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Report to the Chairman, Legislation and National Security Subcommittee, Committee on Government Operations, House of Representatives

July 1990

STRATEGIC DEFENSE SYSTEM

Stable Design and Adequate Testing Must Precede Decision to Deploy

GAO/IMTEC-90-61

GAO

United States
General Accounting Office
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Information Management and
Technology Division

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July 6, 1990

The Honorable John Conyers, Jr.
Chairman, Legislation and
National Security Subcommittee
Committee on Government Operations
House of Representatives

Dear Mr. Chairman:

This report discusses why the Strategic Defense Initiative Organization will not be able to support currently scheduled full-scale development or deployment decisions on any part of Phase I of the Strategic Defense System. The organization will not be able to support these decisions until it has solidified the system architecture, conducted integrated system-level testing in real time involving actual pieces of hardware and software, and until the Department of Defense adheres to technical and programmatic oversight, commensurate with such a system.

As arranged with your office, unless you publicly announce the contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. We will then send copies to other appropriate congressional committees; the Director, Strategic Defense Initiative Organization; the Director, Office of Management and Budget; the Secretary of Defense; and other interested parties.

This report was prepared under the direction of Samuel W. Bowlin, Director for Defense and Security Information Systems, who may be reached at (202) 275-4649. Other major contributors are listed in appendix IV.

Sincerely yours,

Ralph V. Carlone
Assistant Comptroller General

Executive Summary

Purpose

The Department of Defense plans to spend between $69 and $87 billion to develop and deploy the first of a multiple phase Strategic Defense System designed to shield the United States from a massive Soviet nuclear ballistic missile attack. At the request of the Chairman, Legislation and National Security Subcommittee, House Committee on Government Operations, GAO reviewed the Strategic Defense Initiative Organization's (SDIO's) test and evaluation plans. These plans are to support a 1993 executive decision by the President on deploying Phase I and a 1994-1995 acquisition decision by the Department of Defense to enter full-scale development. Specifically, GAO was asked to determine

- what test and evaluation requirements were established for making development and deployment decisions for the first phase, and
- whether SDIO's approach will meet those requirements and support a decision on deployment.

Background

The Strategic Defense System is being designed to destroy thousands of incoming ballistic missiles and warheads. This will require detecting the missiles and warheads, discriminating them from hundreds of thousands of decoys, precisely tracking the missiles and warheads, and then destroying them—all within about 35 minutes or less, and despite the enemy's concerted effort to defeat the system. The Strategic Defense System is, by far, the most complex, technologically challenging system ever attempted. As currently envisioned, a sophisticated communications system will link together hundreds, or possibly thousands, of computer-operated components in space and on the ground. The system will consist of several subsystems (elements), which include surveillance satellites, space- and ground-based weapons, and ground-based subsystems to command and control the satellites and weapons.

The Strategic Defense System is being developed in several phases. Phase I will be built using existing technologies; later phases would use more exotic technologies, such as lasers and particle beams. On September 17, 1987, the Secretary of Defense directed that Phase I enter the concept demonstration and validation stage. This stage is important because enough information must be developed to show that the system is feasible before a decision is made to enter full-scale development. Because Phase I cannot be demonstrated outside of an actual ballistic missile attack, much of this information can be generated only through computer simulation and modeling.

In 1988, SDIO formally adopted a design (architecture) for Phase I. However, in January 1990 SDIO changed the design dramatically by incorporating a new space-based weapon, called Brilliant Pebbles. The idea behind Brilliant Pebbles is that thousands of small, relatively autonomous weapons would be deployed to intercept Soviet intercontinental ballistic missiles.

Results in Brief

The President is scheduled to make a decision in 1993 on deploying Phase I. His options include deploying, delaying, or cancelling Phase I. Public Law 99-145 states that a Strategic Defense System may not be deployed in whole or in part unless the President certifies to the Congress that the system can fulfill its mission. SDIO may be able to justify a decision to delay or cancel Phase I; however, SDIO will not be able to support an informed decision to deploy it. To do so requires a stable design, sufficient testing and evaluation, and according to SDIO, minimum funding levels. However, it is highly unlikely any of these conditions will be met.

The addition of Brilliant Pebbles in January 1990 has reduced, changed, or eliminated the need for some of the space-based elements in the 1988 design. At this point, it is uncertain exactly what Phase I will consist of in terms of elements or what functions they will perform. Additionally, while SDIO initially required real-time integrated system-level testing prior to a presidential deployment decision and a full-scale development decision, SDIO officials now state that such detailed tests will not be conducted prior to either decision. Furthermore, according to SDIO, because of fiscal year 1990 funding cuts, the full-scale development decision has been delayed until 1994-1995, and research efforts have been scaled back, further reducing the amount of information that will be available for a presidential deployment decision. SDIO officials believe they will be able to support a presidential deployment decision with less information than was originally desired, but state that this will be done at increased risk.

