Chapter 2

Introduction

CONTENTS

Box

Figures

Table

Chapter 2
Introduction

ORGANIZATION OF THIS REPORT

This report identifies questions to be answered before the technical feasibility of achieving the goals set for the Strategic Defense Initiative (SDI) can be determined. The report also offers a snapshot of how far researchers have come toward answering these critical questions and how much remains unknown.

Chapter 1: Summary

Chapter 1 summarizes and explains the principal findings of this OTA study.

Chapter 2: Introduction

This introductory chapter devotes considerable attention to goals for the SDI, since this subject continues to be a source of confusion and debate in the country. Various leaders in the Administration and in Congress have at one time or another emphasized different goals, and which goals will ultimately prevail remains uncertain. Clearly, some goals would be easier to reach than others. This discussion does not include a critical analysis of the goals nor does it attempt to resolve the debate about them. Instead, this chapter tries to provide a context for the issues of technical feasibility.

Chapter 3: Designing a Ballistic Missile Defense (BMD) System: Architecture and Trade-off Studies

To assess the feasibility of a potential BMD system, the United States needs to know both what the system's elements and the system as a whole might look like. To this end, the Strategic Defense Initiative Organization (SDIO) has awarded a series of contracts to several teams of defense companies to try to define some candidate "system architectures" for BMD. Drawing on these studies, SDIO synthesized its own "reference architecture" to help SDI researchers understand the requirements that the technologies being developed eventually must meet.

Late in 1986 and in the first half of 1987, system architecture analysis was in a state of flux as SDIO instructed its contractors to conceptualize the early stages of a BMD deployment. In mid-1987, the SDIO proposed a first-phase architecture to the Defense Acquisition Board and in September the Secretary of Defense approved a program of 'demonstration and validation" for this architecture. The process of evolving system architecture analysis and design is likely to continue throughout the life of the program and into the period during which defenses are actually deployed, if they are. There should be continuing feedback between system designers and technology developers, balancing the desirable and the possible. This chapter introduces that process, discusses its importance, and describes where it has led so far.

Chapter 4: Status and Prospects of Ballistic Missile Defense Technologies, Part I: Sensors

Chapter 5: Status and Prospects of Ballistic Missile Defense Technologies, Part II: Weapons, Power, Communication, and Space Transportation

These chapters are organized as reference works on several of the key technologies under research in the SDI program-describing them, surveying the requirements they must ultimately meet, and reporting their status (including key unresolved issues) as of early 1988. The chapters also examine the requirements for combining those technologies into working components of a BMD system, with emphasis on the kinds of components needed for recent SDIO "reference architecture" formu-

Note: Complete definititions of acronyms and initialisms are listed in Appendix B of this report.

lations. Chapter 4 reviews technologies for finding, tracking, and pointing weapons at missile boosters, post-boost vehicles, and reentry vehicles and for discriminating between genuine targets and decoys. Chapter 5 reviews the weapon technologies for delivering lethal doses of energy (kinetic or electromagnetic) to targets. It also addresses the key technologies of space transportation, communication, and power supplies for space assets.

Chapter 6: System Development, Deployment, and Support

If BMD is to play a role in U.S. national strategy, the technologies described in the previous chapters must be incorporated into working weapon components. Those components must be integrated into effective weapon systems that are affordable, maintainable, and adaptable over time to possible adversary responses. By focusing on some particularly challenging issues, such as the development and engineering of a space-based space surveillance system and the logistics of space transportation, chapter 6 attempts to give an appreciation of the steps involved in these processes.

Chapter 7: System Integration and Battle Management

With variations on SDIO's reference architecture for a BMD system as models, this chapter shows how the various components of such a system would have to work together to intercept a ballistic missile attack in its several phases. The chapter attempts to give an appreciation of the complexities of integrating BMD system components into a quickly reacting system. It does so by presenting an overview of the tasks a BMD system would have to perform and examples of how it would perform them. It also exaxnines the concept of BMD battle management and the roles of humans and computers in such a battle.

Chapter 8: Computing Technology

Computers would be crucial to any BMD system, from simulation testing of theoretical designs, through operation of most of the hardware, to management of the battle. Chapter 8 focuses on the roles of computers in BMD and on the computation capabilities needed to satisfy SDI requirements. Computing technology encompasses both hardware and software. This chapter, however, emphasizes hardware questions while chapter 9 focuses on software.

Chapter 9: Software

The legislation mandating this study instructed that it include an analysis of the feasibility of meeting SDI software requirements. Chapter 9 examines the question of whether the complex computer programs that BMD will require could be made sufficiently dependable. It analyzes the concepts of software trustworthiness and reliability, as well as other important software issues. It compares requirements and characteristics of BMD software to existing, trusted software systems. The chapter ends with conclusions about the prospects for producing trustworthy software for the SDI.

NOTE: Chapters 10, 11, and 12 are now available only the classified version of this report. The descriptions here are for reference.

Chapter 10: Nondestructive Countermeasures Against Ballistic Missile Defense

Ballistic missile defense systems must be designed to cope with the kinds of countermeasures the Soviets might deploy against them. These include modified or new ballistic missiles, devices intended to make reentry vehicles harder to find or shoot at, and weapons that could attack the BMD system. This chapter examines the first two types of countermeasure, while chapter 11 describes the latter, or "defense suppression" technologies and their counters. Estimates of physically possible countermeasures must be refined by estimates of what is technically, economically, and strategically feasible for the Soviet Union. The chapter concludes with a review of the tech-

nologies that might provide responses to the potential Soviet countermeasures.

Chapter 11: Defense Suppression and System Survivability

The legislation instructing OTA to carry out this study placed special emphasis on the survivability of an SDI-produced BMD system in the face of an enemy attack on the system itself. The chapter reviews the technologies that might be applied to defense suppression and the technologies and tactics that might counter them.

Chapter 12: Defense Suppression Scenarios

In a variety of "scenarios," chapter 12 identifies the most stressing attack threats that various BMD elements would be likely to face and the methods a BMD system might use to defend itself, actively or passively.

