV SICBMs, about 89 percent of the SICBMs survived. Or, about 55 SICBMs--110 warheads--were destroyed by the Soviet barrage. If a defense were de-

11. This is known as the Impact Point Prediction ambiguity problem. Since the rail-MX is not hardened, its vulnerability volume is larger than that of the SICBM.

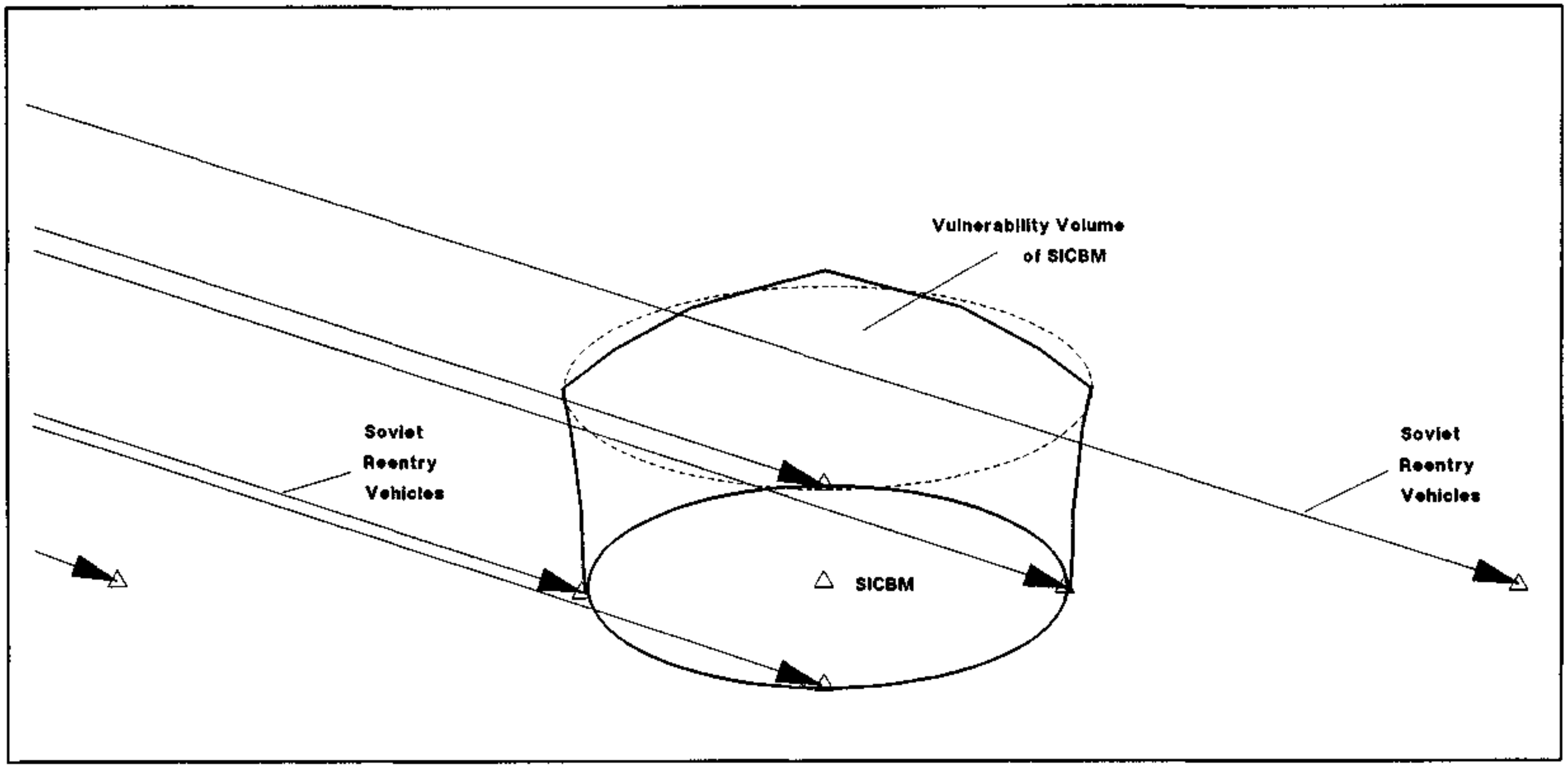
Figure 4.
Barrage Attack Against an SICBM: Best Case for the Defense



SOURCE: Congressional Budget Office.