Phase I has not received the scrutiny and oversight that Defense initially envisioned. The Defense Acquisition Board did not conduct its scheduled 1989 review, nor has it assessed how Brilliant Pebbles affects the design and test and evaluation requirements. The lack of effective agency oversight has contributed to the failure of other automated weapons systems, none of which matches the scale and technological complexity of Phase I. Consequently, any executive decision in 1993 to deploy Phase I would be premature and fraught with high risk.

Principal Findings

SDI Design and Test Plans in State of Flux

Several problems are hampering SDIO's design and test plans. First, Brilliant Pebbles radically changed the design and sent the program into a state of flux. SDIO has not yet solidified the role of Brilliant Pebbles or what elements will be in the final design. This causes problems because without a stable design detailed Strategic Defense System requirements cannot be determined. Setting requirements is especially important for Phase I where weapon, sensor, and communication systems are interdependent. Changing a requirement for a weapon system could significantly affect sensor and communications systems as well. Further, an unstable design increases the probability that system requirements will not be adequately determined and sufficient testing will not be performed to ensure that the system works. Nevertheless, Defense has requested $265 million for full-scale development of one of the sensor elements, the Boost Surveillance and Tracking System, for fiscal year 1991 even though Brilliant Pebbles may eliminate or reduce the requirements for this system.

Second, SDIO does not plan to conduct integrated system-level testing by the scheduled 1993 presidential decision. SDIO-funded studies and test plans have cited the importance of running real-time integrated system-level tests, which combine computer simulation and actual hardware and software prototypes with human intervention. Furthermore, most of the system tests and evaluations so far have been based on the pre-Brilliant Pebbles design. Consequently, much of the testing and analyses may no longer be relevant and will have to be repeated.

Also, according to SDIO, its ability to support an informed deployment decision depended on a minimum funding level of $4.6 billion for fiscal year 1990. However, funding was cut by 20 percent. According to SDIO, such a cut will reduce the amount of research performed, delay SDIO's full-scale development decision by 2 years, and reduce the amount of information available to the President. Nevertheless, SDIO officials have stated that they will be able to support a presidential decision on the program even though less information will be available.

Original Program Oversight Reduced

Because of the complexity, uniqueness, and cost of Phase I, the Defense Acquisition Board initially was to follow a highly structured oversight system of annual reviews looking at cost growth, changing requirements, and test and evaluation results. However, the October 1989 program review scheduled by the Defense Acquisition Board did not occur. According to Defense officials, the review was cancelled because the fiscal year 1990 budget had not yet been finalized and because Defense was reassessing the amount of oversight needed for the Strategic Defense System. Even though a Defense Acquisition Board review is scheduled for June 15, 1990, major changes to the Phase I design and significant reductions to test and evaluation requirements have already occurred without the Board's review and evaluation.

Recommendations to the Secretary of Defense

GAO recommends that the Secretary of Defense advise the President to defer a decision to deploy any element of the Phase I system until SDIO has stabilized the design and has demonstrated the effectiveness of the system through integrated system-level tests in real time, using system hardware and software prototypes with human intervention. Further, the Secretary should ensure that required oversight by the Defense Acquisition Board be followed. The Board should more closely monitor system design, development, testing, and evaluation. GAO is making other recommendations in chapter 4.

Recommendation to the Congress

GAO recommends that the Congress not fund full-scale development for any element of Phase I, including $265 million for the Boost Surveillance and Tracking System in fiscal year 1991, until SDIO has stabilized the design and has demonstrated the effectiveness of the system through integrated system-level tests in real time, using system hardware and software prototypes with human intervention.

Agency Comments

As requested by the Chairman's office, GAO did not obtain official agency comments on a draft of this report. However, GAO discussed the information contained in this report with SDIO officials and has incorporated their comments where appropriate.

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Abbreviations

DAB	Defense Acquisition Board
GAO	General Accounting Office
IMTEC	Information Management And Technology Division
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization

Introduction

The Strategic Defense Initiative (SDI) is a program to develop and deploy a Strategic Defense System to shield the United States against a Soviet nuclear ballistic missile attack. Research and development for the SDI program began in 1984, and in 1987 a Strategic Defense System was approved for acquisition. This system is to be developed in multiple phases. Phase I, the subject of this report, is in the concept demonstration and validation stage of the Department of Defense's acquisition process.[1]

The Strategic Defense System will be an expensive undertaking. The Strategic Defense Initiative Organization (SDIO) cost estimates range from $69.6 to $87 billion for completion of Phase I development and deployment—with an additional $10.1 billion for Phase I operation and support until deployment is completed. While the cost of follow-on phases is unknown, SDIO estimates that, in addition to the Phase I costs, approximately $26.4 billion will be needed for fiscal years 1990 through 1994 to pursue non-Phase I research and development. GAO has recently reported to the Congress that the above figures are, at best, optimistic.[2]

Genesis/Evolution of the SDI Program

On March 23, 1983, President Reagan called for a comprehensive scientific research effort to develop a system that would render nuclear ballistic missiles impotent and obsolete. In January 1984, SDI was established as a research and technology development program, and in April 1984, Defense formally chartered the Strategic Defense Initiative Organization as the agency responsible for managing Defense's efforts.