THE GOALS OF THE STRATEGIC DEFENSE INITIATIVE

According to the Strategic Defense Initiative Organization in 1986:

> The goal of the SD I is to conduct a program of vigorous research and technology development that may lead to strategic defense options that would eliminate the threat posed by ballistic missiles, and thereby:
>
> - support a better basis for deterring aggression,
> - strengthen strategic stability, and
> - increase the security of the United States and its Allies.
>
> The SDI seeks, therefore, to provide the technical knowledge required to support an informed decision in the early 1990s on whether or not to develop and deploy a defense of the U.S. and its Allies against ballistic missiles.[1]

What does the phrase, "eliminate the threat posed by ballistic missiles, " mean, and how might doing so enhance deterrence, stability, and security? Proponents of BMD have argued that increasing levels of defense could offer increasing benefits. Fairly modest levels of BMD, they say, might improve deterrence of a Soviet nuclear attack by increasing Soviet military planners' *uncertainty* about the effectiveness of such an attack. Higher levels of defense capability might actually *deny* the Soviets even the possibility of achieving whatever military goals they might have for attack. Finally, extremely good defenses against all types of nuclear attack–including attacks by ballistic missiles, cruise missiles, bombers, and other means of delivery-might essentially *assure* the *survival* of the U.S. population and society no matter what the Soviets tried to do. Then U.S. security would no longer rely on the threat of retaliation to deter a nuclear attack.

SDIO officials emphasize that currently the preponderance of their attention is focused on systems and technologies intended to lead to early accomplishment of the first goal of enhancing deterrence.

[1] Strategic Defense Initiative Organization, Report to *the Congress on the Strategic Defense Initiative,* June 1986, p. IV-1. In its 1987 report, SDIO dropped "in the early 1990s" from its goal; it also dropped the "not" from the phrase "whether or not" in the above quotation.

THREE GOALS FOR STRATEGIC DEFENSE

Increase Attacker Uncertainty

Working with assumptions about the accuracy, explosive power, and reliability of weapons systems as well as the nature of intended targets, Soviet military planners can make some predictions about Soviet ability to destroy a chosen set of targets. Just how confident Soviet planners would or should be

about the validity of their assumptions is extremely difficult for U.S. analysts to determine.

Relatively modest amounts of strategic defense,[2] some argue, might add to the uncertainties that the potential attacker already faces.[3] He would be forced to make additional assumptions about how—and which-of his warheads would be intercepted by the defenses. Insofar as a Soviet decision to launch a nuclear attack on the United States might depend on Soviet confidence in their ability to destroy a given set of targets, the protection added by modest U.S. strategic defenses might help deter such a decision.[4] Presumably, the larger factor in a Soviet decision on whether to strike first is the current high probability that a U.S. retaliatory attack would devastate much of the Soviet Union.

In its 1987 report to Congress, SDIO suggested that relatively modest levels of defense might begin to add to Soviet uncertainties by "denying the predictability of Soviet attack outcome . . . and imposing on the Soviets significant costs to restore their attack confidence."[5]

There are ways the Soviets might try to reduce the uncertainties added by U.S. defenses. They might deploy offensive countermeasures designed to restore their previous level of confidence in their weapons' ability to reach and destroy assigned targets. They might deploy additional weapons intended just to exhaust the defenses, assuring that some weapons face no defensive screen. They might attempt to circumvent the BMD system by adding more bombers and cruise missiles to their arsenal.

On the other hand, the Soviets would have to make new assumptions about how well these responses would work. The Soviets might also choose to give up some weapon capabilities to preserve others: for example, some countermeasures intended to assure that a given number of nuclear warheads could penetrate the defense might be traded against sacrifices in the number, accuracy, or yield (explosive power) of those warheads. If only because the offensive task had become more complicated, at least some more uncertainty would exist than if the United States had no defenses at all.[6] Opinions vary, however, on what margin of additional uncertainty the Soviets would face and whether there might be other, less costly, and earlier ways to complicate Soviet attack problems.

Deny Military Objectives

Some analysts have argued that an increase in attacker uncertainty as described above is itself a sufficient enhancement of deterrence to justify deploying ballistic missile defenses. The SDIO, however, places a more rigorous requirement on defense:

> A defense against ballistic missiles must be able to destroy a sufficient portion of an aggressor's attacking forces to deny him the confidence that he can achieve his objectives. In doing so, the defense should have the potential to deny that aggressor the ability to destroy a militarily significant portion of the target base he wishes to attack.[7]

The goal here is not just to reduce the attacker's confidence in achieving some set of goals, but to deny him any reasonable pros-

[2] This section addresses strategic defense generically -i.e., goals for defense against all means of delivering nuclear weapons, not just against ballistic missiles. Since the SDI is directed at developing defenses only against ballistic missiles, we quickly turn to that particular task for strategic defenses. Where relevant, the report will call attention to the relationships between ballistic missile defense and other kinds of strategic defense.

[3] These would include uncertainties about: the accuracy of missiles over untested trajectories; the vulnerabilities of some kinds of targets, such as command and control systems; whether the victim of the attack would launch his own missiles "on warning, " thus defeating the most critical objective of the attack; and the nature and results of the retaliation carried out by submarine-launched missiles, bombers, and cruise missiles that escaped the attack.

[4] For a more detailed discussion of deterrent strategy, see U.S. Congress, Office of Technology Assessment, *Ballistic Missile Defense Technologies,* OTA-ISC-254 (Washington, DC: U.S. Government Printing Office, September 1985), pp. 67-132.

[5] Strategic Defense Initiative Organization, *Report to* the Congress *on the Strategic Defense Initiative,* April 1987, p. II-11.

[6] Alternatively, some would argue that the Soviets might find a secret countermeasure that they were certain was capable of totally disabling the U.S. BMD system; if they combined this countermeasure with expanded offensive forces, their net certainty of attack success might be increased over what it is today.

[7] Strategic Defense Initiative Organization, *op. cit.,* p. IV-2.

pect of doing so. Suppose, for example, that the Soviets have set for their strategic forces the goal of destroying 75 percent of a particular target set. A U.S. strategic defense that could predictably allow them to destroy only 50 percent of this set would therefore deny the Soviets their goal. If the difference between the Soviets' choosing to attack and refraining from attack rested on their confidence in their ability to destroy 75 percent of the targets, they would be deterred.

An attack of thousands of nuclear weapons that failed in its purely military objectives, whatever they might be, would still wreak great, perhaps irreparable, damage on U.S. society. Such damage would include not only the direct effects of nuclear weapons exploding near U.S. cities, but the longer-term effects of nuclear fallout and economic and social disruption.[8] Moreover, for purposes of intimidation or deterrence, the Soviets might change their target plans to retain their ability to destroy U.S. cities intentionally. Thus we would still need to rely on the threat of retaliation to deter Soviet or other attacks (or, perhaps more to the point, threats of attack) on our economy and society.