NOTE: A reentry vehicle that explodes at any point on its trajectory within the vulnerability volume of the SICBM would destroy it. The Soviet reentry vehicles are assumed to be aimed so as to completely barrage a portion of the SICBM dispersal area with lethal effects.

Figure 5.
Barrage Attack Against an SICBM: Worst Case for the Defense



SOURCE: Congressional Budget Office.

NOTE: A reentry vehicle that explodes at any point on its trajectory within the vulnerability volume of the SICBM would destroy it. The Soviet reentry vehicles are assumed to be aimed so as to completely barrage a portion of the SICBM dispersal area with lethal effects.

ployed to save those SICBMs, the defense would require about 193 interceptors (3.5 interceptors each for 55 SICBMs).

CBO estimated the cost to purchase, and operate for 10 years, a system of defenses with 193 interceptors at about $14.5 billion. If that cost is allocated among the 55 SICBMs (110 warheads) defended, the cost per additional SICBM warhead surviving is about $132 million. (Actually, the cost would be somewhat higher because not all the SICBMs that were defended would survive.) To get the same number of additional surviving warheads by buying and operating more SICBMs (at 89 percent survivability) would cost about $4 billion, or about $36 million per surviving warhead.[12]

What if fewer SICBM were bought initially (890 warheads instead of 1,000) and defended to achieve the same level of survivability as the 1,000 warhead force without defenses. The cost of the defense less the cost of the SICBMs that were not procured would be about $10.0 billion, or about $102 million per surviving SICBM warhead provided by the defense. (This assumes the defense could work perfectly for the 98 warheads that would otherwise be destroyed.)

A much larger defense could have a lower cost per interceptor and thus per SICBM defended. However, there are not enough missiles to defend to warrant a significantly larger defense, because the mobile force has an inherently high level of survivability when dispersed.

A system of defenses could also be designed to defend the rail-MX missiles. In peacetime, the trains carrying the MX missile would be based at military garrisons--current plans include seven bases--and could be easily destroyed. The trains would need about six hours of travel time to disperse over a sufficiently wide area to guarantee that a large number of MX missiles would survive a Soviet attack. Would it be cost-effective to defend rail-MX missiles, especially in view of this vulnerable six-hour period?

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12. One potential way to increase the defense's leverage would be to cluster the SICBMs and defend a cluster of perhaps 10 SICBMs. If the defense worked perfectly, this would lead to a more favorable cost ratio. But if the defense was less than perfect, each RV that got through would destroy not just one, but ten SICBMs. If, in compensation, the defense deployed more interceptors to try to get close to "perfect," the cost ratio could again become unfavorable.

The MX missile, with its 10 warheads, represents a major threat to the Soviets and a lucrative target. Therefore, the Soviets would probably target it heavily both in garrison and as it was dispersing. A defender would suffer from a problem similar in concept to the one facing defenders of SICBMs--any enemy reentry vehicle passing through a wide area would be a potential killer that would have to be attacked. Furthermore, the MX would not generate as much dispersal area in the one-half hour or so of notice an attack was under way as the SICBM would.[13] These considerations make it unlikely that the cost of the rail-MX system, plus the cost of a system of defenses, would be less than the cost of the SICBM system necessary to provide the same number of surviving warheads without any defenses.

13. A train would not have the initial acceleration of a SICBM's mobile launcher. If the trains could travel about 10 miles in the one-half hour or so of warning that an attack was under way, then the dispersal area around the seven bases would be about 2,200 square miles.