After several years of research, SDIO decided in 1987 to develop and deploy the system in phases. SDIO felt that working in phases would allow SDIO to be prepared for an early deployment, if such a decision were made, and to respond to changing threats. Phase I of the system is to be based on currently available technologies, while later phases are to incorporate technologies that are expected to be available in the future, such as neutral particle beams and lasers. Phase I is not intended to be a "total defense", but is being designed to destroy a certain percentage of some intercontinental and sea-launched ballistic missiles (the exact percentages are classified). Creating a full strategic defense capability will

[1]The Department of Defense's major system acquisition process is supposed to provide a single approach to designing, developing, implementing, and maintaining major weapons systems. (The five stages of the acquisition process are discussed in appendix I.)

[2]Strategic Defense Initiative: Funding Needs Through Completion of Phase I System (GAO/NSIAD-90-79FS, Jan. 29, 1990).

require the deployment of the follow-on phases. Therefore, a critical aspect of the first phase is the capability to evolve and support future phases. Further, the system is not being designed to destroy sea-and air-launched cruise missiles.[3] Other costly systems independent of the SDI program will be needed to defend against these weapons.

From the beginning, SDIO has had one overall goal—to conduct a vigorous research and technology program that would provide the basis for an informed decision regarding the deployment of a Strategic Defense System. The current Phase I program is intended to support an executive decision on deployment by the President in 1993 and an acquisition decision on full-scale development by Defense in 1994 or 1995. According to SDIO test and evaluation officials, the President will have a range of options including deploying, delaying, or cancelling Phase I. However, if the President decides to deploy the system, Phase I development will not be consistent with Defense's prudent acquisition policies specifying that deployment decisions be made after full-scale development.

Objective of a Strategic Defense System

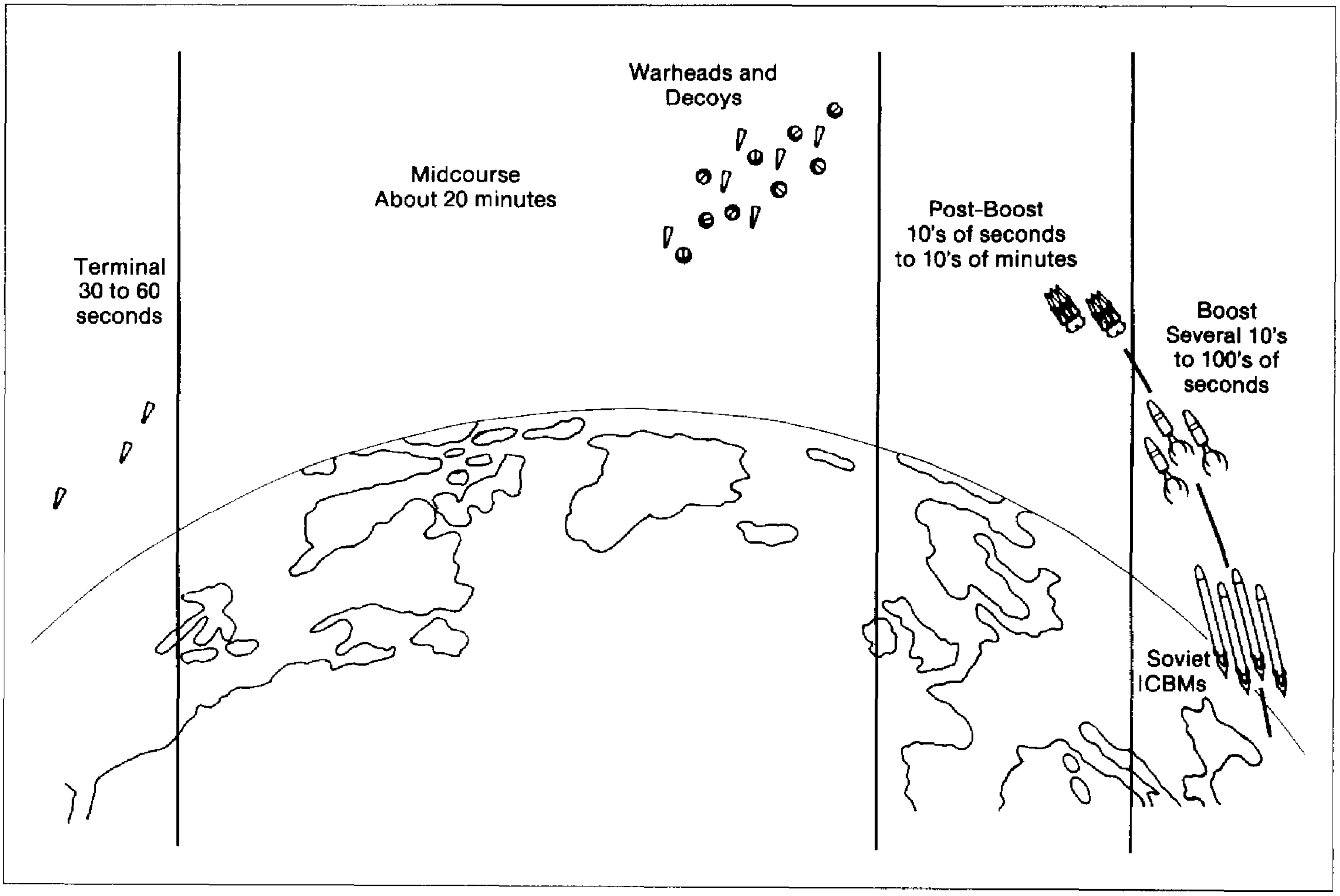
The Strategic Defense System is based on a layered defense concept; the system is supposed to intercept a missile or a deployed warhead, as it travels toward its target. The basic concept is that separate sensor, weapon, and command and control systems (SDIO refers to these separate systems as elements) would be in space and on the ground. The system would be tied together by a complex communications network and a sophisticated computer-based command and control element. During an attack, the system would have to function in an extremely hostile environment, including nuclear explosions and a concerted effort by the enemy to destroy the Strategic Defense System.