Assured Survival

In his speech of March 23, 1983, inaugurating the SDI, President Reagan set an even higher goal for strategic defenses:

> What if free people could live secure in the knowledge that their security did not rest upon the threat of instant U.S. retaliation to deter a Soviet attack, that we could intercept and destroy strategic ballistic missiles before they reached our own soil or that of our allies?[9]

This goal goes beyond denying the Soviets an ability to destroy a "militarily significant portion" of some target base; it would be to protect people. As the President said over 3 years later:

> Our research is aimed at finding a way of protecting people, not missiles. And that's my highest priority and will remain so.[10]

The goals of increasing attacker uncertainty, denying military objectives, and assuring national survival imply progressively more capable defensive systems, and correspondingly more difficult technical challenges. The following survey of the Soviet missile threat and the kinds of targets the United States would need to defend against that threat illustrates the scope of the strategic defense problem.

The Soviet Ballistic Missile Threat

The Soviets now have about 1400 intercontinental ballistic missiles (ICBMs) carrying about 6300 nuclear-armed re-entry vehicles (RVs). They also have about 944 submarine launched ballistic missiles (SLBMs) with about 2800 nuclear-armed RVs (see figure 2-l). The Soviets also have several hundred intermediate-range ballistic missiles based in the Soviet Union that can reach all or part of Europe and Asia with about 1400 nuclear RVs—but these are to be eliminated under the Intermediate Nuclear Forces (INF) agreement signed in December 1987. Several hundred shorter-range missiles can deliver single warheads from tens to hundreds of kilometers; many are based in Soviet Bloc countries and can reach important targets in NATO countries. Under the terms of the INF agreement, the Soviets are also to eliminate their other missiles with ranges above 500 km.

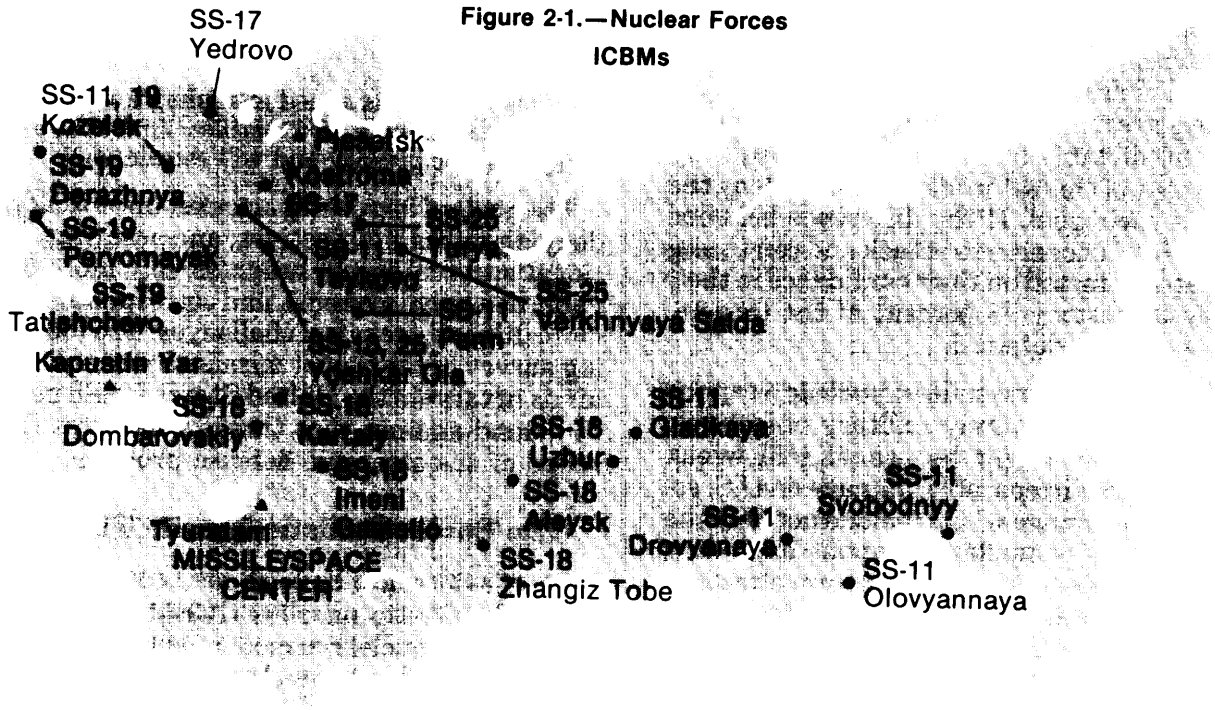
The composition of the Soviet ballistic missile force will change over the years during which BMD might be developed and deployed

[8] See, for example, U.S. Congress, Office of Technology Assessment, *The Effects of Nuclear War, OTA-NS-89* (Washington, DC: U.S. Government Printing Office, May 1979), esp. ch. 4, pp. 109-118.

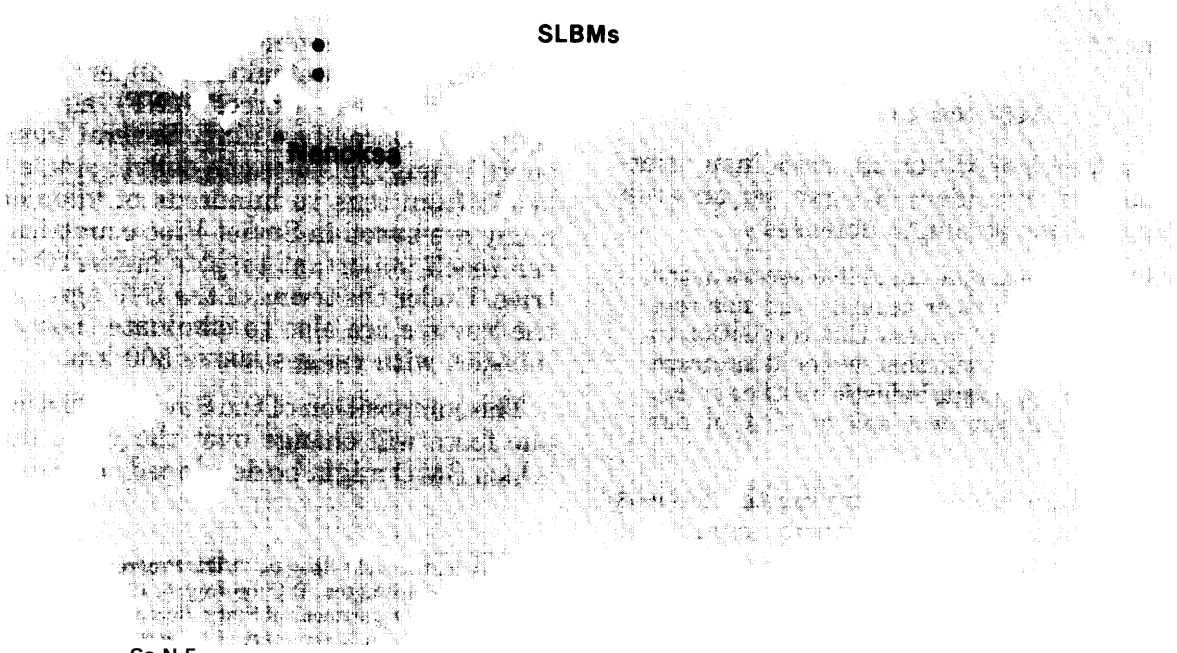
[9] Ronald Reagan, televised speech, Mar. 23, 1983.