CHAPTER VI

BUDGET MISSION FOUR:

ADMINISTRATION PLANS

The Reagan Administration repeatedly made it clear that its ultimate goal was to protect the people of the United States and its allies from a large-scale nuclear attack--not to protect only silo-based missiles or to provide insurance against an accidental or unauthorized launch. President Bush has indicated that he supports the Reagan goals for a system of strategic defenses. The discussion in this section relies on the detailed goals and plans established by the Reagan Administration, noting where possible the changes that have been made by the Bush Administration.

To reach this broad goal, the Administration established a phased plan for developing and deploying a system of strategic defenses. The initial deployment--designated Phase I--would be designed to provide limited protection against a large nuclear attack by the Soviet Union. Specifically, the system would meet classified criteria developed by the Joint Chiefs of Staff and would, in their view, increase U.S. deterrent capability by a meaningful amount.[1] Deployment of Phase I would not be compatible with the ABM Treaty.

During the 1990s, Phase I--along with its technology base--would be the primary recipient of funding for strategic defenses under the Administration plan. Phase I would consist of the development and deployment of a number of systems discussed earlier in this paper (see Box 1). These include sensors (Boost Surveillance and Tracking System, Space-Based Surveillance and Tracking System, Ground-Based Surveillance and Tracking System, and Ground-Based Radar) and weapons (Space-Based Interceptor and Ground-Based Interceptor). If fiscal limits permit, the Administration hopes that full-scale development of these weapons could begin in the early or mid-1990s; procurement might begin in the late 1990s.

1. The JCS operational requirements also "acknowledge and confirm the President's long-term objective 'to develop a thoroughly effective defense that will protect the United States and its allies from the threat of attack from ballistic missiles of all ranges'...."

Because of technological and fiscal limits, Phase I would not be sufficiently effective to avoid substantial destruction of property and population in the event of a large-scale attack. Follow-on phases would, however, provide increasing levels of protection against a Soviet attack, with the hope of leading over the long term to a system that provided effective defenses.[2] Follow-on phases would also add improvements designed to respond to Soviet countermeasures.

Under the Administration plans, costs in the 1990s would depend on how quickly these follow-on phases were developed. Initial plans called for development of the various phases to proceed in parallel, with progress on follow-on phases remaining only a few years behind progress on the initial phase. Recent statements suggest, however, that the Administration plans to emphasize Phase I while proceeding more slowly with subsequent phases. This approach should reduce costs in the 1990s. But it raises the risk that the Administration might deploy an early phase at substantial cost--both in terms of dollars and in terms of the political costs associated with abrogating the ABM Treaty--only to discover that the goal of protecting U.S. and allied populations could not be achieved because of limited technology or budgets.

COSTS UNDER THE ADMINISTRATION PLAN

In 1990, the Bush Administration proposes spending $4.6 billion on funding for strategic defenses. Under current proposals, that spending would rise to $8.2 billion by 1994 (or about $9 billion including anticipated inflation). Table 8 shows the details.

These proposed spending levels were announced in April 1989. The Bush Administration has not released details beyond 1990 of how the funds would be allocated among the various SDI program elements. Such an allocation is available, however, for the Reagan Administration plans submitted in January 1989 (see Table 8). The most notable differences between the two plans for 1990 is the increase in

2. No prediction has been made as to the number of phases that would be required before the Administration could meet its goal of protecting the population from the effects of a large nuclear attack. It is clear, however, that substantial capability would be required beyond that available for Phase I.

the percentage of funding for the Surveillance, Acquisition, Tracking, and Kill Assessment (SATKA) element under the Bush plans--from 23 percent to 29 percent--and the elimination of funding for Phase I full-scale development.