The threat the system would be facing, along with the environment in which it would be operating, creates a unique and demanding challenge. First, the space-based elements of the Strategic Defense System would have to be able to detect and begin tracking thousands of missiles almost immediately after launch, and then intercept and destroy some of them. Those missiles that are not destroyed would release warheads, along with decoys intended to confuse the system, forcing the system to track hundreds of thousands of objects. Also at this point, space-based elements of the system would have to distinguish the warheads from the

[3] Cruise missiles are guided missiles that have terrain-seeking radar and fly at moderate speed in low altitude.

decoys, and intercept and destroy some of the warheads. The system would need to continue discriminating and tracking the surviving warheads so that the ground-based elements could intercept more warheads before they hit the United States. These functions would have to be tightly coordinated and performed in less than 35 minutes—all this with nuclear warheads exploding, anti-satellite weapons attacking the system, and the enemy trying to disrupt communications and computer operations. Figure 1.1 describes the phases of a ballistic missile attack.

Figure 1.1: Phases of a Ballistic Missile Attack



Source: Adapted from SDI Technology Survivability and Software, Office of Technology Assessment, May 1988.

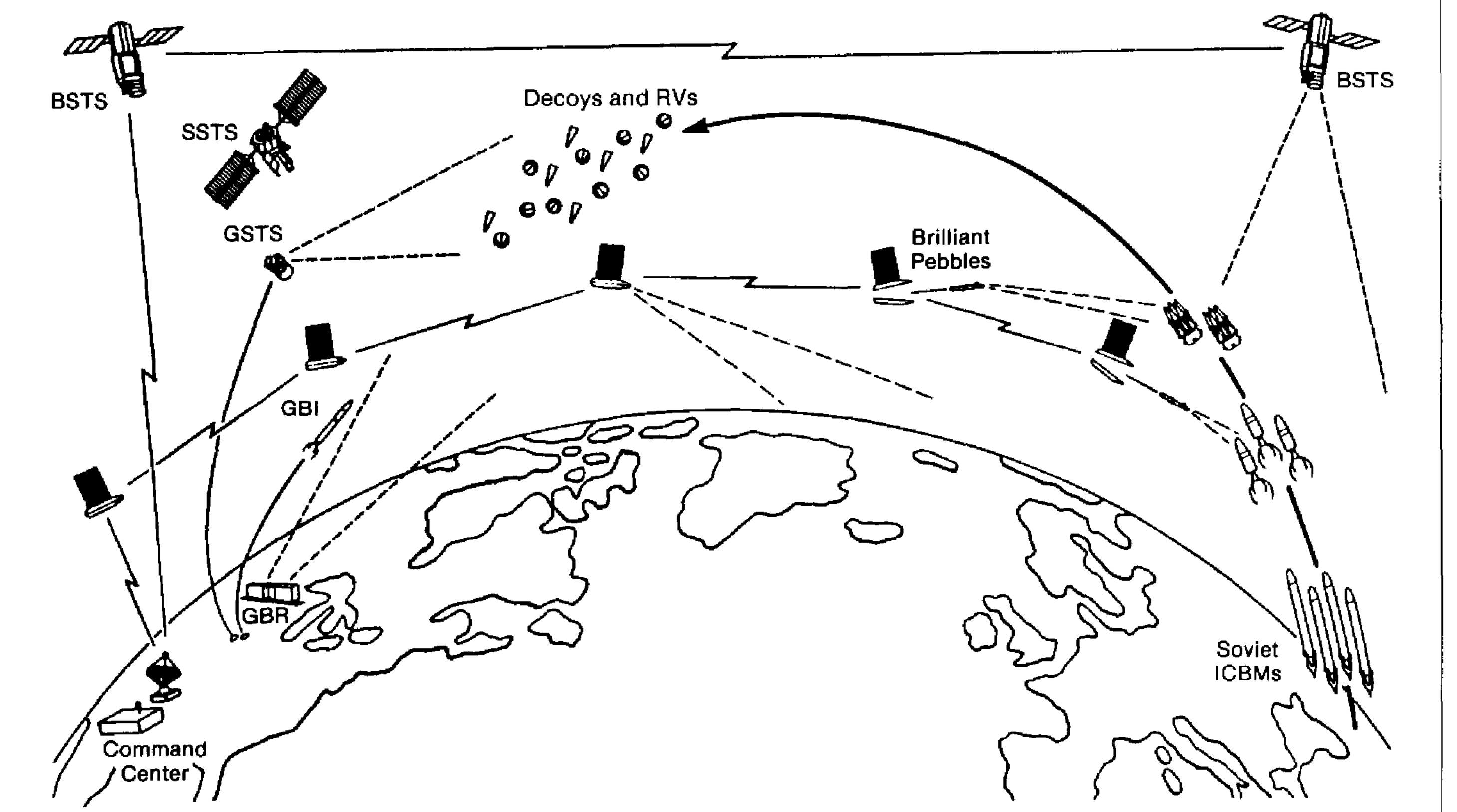
Description of Phase I

In 1988, a Phase I design, made up of seven elements, was approved by the Defense Acquisition Board. The design consisted of two space-based sensors (Boost Surveillance and Tracking System and Space Surveillance and Tracking System); a space-based weapon (Space-Based Interceptor); two ground-based sensors (Ground Surveillance and Tracking System and Ground-Based Radar); and a ground-based weapon (Ground-Based Interceptor), all managed by a command and control system (Command Center Element). (Appendix II describes each element.) The six surveillance and weapon elements would be highly interdependent and rely heavily on the