[10] "President Ronald Reagan, "SDI: Progress and Promise," briefing in Washington, D.C. on Aug. 6, 1986, Current Policy No. 858, U.S. Department of State, Bureau of Public Affairs, Washington, DC, p. 2. Secretary of Defense Caspar Weinberger has said, "When the President says that we are aiming at a strategic defense designed to protect people, that is exactly what he means." Speech at Harvard University, Sept. 5,1986, quoted by David E. Sanger, "Weinberger Denies Antimissile Shift," The New *York Times,* Sept. 6, 1986, p. 9.

Figure 2-1.—Nuclear Forces



Ss-11	440	SS-18	308
SS-13	60	SS-19	360
SS-17	150	SS-25	About 100
Test Center	A	ICBM Base	●



Ss-N-5	39	SS-N-18	224
SS-N-6	272	SS-N-20	80
SS-N-8	292	SS-N-23	48
SS-N-17	12		
Test Center	A	SLBM/SSBN Port	●

SOURCE U.S. Department of Defense, *Soviet Military Power* (Washington, DC: U.S. Government Printing Office, 1987),

(see figure 2-2). The changes would be more dramatic if the Soviets attempted to counter the effectiveness of prospective U.S. defenses. Anticipating this "responsive threat" is a major challenge for BMD planners. The SDIO has not been assigned to address the Soviet ability, present and forecast, to deliver nuclear weapons with aircraft and ground-, sea-, or air-launched cruise missiles. The Air Force is conducting an "Air Defense Initiative" (ADI) that is studying the interception of air-breating weapons. The ADI, however, is operating at much lower funding levels than the SDI.

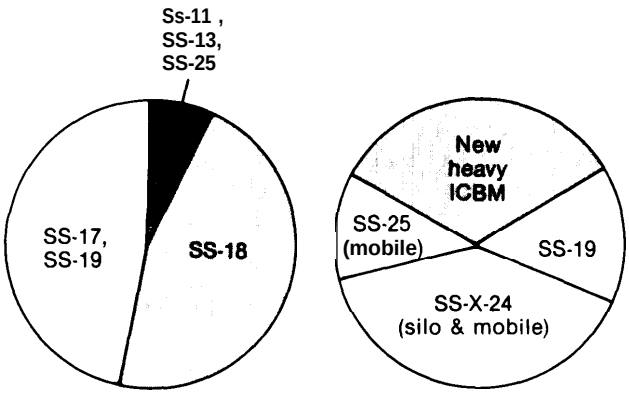
Targets To Be Defended

The three goals of uncertainty, denial, and assured survival remain abstract and ambiguous until we consider the kinds of targets to be defended against nuclear attack. Soviets attack objectives might include four broad categories of targets:

1. *strategic retaliatory* forces—ICBM silos (or, in the future, mobile ICBMs), bombers (and refueling tankers) at their bases, submarines in port, command posts, and communications nodes;
2. *other military* targets-including military headquarters, barracks, nuclear and conventional ammunition dumps, supply depots, naval ports and shipyards, airfields, and radars;
3. *enconomic* targets-industrial facilities, fuel reserves, research centers, transportation nodes, and cities; and
4. *political* targets-non-military government facilities, and civil defense shelters.

Each of these sets of targets (for further explanation, see box 2-A) has different implications for strategic nuclear offensive and defensive operations.

Figure 2-2.— Modernization of Soviet ICBMs Warhead Mix



[a]Estimates based on current trends.

SOURCE: U.S. Department of Defense, Soviet Military Power (Washington, DC: U.S. Government Printing Office, 1987),

Strategic Retaliatory Forces

The purpose of a Soviet nuclear attack on U.S. strategic nuclear forces—a so-called "counterforce" attack—would be to reduce the ability of those forces to carry out a retaliatory nuclear attack on the Soviet Union. In 1986 the Department of Defense estimated that by attacking each of 1000 U.S. Minuteman missile silos with two SS-18 warheads, the Soviets could destroy about 65 to 80 percent of U.S. land-based ICBMs.[11]

An attack would have to succeed quickly and destroy a high percentage of the targets. Otherwise, U.S. weapons could be launched against the Soviet Union (assuming they had not already been launched on warning, before the first Soviet missiles arrived). The objective of substantially reducing the retaliatory damage inflicted on the Soviet Union would not be met. Thus slower bombers and cruise missiles would be less suitable than ballistic missiles for this kind of disarming attack.

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*'U.S. Department of Defense, *Soviet Military Power 1986* (Washington, DC: U.S. Government Printing Office, 1986), p. *25.* The United States maintains several hundred Poseidon and Trident missiles at sea at all times and is adding sea-launched nuclear cruise missiles to its arsenal It also maintains bombers (many with cruise missiles) on alert for rapid escape on warning. The President's Commission on Strategic Forces (the "Scowcroft Commission" argued in 1983 that, in view of overall U.S. retaliatory capabilities, ICBM vulnerability did not warrant ABM (anti-ballistic missile) defense of missile silos in the near term. Some argue that future Soviet anti-submarine warfare developments might compromise the survivabilit, of U.S. ballistic missile submarines, and that defense of land-based missiles might compensate for that eventuality. Others argue that if both the United States and the Soviet Union were to deploy BMD, U.S. retaliatory missiles would be less able to fulfill their missions, whether launched from land or sea.