Under the Reagan Administration plan, total spending for the five program elements that comprise the technology base (shown in the top five lines of Table 8) would rise between 1990 and 1991, but after that

TABLE 8. COSTS OF MISSION 4: REAGAN ADMINISTRATION PLAN AS REVISED BY BUSH ADMINISTRATION
(In millions of 1990 dollars of budget authority)

Program Elements	1990	1991	1992	1993	1994	Total 1990-1994
Directed-Energy Weapons (DEW)	1,120 *830*	1,285	1,590	1,640	1,655	7,290
Kinetic Energy Weapons (KEW)	1,345 *1,110*	1,490	1,555	1,520	1,070	6,980
Surveillance, etc. (SATKA)	1,280 *1,340*	1,395	1,335	1,205	890	6,105
Systems Analysis, etc. (SABM)	780 *720*	950	1,090	1,095	1,105	5,020
Survivability, etc. (SLKT)	775 *570*	920	1,075	1,260	1,315	5,345
Deploy Phase I	260 *0*	415	1,000	2,080	3,680	7,435
Total, Reagan Plan	5,560	6,455	7,645	8,800	9,715	38,175
Total, Bush Plan	*4,570*	*5,215*	*5,965*	*7,145*	*8,205*	*31,100*

SOURCE: Congressional Budget Office, based on data from the Department of Defense, rounded to the nearest $5 million.

NOTE: Revisions by the Bush Administration are shown in italics. Details on the revisions are not available beyond 1990.

would not grow much, if at all, in real terms. There would, however, be sharp growth in spending for full-scale development of Phase I. Spending for that program element would rise from $260 million in 1990 to $3.7 billion by 1994.

Acquisition Costs Beyond 1994

In the years beyond 1994, the Administration would begin procurement of the systems needed to deploy Phase I. As of October 1988, the Defense Department estimated that the total acquisition costs for Phase I would amount to $69.1 billion in 1988 dollars--or about $74 billion in 1990 dollars. Most of these costs would be incurred beyond 1994. Phase I cost estimates have undergone several revisions in recent years. For example, as recently as June 1988, the Defense Department estimated that the costs of Phase I would range from $75 billion to $150 billion. Estimated costs were later reduced because the department decided that, among other things, the goals of Phase I could be achieved with fewer numbers of space-based systems and less redundancy in sensor systems. Costs of Phase I could undergo further revision. As was noted early in this paper, the Administration is investigating a new concept called Brilliant Pebbles, which would use a large number of low-cost, autonomous space-based weapons to destroy ballistic missiles and reentry vehicles. It is possible that implementation of the Brilliant Pebbles concept could further reduce the costs of Phase I. On the other hand, programs at the cutting edge of technology have often had a history of increasing costs during full-scale development.

Annual Budgets Beyond 1994

The Administration does not provide estimates of annual SDI budgets beyond the next five years. Such estimates would, however, be useful in assessing the level of resources that could eventually be required under Administration plans. Details currently available concerning SDI plans do not permit CBO to estimate long term annual budgets. Instead, this section discusses the possible size of the components of annual SDI budgets beyond 1994. They would essentially include three components: costs of Phase I; costs of maintaining the technology base for the development of follow-on phases; and costs of developing and deploying follow-on phases.

Of the Administration's estimate of about $74 billion for Phase I, about $14.4 billion would have been spent through 1994 under the Reagan Administration's plan (including about $7 billion for demonstration/validation of Phase I and about $7.4 billion for full-scale development of Phase I in the Phase I SDS program element). About $60 billion would be left for spending through about the year 2003. The Bush Administration plan allots a lesser amount for spending through 1994, so unless total costs changed significantly, more would be spent under the Bush plan in the late 1990s.

In addition, continued funding for the technology base would be necessary to support the development of follow-on phases. This level of funding has not been specified, but could reasonably be expected to continue at about the average real level of the 1992-1994 period--before the beginning of most full-scale development for Phase I--which would total about $6.4 billion under the Reagan Administration plan. This would maintain roughly constant research support for the development of follow-on phases for the Strategic Defense System.

Finally, costs in the 1990s and beyond would depend on the pace of development and deployment of follow-on systems. Proceeding more slowly with subsequent phases in parallel with Phase I would reduce annual costs, but would increase the risk of deploying an initial system and not having a more capable system available in a timely fashion. In that case, the capability of the initial system could be eroded by Soviet countermeasures, as could the potential for achieving a true shift in the basis for deterrence.