command and control element, along with a complex communications system. The individual elements would work together as an integrated system to detect, track, discriminate, and destroy ballistic missiles and their warheads. At the heart of the system is a large, distributed, real-time computer software system which, by some estimates, could have 40-100 million lines of code. The complexity and risk of this undertaking cannot be overstated. We have reported repeatedly on Defense systems that were far less complex, contained far fewer lines of code, but have yet to perform as intended.[1]

In January 1990, SDIO decided to include a new weapon concept, called Brilliant Pebbles, in Phase I. Brilliant Pebbles involves several thousand individual interceptors orbiting the earth in order to detect and destroy a target by smashing into it at high speed. Brilliant Pebbles is supposed to improve system survivability and reduce costs by dispersing thousands of space-based interceptors that are smaller and more autonomous than the Space-Based Interceptor. The Space-Based Interceptor would house a number of interceptors, but unlike Brilliant Pebbles, it would rely on other satellites for tracking, targeting, and communications. By making interceptors autonomous, they would no longer need to rely on other satellites to perform these functions. Further, because each interceptor would work independently, the system's survivability would be increased, in principle, because the loss of any one interceptor would not greatly affect the system's overall effectiveness. Figure 1.2 shows Phase I with the six elements and Brilliant Pebbles.

[1] Military Space Operations: Operational Problems Continue With the Satellite Control Computer System (GAO/IMTEC-89-56, Aug. 8, 1989); Space Defense: Management and Technical Problems Delay Operations Center Acquisition (GAO/IMTEC-89-18, Apr. 20, 1989); Attack Warning: NORAD's Communications System Segment Replacement Program Should Be Reassessed (GAO/IMTEC-89-1, Nov. 30, 1988); Military Space Operations: Shuttle and Satellite Computer Systems Do Not Meet Performance Objectives (GAO/IMTEC-88-7, Aug. 5, 1988).