Box 2-A.—Potential Targets for a Soviet Nuclear Ballistic Missile Attack

Strategic Retaliatory Forces

Land-based ICBMs. -The United States has about 1,000 intercontinental ballistic missiles in hardened silos. In the 1990s it may deploy "Midgetman" missiles on road-mobile carrier vehicles. It may deploy some MX "Peacekeeper" ICBMs on railroad cars within U.S. military lands. An attack on land-based ICBMs would have to be swift, well-coordinated, and accurate. Otherwise, many of the missiles would remain available for striking back at the Soviets. (The Soviets would also have to consider the risk that the United States would launch its ICBMs while they were under attack, with many escaping destruction to retaliate against the Soviet Union.

Bomber Bases. –About 350 strategic bombers, able to carry several thousand nuclear bombs and cruise missiles, are based at some tens of airfields around the United States. Additional aircraft are needed to refuel the bombers in flight. Normally, a substantial number of the U.S. strategic aircraft are on standby alert and might be expected to escape a Soviet missile attack given several minutes of warning; in times of crisis, more bombers would be placed on alert. A Soviet attack might try to catch as many as possible of the U.S. bombers (and their refueling tankers) on the ground or just after take-off.

Submarine Bases. —Thirty-odd submarines with several hundred underwater-launched ballistic missiles are based at just a few U.S. ports. By plan, in peacetime somewhat more than half these submarines, with 2,500-3,000 nuclear warheads, are always at sea. Those in port would be easy, inviting targets for a Soviet strategic counterforce attack. During a crisis, some of the submarines in port could be sent to join those already at sea.

Communications, Command, and Control Facilities.- Linking the above forces to U.S. National Command Authorities is a network of underground command posts, mobile command posts, mobile communications (air, ground, and space) relays, and fixed communications transmitter and receiver stations. A Soviet nuclear attack is likely to try to disrupt this network by direct nuclear destruction of the fixed land facilities or by means of nuclear-generated electromagnetic pulses intended to interfere with the functioning of electronic devices.

Other Military Targets

Military Headquarters; Barracks, Nuclear and ConventionalAmmunition Dumps, Supply Depots, Naval Ports and Shipyards, and Airfields.–Many other military facilities, while not directly supporting U.S. rapid-response strategic nuclear forces, would be essential to the conduct of conventional warfare or tactical nuclear warfare abroad. Many of these targets are "soft" . . . difficult to shelter from the effects of even relatively inaccurate nuclear weapons.

Economic Targets

Factories, Power Plants, Fuel Supplies, and Transportation Nodes. -These are sometimes called "economic recovery" targets. The military purpose of attacking them might be to eliminate the economic base that supports U.S. military power. While the United States might be able to carry out a strategic nuclear retaliatory attack if its cities were destroyed, it could not carry on a conventional war abroad very long.

Political Targets

Government Facilities and Civil Defense Shelters.–The Soviets might also attempt to disrupt government to hinder economic and political recovery.

The purpose of a U.S. ballistic missile defense against such an attack would be to preserve enough missiles and bombers to retaliate successfully against the targets in the Soviet Union designated by U.S. military planners.[12] At a minimum, the United States might wish defenses to add to current Soviet uncertainties about how well they could prevent those offensive weapons from reaching the Soviet Union. If these redundant, hardened targets could be defended preferentially, that is, if defensive resources could be devoted to protecting a sub-set of them that is unknown to Soviet planners, then Soviet confidence in being able to destroy the whole force might be reduced to a very low level.[13]

At best, we would want defenses that persuaded the Soviet Union of the *certainty* of *failure* of any preemptive attack on our strategic forces that had the purpose of reducing significantly the damage we could do to the Soviet Union.

Other Military Targets

The purpose of attacking U.S. military targets other than those connected with strategic nuclear forces would be to weaken or eliminate the ability of the United States to project military power abroad (to fight conventional or limited nuclear wars in Europe, Asia, or elsewhere), or even to defend its own territory against invasion. Unlike sheltered ICBMs, most of these other military targets are relatively soft–each could be easily destroyed by one or a few moderately accurate nuclear weapons. Nor must they be destroyed instantaneously, since they cannot be used for a prompt nuclear retaliation against Soviet territory.

Since these other military targets can be destroyed more or less at leisure, strategic delivery vehicles other than ballistic missiles can be used against them—bombers and cruise missiles in particular. Therefore, a strategic defense intended to protect these targets must be highly effective against "air breathing" weapons as well as against ballistic missiles.

The purpose of defending such targets would be to decrease the probability that a nuclear attack on them could significantly weaken our military power; at best we would want the Soviets to be certain that such an attack would fail.

It is important to note that many of these "other military targets" are located in or near urban complexes, and an attack on them might be hard to distinguish from a punitive city attack. Fallout would reach extensive areas of the United States and millions of people might die.

Urban Economic and Political Targets

The main military purpose of attacking the U.S. industrial and political infrastructures would be to remove the base from which the United States exerts military and economic power abroad. Another purpose, however, might simply be to inflict punishment. Before a war occurred, the purpose of having such an ability to punish would be to deter actions (e.g., nuclear or nonnuclear attacks) by threatening to impose a cost higher than the expected gain of such actions. For example, Britain and France maintain nuclear deterrent forces that they believe help deter the Soviet Union from attacking them, even though the effects of those forces on Soviet military capabilities might be more indirect than direct.[14]

Even a few tens of nuclear weapons landing on U.S. cities would cause unprecedented destruction in this country. Extensive use of civil defense measures, if feasible, might ameliorate the effects of such destruction (e.g., if city populations could be evacuated and sheltered from radioactive fallout and if industrial machinery could be sheltered). But even more so than the

[12] "Opinions vary greatly on how many of what kinds of targets the Soviets would have to believe they would lose in such a retaliation before they would be deterred from launching an attack on the United States. See OTA, *Ballistic Missile Defense Technologies*, *op. cit.*, pp. 68-76.

[13] For a more detailed explanation of the concept of preferential defense, see OTA, *Ballistic Missile Defense Technologies*, *op. cit.*, pp. 94-98.

[14] It might be noted, however, that the Moscow area has many military facilities; attacks on them would have widespread military as well as civilian consequences.

kinds of "soft" military targets described above, cities are vulnerable to attacks over hours and days by bombers and cruise missiles as well as by ballistic missiles. Defending cities, then, would require extremely effective air defenses as well as missile defenses.

The purpose of defending against attacks on urban industrial targets would be primarily to save lives, property, and civilized society. Militarily, the purpose of having such defenses would be to persuade potential attackers that we could so limit damage to our Nation that we would not have to constrain our own actions out of fear of the effects of an enemy nuclear attack.