ADVANTAGES AND DISADVANTAGES OF THE ADMINISTRATION PLAN

The Administration's proposals for strategic defenses have been debated extensively. It is not the intent of this short discussion to repeat the many arguments. Rather, this paper briefly notes a few of the key points made by proponents and opponents.

If it could achieve its goal of effective population defense, a system of strategic defenses would alter the basis for nuclear deterrence in ways that would be reassuring. Today the United States relies on the threat of retaliation to deter nuclear attack. So far, the threat alone has been sufficient. But if this country ever had to carry out the threat and retaliate, the result could be the destruction of civilization. An effective system of defenses might also deter a potential aggressor by convincing it that an attack would be ineffective. If an enemy attacked anyway, the results of destroying enemy warheads--rather than retaliating with U.S. warheads--would be much less lethal to mankind.

Moreover, as has been noted, the Soviet Union has an active program to develop strategic defenses and has deployed systems that have modest capability. Proponents argue that, to guard against a Soviet breakthrough, the United States must pursue an aggressive program of research and, possibly, deployment.

There is, however, great doubt as to the ability of the United States to develop and deploy truly effective defenses. Formidable technical problems must be overcome. That accomplished, the United States would have to commit adequate resources to deploy a system of sufficient size to be effective. This paper suggests that substantial outlays could be required during the 1990s. The sums required in the next century could be much larger.

Some analysts also express concern that, since nuclear weapons are thought to deter conventional war as well as nuclear war, effective defenses might increase the risk of a large-scale conventional war. While conventional warfare is not likely to destroy mankind, it certainly promises widescale destruction.

There is also the question of how the Soviet Union would respond to a U.S. deployment of strategic defenses. It could respond by adding offensive warheads in an effort to overwhelm U.S. defenses. In that case, the United States might respond with an offensive buildup of its own, thus touching off a new arms race.

Or, the Soviet Union might deploy strategic defenses of its own. Eventually, if both sides deployed effective defensive systems, a stable environment might result in which neither side had an incentive to initiate a nuclear attack. In the process of moving to that point, however, one side or the other might achieve effective defenses before the other, giving it an opportunity to coerce or attack the weaker country without fear of effective retaliation. The country that did not have effective defenses could be tempted to strike first in a crisis, believing that its smaller retaliatory force might be negated by the defense. These potential periods of instability could be very dangerous, particularly if they happened to occur during a period of heightened tension between the two powers. For all its faults, the present system of retaliation as a deterrent is well understood and has effectively prevented nuclear attacks for several decades.

APPENDIXES

APPENDIX A

COSTS OF ALTERNATIVES COMPARED WITH CBO BASELINE

TABLE A-1. COSTS OF ALTERNATIVE SDI BUDGET MISSIONS COMPARED WITH SDI COSTS IN THE CBO JANUARY 1989 BASELINE (In billions of 1990 dollars of budget authority)

	1990	1991	1992	1993	1994	Total 1990-1994
SDI Costs in CBO Baseline[a]	3.8	3.8	3.8	3.8	3.8	19.0
Maintain a Hedge						
Higher option	2.6	2.7	2.9	3.1	3.4	14.5
Lower option	1.9	2.0	2.3	2.4	2.7	11.3
Deploy an Accidental Launch Protection System	2.6	3.0	3.4	3.9	4.0	17.0
Deploy a System to Protect Silo-Based ICBMS	2.7	3.2	3.7	4.4	4.5	18.4
Bush Administration	4.6	5.2	6.0	7.1	8.2	31.1

SOURCE: Congressional Budget Office.

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

a. The CBO baseline assumes that defense appropriations are held constant in real terms.

APPENDIX B

DESCRIPTION OF THE ABM TREATY

This appendix provides a brief description of the 1972 Anti-Ballistic Missile Treaty excerpted from an Arms Control and Disarmament Agency publication.