Figure 1.2: Phase I Architecture Incorporating Brilliant Pebbles



BSTS is Boost Surveillance and Tracking System
GBI is Ground-Based Interceptor
GBR is Ground-Based Radar
GSTS is Ground Surveillance and Tracking System
SSTS is Space Surveillance Tracking System
RVs are Reentry Vehicles (nuclear warheads)

SDIO funded three Brilliant Pebbles research and development studies during 1989 and 1990. Studies completed by the Defense Science Board and the JASONs—a group of scientists who periodically provide technical support to the Department of Defense—determined that the Brilliant Pebbles concept was technically feasible. Along with these two studies, Defense issued a Space-Based Architecture Study which reviewed the four space-based elements of Phase I—Space Surveillance and Tracking System, Boost Surveillance and Tracking System, the Space-Based Interceptor, and Brilliant Pebbles—and defined and justified a recommended space-based architecture. The Space-Based Architecture Study recommended that research continue on both Brilliant

Pebbles and the Space-Based Interceptor and that modified versions of the Boost Surveillance and Tracking System and the Space Surveillance and Tracking System sensors be included.

SDIO has decided to eliminate the Space-Based Interceptor from Phase I, claiming that Brilliant Pebbles will cut costs by 20 percent, that is, from $87 to $69.6 billion. However, it is unclear whether the costs for all Phase I requirements have been incorporated into the $69.6 billion. Further, neither figure includes the costs for operating and maintaining the system.

Importance of Concept Demonstration and Validation and Defense Acquisition Oversight

On September 17, 1987, the Secretary of Defense directed that Phase I of the Strategic Defense System enter the concept demonstration and validation stage of Defense's major systems acquisition process. SDIO's basic acquisition strategy is to complete Phase I while researching later phases of a Strategic Defense System. After successfully completing concept demonstration and validation, Phase I could enter full-scale development.

According to the Defense Systems Management College, concept demonstration and validation may be the most critical of all acquisition stages. The primary purpose of this stage is to validate the feasibility of Strategic Defense System concepts and technologies, and show that the risk is low enough to enter full-scale development. According to the College, the Secretary of Defense's decision to place a major system in full-scale development is extremely important. During full-scale development, the system is built, tested, and ready for full-rate production. Not only will development consume enormous resources, but major systems, at this point, take on a life of their own and are seldom cancelled.

To help Defense gain sufficient design and development information, major system acquisitions are reviewed by the Defense Acquisition Board (DAB). The purpose of the DAB, which is chaired by the Under Secretary of Defense for Acquisition, is to oversee major Defense acquisitions. The DAB reviews each acquisition stage to ensure that every program is ready to proceed into more advanced stages of development or production. Each stage of the acquisition process, as well as each milestone decision, is to be supported by test and evaluation. The purpose of test and evaluation is to help ensure the timely development, production, and fielding of systems that meet users' requirements and perform as intended. The DAB relies on information from test and evaluation to determine whether a system is ready to enter full-scale development. The DAB reviews also ensure that plans for later stages follow sound acquisition management practices.

The complexity, cost, and uniqueness of the Strategic Defense System has prompted the need for a more detailed program review process. For example, the DAB developed a guidance document called the Implementor, which provides a framework for additional oversight. Although formal DAB reviews are usually only required at major milestones, the Implementor recommends yearly DAB reviews. Further, SDIO must submit additional documentation to the DAB to ensure program goals are being met.

Constraints Affecting SDIO's Approach to Concept Demonstration and Validation

Constraints exist which affect how the Strategic Defense System can be demonstrated. Although the 1972 Anti-Ballistic Missile Treaty permits research, it limits the development, testing, and deployment of different types of strategic defense systems and components. According to SDIO's 1989 report to the Congress on SDI compliance with the treaty, research includes conceptual design and laboratory testing. Development occurs after research but precedes full-scale testing of systems and components designed for actual deployment. The development, testing, and deployment of launchers, interceptors, and radars are restricted. Also, the extent to which the system can demonstrate its ability to interact in a nuclear environment is constrained by limits on nuclear testing.

Because the Strategic Defense System cannot be tested in its operational environment, many system capabilities must be demonstrated through computer modeling and simulation. For example, in simulations, software models would mimic the behavior of sensors and weapons and be used in place of the actual elements to evaluate system performance. A ballistic missile attack from launch to impact must also be simulated in software to prompt the element models to respond. Eventually, some of these tests would involve actual prototypes[5] of weapons and sensor hardware and software interacting in the simulation. This type of integrated system-level testing would be used to evaluate the performance of elements within the context of the entire Strategic Defense System. Thus, the ability to simulate the interaction of the systems' hundreds of

[5]A prototype is an original or model on which a later item is formed or based. A prototype is usually built during the concept demonstration and validation stage and tested prior to the full-scale development decision.

computers with their many millions of lines of software code becomes of paramount importance in demonstrating whether the system can perform its mission.

Early in the SDI program, SDIO recognized the need for integrated system-level testing prior to a full-scale development decision. Defense policies state that models or simulations can support a full-scale development decision and that prototyping is one of the most powerful tools available for determining system feasibility and capability. Consequently, SDIO initially planned to build a simulation framework to conduct tests using software and hardware prototypes. SDIO studies and contractor documents have supported the need for such test capabilities before a full-scale development decision. However, because SDIO believed building such a simulation framework would be very complex, it explored other approaches for demonstrating and validating the Phase I system.