From the standpoint of deterrence, various considerations may affect just how much we believe we need to limit damage to our Nation. One consideration might be relative damage: would the damage the United States is likely to suffer in a nuclear war be more or less acceptable to us than the damage the Soviets are likely to suffer would be to them? Another measure might be absolute: regardless of how much damage we could inflict on the Soviets, under what conditions would we be willing to accept the amount of damage they could inflict on us (and vice-versa)?

An open question is just how limited the potential damage would have to be before the United States would decide to give up entirely its own ability to carry out a nuclear retaliation against potential attackers. That is, at what point would we decide to rely on defense rather than the threat of retaliation for our own security?

The Special Case of Defense of Allies

Part of the stated mission of the SDI is to design defenses to protect U.S. allies against ballistic missiles. But the purposes and technical problems of doing so differ somewhat from those of defending the continental United States.

In the case of North Atlantic Treaty Organization (NATO) allies, for example, the Soviet ability to deliver nuclear weapons onto Western European soil is massive and diverse. Besides their land- and sea-based long-range ballistic missiles, the Soviets might use hundreds of short-range ballistic missiles (intermediate and medium-range missiles with ranges above 500 km are to be eliminated under the terms of the INF Treaty signed in December 1987). Thousands of Soviet and Warsaw Pact tactical aircraft are credited with the ability to strike Western Europe. Air- and ground-launched cruise missiles are or will be available.

The probability of being able to defend Europe's densely populated territory against all the potential kinds of nuclear attacks on cities and industries seems low. Therefore, most proponents of BMD for the European theater of war focus on the defense of what are above called "other military targets' '-command posts, communications nodes, sheltered weapons-storage sites (nuclear and nonnuclear), and airfields. Ballistic missile defenses might at least disrupt and reduce the effectiveness of Soviet nuclear missile attacks on such targets (though other means of delivery would also need to be dealt with).

Moreover, some believe that as Soviet ballistic missile accuracies increase, the Soviets might use those missiles to attack military targets with nonnuclear explosive or chemical warheads. Stopping moderately high (and in some cases even modest) percentages of the warheads in such attacks might make a military difference.[16] Others argue, however, that the conventional tactical ballistic missile threat, if it exists, is minor compared to others NATO will have to contend within the future.[16]

Another mission for Soviet "theater" ballistic missiles might be the delivery of chemical weapons intended to incapacitate NATO troops. Again, the interception of a significant percentage of such missiles might make the difference between some troops surviving a chemical attack or not.

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[15] See Manfred Woemer, "A Missile Defense for NATO Europe," *Strategic Review*, Winter 1986, pp. 13ff.

[16] For a detailed technical analysis, see Benoit Morel and Theodore A. Postol, "A Technical Assessment of The Soviet TBM Threat to NATO, " to be published by the American Academy of Arts and Sciences, Cambridge, MA.

The shorter range Soviet ballistic missiles differ in flight characteristics from their larger relatives: their trajectories are shorter and confined to lower altitudes. While they travel more slowly, their shorter flight times also leave less time for them to be intercepted. On the other hand, because these missiles spend a greater part of their flight time inside the atmosphere, reentry vehicle decoys present less of a problem to the defense. Space-based BMD (especially of the kinetic kill variety) would be of limited utility, and ground-based rocket-interceptors would be the likeliest BMD candidates.

The SDI Scenario

Various statements by Reagan Administration officials over the first 4 years of the Strategic Defense Initiative can be combined to form a scenario about how successively more ambitious goals for strategic defenses might be achieved.[17] The expectation of the Administration is that SDI research will show that deployment of ballistic missile defenses is feasible and desirable. As President Reagan has said, "When the time has come and the research is complete, yes, we're going to deploy.'"

In the early stages of deployment, according to the Administration scenario, Soviet attack uncertainties would increase, thus reducing the probability of a Soviet first-strike decision (though not the damage they might inflict should they choose to attack). At first, minimal defense capabilities would only complicate Soviet attack plans. As strategic defenses became more capable, the Soviets ought to be more persuaded that the military purposes of any attack would fail. Nevertheless, as long as a substantial number of targets in the United States were still vulnerable to attack, we would have to continue developing and deploying offensive strategic nuclear weapons. As Secretary of Defense Weinberger has written:

> From the outset, we have insisted that progress toward an effective SD I will have to proceed hand in hand with regaining an effective offensive deterrent. . .[19]

The Administration hopes, however, that ultimately offensive deterrence can be abandoned:

> As the United States has repeatedly made clear, we are moving toward a future of greater reliance upon strategic defense. The United States remains prepared to talk about how–under what ground rules and process-we and the Soviet Union can do this cooperatively. Such strategic defenses, coupled with radical reductions inoffensive forces, would represent a safer balance and would give future statesmen the opportunity to move beyond it—to the ultimate elimination of nuclear weapons from the face of the Earth.[20]

The key to this ultimate goal is seen to be the development and deployment of defenses that are unequivocally cheaper than corresponding amounts of offense. As SDIO puts it:

> We seek defensive options–as with other military systems–that are able to maintain capability more easily than countermeasures could be taken to try to defeat them. This criterion is couched in terms of cost-effectiveness. However, it is much more than an economic concept.[21]

"For a list of statements prior to August, 1985, see OTA, *Ballistic Missile Defense Technologies*, *op. cit.*, App. I, pp. 308-309.

"President Ronald Reagan, "SDI: Progress and Promise," briefing in Washington, DC, on Aug. 6, 1986, Current Policy No. 858, U.S. Department of State, Bureau of Public Affairs, Washington, DC, p. 2.

[19] Caspar W. Weinberger, "U.S. Defense Strategy," *Foreign Affairs*, Spring 1986, p. 678.

Earlier in the same article Weinberger explained his concept of a multi-leveled deterrent:

> If the adversary calculates that his aggression is likely to fail in its own terms, he will not attack. Further, he must know that even if his aggression should succeed in achieving its immediate objectives, he faces the threat of escalation to hostilities that would exact a higher cost than he is willing to pay. In addition to defense and escalation, the third layer is retaliation: if the adversary confronts a credible. threat that aggression will trigger attacks by a surviving U.S. retaliatory capability against the attacker's vital interests that result in losses exceeding any possible gain, he will not attack.

Ibid., p. 678.

[20] President Ronald Reagan, Speech to the U.N. General Assembly, Sept. 22, 1986, reprinted in The Washington *Post*, Sept. 23, 1986, p. A16.