In the Treaty on the Limitation of Anti-Ballistic Missile Systems the United States and the Soviet Union agree that each may have only two ABM deployment areas,[1] so restricted and so located that they cannot provide a nationwide ABM defense or become the basis for developing one. Each country thus leaves unchallenged the penetration capability of the other's retaliatory missile forces.

The treaty permits each side to have one limited ABM system to protect its capital and another to protect an ICBM launch area. The two sites defended must be at least 1,300 kilometers apart, to prevent the creation of any effective regional defense zone or the beginnings of a nationwide system.

Precise quantitative and qualitative limits are imposed on the ABM systems that may be deployed. At each site there may be no more than 100 interceptor missiles and 100 launchers. Agreement on the number and characteristics of radars to be permitted required extensive and complex technical negotiations, and the provisions governing these important components of ABM systems are spelled out in very specific detail in the treaty and further clarified in the "Agreed Statements" accompanying it.

Both parties agreed to limit qualitative improvement of their ABM technology, e.g., not to develop, test or deploy ABM launchers capable of launching more that one interceptor missile at a time or modify existing launchers to give them this capability, and systems for rapid reload of launchers are similarly barred. These provisions, the

1. Subsequently reduced to one area.

Agreed Statements clarify, also ban interceptor missiles with more than one independently guided warhead.

There had been some concern over the possibility that surface-to-air missiles (SAMs) intended for defense against aircraft might be improved, along with their supporting radars, to the point where they could effectively be used against ICBMs and SLBMs, and the treaty prohibits this. While further deployment of radars intended to give early warning of strategic ballistic missile attack is not prohibited, they must be located along the territorial boundaries of each country and oriented outward, so that they do not contribute to an effective ABM defense of points in the interior.

Further, to decrease the pressures of technological change and its unsettling impact on the strategic balance, both sides agree to prohibit development, testing, or deployment of sea-based, air-based, or space-based ABM systems and their components, along with mobile land-based ABM systems. Should future technology bring forth new ABM systems "based on other physical principles" than those employed in current systems, it was agreed that limiting such systems would be discussed, in accordance with the treaty's provisions for consultation and amendment.

The treaty also provides for a U.S.-Soviet Standing Consultative Commission to promote its objectives and implementation. Both the United States and the Soviet Union have raised a number of questions in the Commission relating to each side's treaty compliance.

Article XIV of the treaty calls for review of the treaty five years after its entry into force, and at five-year intervals thereafter. The first such review was conducted by the Standing Consultative Commission at its special session in the fall of 1977.

APPENDIX C

MISSION THREE: ASSUMED U.S. AND SOVIET FORCE STRUCTURES UNDER START, AND ASSUMED SOVIET THREAT TO U.S. ICBMS

TABLE C-1. THREE U.S. FORCE STRUCTURES UNDER START

Kind of Vehicle	Force Structure (1)		Force Structure (2)		Force Structure (3)	
	SNDVs	Warheads	SNDVS	Warheads	SNDVs	Warheads
ICBMs						
Minuteman III	260	780	194	582	527	1,581
SICBM 1-RV	300	300	0	0	0	0
SICBM 2-RV	0	0	500	1,000	0	0
MX/rail-based	50	500	0	0	0	0
Subtotal	610	1,580	694	1,582	527	1,581
SLBMs						
Trident II (D-5)	408	3,264	408	3,264	408	3,264
Subtotal	408	3,264	408	3,264	408	3,264
Bombers						
B52-H Standoff-penetrate	71	923	71	923	71	923
B-1B Penetrate	97	97	97	97	97	97
B-2 Penetrate	132	132	132	132	132	132
Subtotal	300	1,152	300	1,152	300	1,152
Total	1,318	5,996	1,402	5,998	1,235	5,997

SOURCE: Congressional Budget Office.