SDIO decided instead to use multiple test beds.[6] Under this approach, each test bed would address critical strategic defense issues such as system performance, command and control, communications, and sensing and tracking. The system performance test bed, known as the System Simulator, would be at the core of this test environment. The System Simulator, using computer models of individual elements, would perform end-to-end, system-level tests in which all aspects of Phase I's performance would be evaluated while under a simulated ballistic missile attack. Although the System Simulator, or some other simulation framework, might evolve to include real-time integrated hardware-, software-, and human-in-the-loop capabilities, SDIO has no plans to accomplish this prior to either the presidential decision on deployment or the full-scale development decision.

Objectives, Scope, and Methodology

On June 5, 1989, the Chairman, Legislation and National Security Subcommittee, House Committee on Government Operations, requested that we assess the Strategic Defense Initiative Organization's program activities, test and evaluation requirements, and decisions on the development and deployment of Phase I of the Strategic Defense System. Specifically, the objectives of our review were to determine (1) what test and evaluation requirements were established for making development and deployment decisions for the first phase of the Strategic Defense System and

[6]Test beds are sites, facilities, or activities used for testing models or prototypes. SDIO refers to its network of geographically dispersed test facilities as the National Test Bed.

(2) whether the current program approach will meet those requirements and support a decision on whether to deploy.

To address our objectives, we interviewed a wide range of officials involved in the Strategic Defense Initiative. SDIO representatives included: (1) the Phase I System Engineer, as well as other Engineering Office officials, (2) test and evaluation officials, (3) Brilliant Pebbles Program Office officials, and (4) National Test Bed Program Office officials. We discussed technical issues with members of the Phase One Engineering Team, which acts as a consultant to SDIO. Team members are experts in ballistic missile defense and include physicists, software and electrical engineers, and simulation analysts. We also met with officials from Martin Marietta, the prime contractor for the National Test Bed, and officials from General Electric Company, the system engineer and integration contractor for the Strategic Defense System. General Electric has the responsibility for defining Phase I demonstration and validation requirements, including those for test and evaluation. We met with Army and Air Force officials involved in major SDI research and development as well as Defense Acquisition Board officials. Additionally, we consulted with ballistic missile defense experts at Sandia and Los Alamos National Laboratories.

Our approach was to obtain a thorough understanding of the underlying engineering concepts for the Strategic Defense System by (1) obtaining and analyzing key system design and requirements documents, (2) interviewing and consulting with experts from the ballistic missile defense community, and (3) visiting and assessing research and development sites. We reviewed pertinent management, technical, and contract documents provided by SDIO, SDIO contractors, the Air Force, the Army, Los Alamos National Laboratory, and the Defense Science Board. We analyzed and compared system documents such as the 1988 System Description Document, the 1990 System Description Document, the Brilliant Pebbles System Description Document, and the Space-Based Architecture Study. Furthermore, we analyzed and compared test and evaluation documents including the 1987 and 1989 Test and Evaluation Master Plan, the Phase I Integrated Test Plan, the System Simulator requirements document, the technical specifications and software for the current System Simulator, the Brilliant Pebbles Integrated Test Plan, and the Brilliant Pebbles Test and Evaluation Master Plan. Through our analyses we were able to identify the chronology of events that led to SDIO's current test and evaluation approach in support of decisions on deployment and full-scale development. We did not, however, validate test and evaluation results.

Our work was conducted at SDIO Headquarters, Washington, D.C.; the National Test Bed Joint Program Office, Falcon Air Force Base, Colorado Springs, Colorado; Electronic Systems Division, Boston, Massachusetts; the Army Strategic Defense Command, Huntsville, Alabama; Sandia National Laboratory, Albuquerque, New Mexico; Los Alamos National Laboratory, Los Alamos, New Mexico; the Phase One Engineering Office, Crystal City, Virginia; the Defense Acquisition Board, Washington, D.C.; General Electric Corporation, Blue Bell, Pennsylvania; and Martin Marietta Corporation, Colorado Springs, Colorado.

We discussed the facts in this report with SDIO officials and have incorporated their comments where appropriate. However, in accordance with the requester's wishes, we did not obtain official agency comments on a draft of the report. We conducted our work from June 1989 through May 1990, in accordance with generally accepted government auditing standards.

Unstable Architecture and Test Plans Will Not Support a Presidential Deployment Decision in 1993

The President is scheduled to make a decision in 1993 on deploying Phase I of the Strategic Defense System.[1] Public Law 99-145 states that a Strategic Defense System may not be deployed in whole or in part unless the President certifies to the Congress that the system can survive, meaning that it can maintain enough effectiveness during a war to fulfill its mission. However, by 1993 SDIO will not have conducted integrated system-level tests designed to demonstrate that the entire Phase I system will work as planned, so it will not be able to support an informed deployment decision by the President.