[21] Strategic Defense Initiative Organization, *Report to the Congress on the Strategic Defense Initiative*, April 1987, p. IV-3. It should be added that not only should capability be maintainable at the margin, but that our initial acquisition of defense capability needs to be affordable in comparison with the cost to the Soviets of upgrading their current offensive capabilities to counter our defenses. The offense, being already in place, has a head start on defenses yet to be built.

Such a favorable "cost-exchange" ratio between defenses and offenses would be intended to persuade the Soviets of the futility of continuing a competition in offensive arms. The SDIO has stated that:

> Program success in meeting its goal should be measured in its ability both to counter and discourage the Soviets from continuing the growth of their offensive forces and to channel longstanding Soviet propensities for defenses toward more stabilizing and mutually beneficial ends. . . It could provide new and compelling incentives to the Soviet Union for serious negotiations on reductions in existing offensive nuclear arsenals. "[22]

Agreements on mutual offensive reductions could make defensive tasks easier for each side. Thus the Soviets could be offered both a carrot (possibility of their own effective defenses) and a stick (threat of losing an arms race between offenses and defenses) as incentives to subscribe to the U.S. scenario.

Current SDI Goals

The scenario shown in table 2-1 for the SDI suggests the following official attitudes toward the three goals of uncertainty, denial, and assured survival.

Uncertainty

Imposing greater uncertainty on Soviet attack planners would bean initial benefit of deploying BMD, but, presumably is not in itself sufficient to justify the SDI.

Denial

Denial of Soviet military objectives in a ballistic missile would, in itself, justify deploying BMD. Secretary Weinberger has said:

> . . . our strategic defense need not be 100 percent leakproof in order to provide an extraordinary amount of deterrence. Even a partially effective defense would convince Moscow that a first-strike was futile. And once we have rendered a Soviet first-strike obsolete and unthinkable, we will have dramatically increased stability and rested deterrence on a rock-solid basis. But bear in mind that our goal remains to make ballistic missiles-the most destabilizing and dangerous weapons known to man—obsolete.[23]

Table 2=1.—Strategic Defense Initiative Scenario

Stage 1:	
SDI Research	**Leads to national decision in early 1990's to proceed to full-scale engineering development aimed at deployment of BMD (reference to early 1990s date dropped by SDIO in 1987)**
Stage 2:	
Development and production of BMD systems	**Preparation for deployment in mid-to-late 1990s (earlier initial deployments raised as possibility by Secretary Weinberger in 1987)**
Stage 3:	
Initial BMD deployments	**Introduces uncertainty into Soviet strategic nuclear attack planning; deployments preferably coordinated by agreement with Soviets on transition to defenses, but proceeds in any case**
Stage 4:	
Extensive deployment of highly effective BMD	**Denies Soviet strategic forces ability to achieve military objectives; demonstrates to Soviets futility of competition in offensive strategic missiles**
Stage 5:	
Deployment of advanced BMD systems, combined with agreed deep reductions in offenses	**Deep reductions in all types of offensive strategic nuclear forces plus defenses allows abandonment of threat of nuclear retaliation for security: assured survival achieved**

SOURCE: Compiled from U.S. Department of Defense, Report to the *Congress on the Strategic Defense Initiative, June 1986*, p. IV-12 and other Administration statements.

Assured Survival

The goal of assured survival may well require Soviet cooperation in offensive nuclear disarmament. A perfect defense against all ballistic missiles may not be possible, and:

> Even a thoroughly reliable shield against ballistic missiles would still leave us vulnerable to other modes of delivery, or perhaps even to other devices of mass destruction. De-

[22] Ibid., pp. IV-1-2.

[23] Remarks before the Ethics and Public Policy Center, Washington, DC, Sept. 26, 1986.

spite an essentially leakproof missile defense, we might still be vulnerable to terrorist attacks against our cities. Our vision of SDI therefore calls for a gradual transition to effective defenses, including deep reductions in offensive nuclear weapons.[24]

In the expressed Administration view, then, the SDI should aim ultimately for ballistic missile defense systems that are nearly leakproof. One way of achieving assured survival might be to build defenses so effective that they would succeed no matter what the Soviets might throw at them. Another way might be to build defenses that promise to be so effective that the Soviets would prefer to negotiate offenses on both sides away rather than embark on an offense-defense race that they have been persuaded they would lose technically or economically.

[24]Weinberger, "U.S. Defense Strategy, " *op.* cit., p. 684.

THE CRITERIA OF FEASIBILITY

Supporters and critics of the SDI would probably both agree that proposals for deploying ballistic missile defense should meet at least the four following criteria:

1. effectiveness,
2. affordability,
3. favorable cost-exchange ratio, and
4. survivability.

Note that in each case, meeting the criterion will beat least partly dependent on *Soviet* decisions and actions: the Soviets can make the job harder or easier for the defense. In an unconstrained arms race, they would do what they could to make the job harder. In a cooperative regime of mutual defensive deployments and offensive reductions and controls, each side might make the BMD job easier for the other.

Effectiveness

Obviously, before deciding to deploy a BMD system we would want to be confident that it would be effective—that it would work well enough to achieve the goals set for it. Effectiveness needs to be evaluated on two complementary levels. One level is technical performance: how well can the proposed BMD system perform against the missile threat expected at the time of defense deployment? On a higher level, would such performance provide abetter basis for deterrence, strengthen strategic stability, and increase U.S. and Allied security—the goals stated by SD IO? This second level of analyses received considerable attention in the 1985 OTA report on *Ballistic Missile Defense Technologies, so* it will receive much less attention in this report.

On the level of technical performance, it is difficult to decide what "effectiveness" means. For example, one frequently used criterion of BMD effectiveness is "leakage rate": what percentage of a specified Soviet missile attack would we expect to penetrate our defenses and what percentage could we stop? Given the enormous destructive power of nuclear weapons, though, leakage rates may only tell part of the story. A leakage rate of 10 percent might sound worthwhile, and for some purposes it may be. But under an attack of 10,000 nuclear warheads, a 10 percent leakage rate would mean 1000 nuclear detonations on U.S. territory.

Another problem with leakage rate as a measure of effectiveness is that it is likely to vary with the size and nature of attack. For example, a system that could stop only 50 percent of a massive, nearly instantaneous attack might stop 100 percent of an attack consisting of two or three missiles. On the other hand, a system that could stop 50 percent of an attack of a certain size might not be expandable in such a way that it could stop 50 percent of an expanded enemy missile force. In addition, to maintain damage at a fixed level, the defense would have to stop, for example, 75 percent of a doubled attack.