NOTE: Start limits assumed in this study are as follows:

6,000 total warheads
4,900 ballistic missile warheads (ICBM and SLBM)
3,300 ICBM warheads
1,540 "heavy" ICBM warheads
1,600 Strategic Nuclear Delivery Vehicles (SNDVs) or platforms

Penetrating bombers each count as one SNDV and one warhead. Standoff-penetrate bombers count as one SNDV; each cruise missile they carry counts as one warhead, plus one warhead for the penetrating weapons payload.

TABLE C-2. POSSIBLE SOVIET FORCE STRUCTURE UNDER START, MAXIMIZING ICBM WARHEADS

Kind of Vehicle	SNDVs	Warheads
ICBMs		
SS-18	154	1,540
SS-24	140	1,400
SS-25 1-RV	360	360
Subtotal	654	3,300
SLBMs		
SS-N-8 (Delta II)	64	64
SS-N-18 (Delta III)	48	336
SS-N-23 (Delta IV)	64	640
SS-N-X (Delta V)	80	560
Subtotal	256	1,600
Bombers		
Bear-H Standoff	47	376
Blackjack penetrate	200	200
Blackjack standoff-penetrate	40	520
Subtotal	287	1,096
Total	1,197	5,996

SOURCE: Congressional Budget Office.

NOTE: The following assumptions are made regarding the possible Soviet threat to U.S. ICBMs:

- SS-24s and SS-25s are capable of destroying hardened targets such as ICBM silos in this time frame.
- 1,000 ICBM warheads are reserved for non-ICBM high-priority U.S. targets. The ICBMs are divided between SS-18s and SS-24s for reliability.
- 200 mobile SS-25s are kept in reserve.
- SLBMs are assigned to non-ICBM targets and to reserves.
- Warheads for use against U.S. ICBMs include 1,040 SS-18s, 900 SS-24s, and 160 SS-25s.

APPENDIX D

LOS ALAMOS SILO-DEFENSE MODEL

DEFINITIONS

Inventories

M = missiles

H = silos or shelters

X = exoatmospheric interceptors

N = endoatmospheric interceptors

y = endoatmospheric interceptors per defended silo or shelter.

Parameters

μ = warheads per missile

Z = kill vehicles per exoatmospheric interceptor

f = fraction of targets attacked in second strike that are protected by exoatmospheric interceptors.

Kill Probabilities

p = probability that warhead kills silo or shelter

q = probability that exoatmospheric kill vehicle kills warheads

r = probability that endoatmospheric interceptor kills warhead.

Leakage Factors

L_x = percent of warheads that are not killed by exoatmospheric interceptors defending missiles

L_n = percent of warheads that are not killed by endoatmospheric interceptors defending missiles

V_x = percent of warheads that are not killed by exoatmospheric interceptors defending other targets

Outcomes

S = missiles surviving first strike

W = warheads delivered in second strike.

ATTRITION EQUATIONS

The model basically has three levels, as defenses are introduced. The equations are given below. Variables followed by a "prime" symbol (for example, M′) are for Soviet force values. The model assumes that attacking warheads are distributed uniformly over the total number of U.S. silos.

Missiles in Silos or Shelters, No Defense (First Level)

$$S = M(1-p')^{\frac{\mu' M'}{H}}$$

$$W = \mu S.$$

Missiles in Silos or Shelters, Endoatmospheric Defense (Second Level)

$$L_n = (1\text{-}r)^{y/\frac{\mu'M'}{H}}$$

$$S = M(1\text{-}p'L_n)^{\frac{\mu'M'}{H}}$$

$$W = \mu S.$$

Missiles in Silos or Shelters, Exoatmospheric and Endoatmospheric Defense (Third Level)

$$L_x = (1\text{-}q)^{ZX/\mu'M'\left(\frac{M}{H}\right)}$$

$$L_n = (1\text{-}r)^{y/\frac{\mu'M'}{H}\left(L_x\right)}$$

$$S = M(1\text{-}p'L_nL_x)^{\frac{\mu'M'}{H}}$$

$$V_x' = (1\text{-}q')^{Z'X'/\mu Sf'}$$

$$W = \mu S\{f'V_x' + (1\text{-}f')\}$$