A slightly better indicator of effectiveness, then, might be the absolute number of nuclear warheads penetrating the defense under the severest plausible attack. Such an estimate would give abetter indication of the maximum damage a Soviet attack might inflict.

An even better indicator would be the numbers of different types of targets that the United States would expect to survive a missile attack. This approach would take into account the numbers of attacking weapons, the numbers of penetrating weapons, the numbers and types of targets attacked, and the numbers and types of targets protected. These numbers might be translated into percentages of types of targets surviving-e. g., 70 percent of the land-based missile force.[25] We might carry the analysis further by weighing the values of different types of targets. For example, one underground strategic command post might be worth 10 missile silos.

All of the above indicators would be difficult to apply with precision. And the more factors an indicator has to take into account, the more imprecise it is likely to be. Indeed, there would be no direct way to measure the potential effectiveness of a BMD system: only an actual nuclear war would do so. Instead, we would have to rely on estimates, based on assumptions about:

- enemy offensive technical capabilities (numbers of weapons, accuracy, explosive yields, ability to penetrate defenses);
- enemy target attack plans;
- defensive technical capabilities;
- vulnerability of targets defended; and
- the objective and subjective relative values of targets defended.

These factors would be difficult for U.S. planners to assess. They would also be difficult for Soviet planners to estimate. Therefore, if the U.S. goal is mainly to introduce uncertainties into Soviet strategic calculations, precise measures of BMD effectiveness might not be necessary. On the other hand, if we wished to be certain of denying Soviet attack objectives, we might need higher confidence in our estimates.

At the same time, if the Soviets decided, along with the United States, that defenses were desirable, then each side could help make them more effective by agreeing to deep cuts in offensive weapons and to restrictions on countermeasures against defenses.

Affordability

If and when the Department of Defense eventually presents its proposals for deploying BMD, the country will have to decide whether the expected benefits would be worth the expected costs. Part of the SDI research program is to estimate costs for the proposed systems. For various reasons, the initial cost estimates for complex weapon systems tend to be inaccurate, and usually too low. Producing reliable cost estimates for future BMD systems will be a challenging task.

Another part of the SDI program is to attempt to develop new, cheaper ways to manufacture weapons and to deploy them in space.[26] The ultimate weighing of costs and benefits will be a political judgment made by the President and Congress. But a critical part of the demonstration of technical feasibility of BMD will be that the proposed systems can be built at a cost the country would, at least arguably, find reasonable.

As mentioned above, Soviet actions could make effective BMD more or less affordable. If they chose to invest heavily in offensive countermeasures timed to take effect about when our defenses might be deployed, they could make those defenses much more expensive than if they stabilized the threat they pose at today's levels. Alternatively, in a cooperative regime they could make defenses cheaper by agreeing to decrease their offensive threat

[25] Note that planning to penetrate defenses may require the offense to concentrate his attacks on higher-value targets, In that case, the targets which he no longer has enough weapons to strike can be considered "saved" by the defense.

[26] Until a re-organization in 1987, the SDIO Systems Engineering Directorate was in charge of this program, among others. The Systems Engineering program element of the SDI budget received $20.2 million in fiscal year 1987; $39 million was requested for fiscal year 1988.

in exchange for reductions in the U.S. offensive threat.

Favorable Cost-Exchange Ratio

The Nation must decide not only that a particular defense system proposed at a particular time is affordable, but whether the potential long-run competition of U.S. defenses against Soviet offenses is likely to be affordable in the future. In the absence of a long-term U.S. commitment to sustaining defensive capabilities, the Soviets would have incentives to stay in the "game" until the United States' will to spend flagged.

One way to try to persuade the Soviets to abandon efforts to maintain offensive capabilities would be to demonstrate clearly that additional increments of offense would be more costly to the Soviets than corresponding increments of defense would be to the United States. Therefore, a corollary goal of the SDI is to design defenses that are cheaper "at the margin" than offenses. If the "cost-exchange" ratio were favorable to defenses, and if the two sides invested equal resources in defenses and offenses respectively, then the side investing in offenses should find its capabilities inexorably declining.

Achieving this favorable cost-exchange ratio will be technically challenging. Accurately estimating the costs of defensive systems would be difficult enough. Attaining high confidence that the ratio of U.S. defensive costs to Soviet offensive costs would be favorable, even before the United States deployed its defenses and before Soviet offensive countermeasures were known would be even more difficult. Neither side may actually know the relative costs of additional increments of defense and offense until they actually buy them.[27]

[27] It might be argued that, faced with these uncertainties, the Soviets would accede to the U.S. proposal for a negotiated transition that regulated offensive and defensive deployments. On the other hand, drafting such an agreement that both sides would find equitable, given the asymmetries in forces and technologies on the two sides, would be a formidable task.

Because the United States and the Soviet Union have such different economies, it will be difficult to quantify the cost-exchange ratio. Moreover, the effective cost-exchange ratio may differ from the technical one. That is, the ratio depends not only on what things cost, but also on what people are willing to pay. If the Soviets are willing and able to pay for an increment of offense that is more costly than our corresponding increment of defense, for practical purposes the cost-exchange ratio is at least even. The SDI objective, then, is to persuade the Soviets that the defenses we can afford will more than offset the offenses they can afford. Thus the offense/defense cost-exchange ratio may have to be not just 1.5:1 or 2:1, but several-to-one.

On the other hand, if the Soviets were to agree with the United States that a mutual reduction of offensive missile capabilities was worthwhile and that defenses were desirable, then the technical challenge could be reduced. In effect, mutual political decisions could improve the cost-exchange ratio by mandating reductions—rather than enhancements-of offensive capabilities, along with limitations on other offensive countermeasures.

Survivability

One of the many possible types of countermeasures against a BMD system is to attack the system itself-which will be called "defense suppression" in this report. Obviously, to carry out its defensive mission, the BMD system must survive such attacks. "Survivability" does not mean the ability of every element–each satellite, e.g.—to survive any attack. Rather, it means the ability of the system as a whole to perform acceptably despite attacks that may disable some elements.

No BMD system will be *either* survivable *or* not survivable. The question will be, "How survivable, at what cost?' The cost-exchange ratio between defense and offense will have to be calculated on the basis of the costs of all kinds of offensive response, including defense suppression, compared to the costs of all kinds of defensive counter-countermeasures, including "survivability" measures.

The remainder of this report surveys what was—and was not—known as of April 1988 about the potential of the SDI for developing systems that would meet the effectiveness, affordability, cost-exchange, and survivability criteria.