The recent inclusion of Brilliant Pebbles has fundamentally changed the 1988 Phase I architecture by potentially reducing or eliminating the need for two sensors and one weapon component of the system. This change has significantly destabilized the architecture, resulting in a dramatic restructuring of Phase I. According to SDIO test and evaluation officials, the new Phase I architecture will not be solidified until 1991 thus decreasing the level of system testing that can be performed by 1993. Furthermore, according to SDIO's Director, because of fiscal year 1990 funding cuts, research will be scaled back, reducing the information available on which to make a deployment decision in 1993.

Brilliant Pebbles Sends Phase I and Strategic Defense System Into State of Flux

In January 1990, Brilliant Pebbles was formally incorporated into the Phase I design. However, exactly what role Brilliant Pebbles will play in the Phase I architecture and even what pieces of Phase I will be deployed is uncertain and consequently, has put the design of the Strategic Defense System into a state of flux. The result is a destabilized architecture and a major restructuring of SDIO's program.

Stable Integrated Architecture Needed for System Development

The SDIO Phase I System Engineer has stated that his first goal in support of the presidential deployment decision is to create "a complete and coherent system design with definition of all elements and inter-element interfaces."[2] It is important in systems development to have a stable, integrated architecture before detailed system requirements can be determined. A stable architecture provides the blueprint for design and development of each element. An unstable architecture causes confusion and increases the probability that system requirements and integrated

[1] SDIO is conducting the SDI program to support a decision by the President prior to the completion of his current term. Much of the specific program guidance and direction, as well as the timing of the presidential decision is classified.

[2] Interfaces are the internal and external communication paths within and outside of the system.

test objectives will not be met, and that the system will not perform as intended.

The Strategic Defense System is a "system-of-systems" and accordingly, the elements are all interdependent. A requirement change for one element may affect all the others. For example, in the 1988 Phase I architecture, the Boost Surveillance and Tracking System and the Space Surveillance and Tracking System had a requirement to combine their tracking data to provide targeting information for the Space-Based Interceptor. This combined data would also be transmitted to the ground-based elements to help them identify targets. The interfaces must be precisely defined to support such data sharing. If the Space Surveillance and Tracking System's mission changes, then all the elements must reflect the change as well. Accordingly, to ensure integrated system development, each element developer must be aware of all the other elements and the respective interfaces when designing each system.

Brilliant Pebbles Destabilizes Phase I Architecture

Major program restructuring is going on to incorporate Brilliant Pebbles and stabilize the architecture. Brilliant Pebbles is now the focal point of SDIO's efforts. Its effect on the Phase I architecture is far-reaching.

As discussed in chapter 1, the 1988 Phase I architecture was made up of seven highly integrated elements. Command and control relied on rapid communication and data sharing among elements. For example, during a battle, the Boost Surveillance and Tracking System would begin tracking boosters and would be one of several systems to alert national decision-makers. The Boost Surveillance and Tracking System would then transfer the information to the Space Surveillance and Tracking System, which would begin tracking and pass intercept information to the Space-Based Interceptor. At the same time, battle information would be sent to the ground-based weapons and sensors. The Ground Surveillance and Tracking System and the Ground-Based Radar would continue tracking and the Ground-Based Interceptor would destroy the warheads before they reenter the earth's atmosphere. Throughout the battle, command and control information would be centralized at the ground-based Command Center Element.

The addition of Brilliant Pebbles fundamentally changed this highly-integrated approach to strategic defense. Brilliant Pebbles provides for several thousand self-contained interceptors that can detect and destroy missiles independently of the other Phase I elements. As a consequence, interfaces, sensing and tracking capabilities, communications, and the numbers of elements needed—both in terms of types and constellations (numbers of satellites)—will have to be reassessed. For example, the Boost Surveillance and Tracking System may not be required as a Phase I element, and Brilliant Pebbles will add thousands of independent interceptors to the system. Furthermore, Brilliant Pebbles will eliminate the need for the Space-Based Interceptor, could reduce tracking requirements placed on the Space Surveillance and Tracking System, and could expand the mission requirements for the Ground Surveillance and Tracking System. Unlike the Space-Based Interceptor, whose battle management functions were highly dependent on ground-based command and control instructions, Brilliant Pebbles, after being turned on by the commander, could be autonomous.

Phase I Architecture Remains Uncertain

Defense officials have stated that the elements that will make up the Phase I architecture have not yet been solidified. However, several scenarios have been given. An Office of the Secretary of Defense official stated that a space-based system made up of the Boost Surveillance and Tracking System and Brilliant Pebbles could be initially deployed as the Phase I architecture, followed by the Phase I ground-based elements. Another scenario is that the Boost Surveillance and Tracking System and Brilliant Pebbles would be deployed with a terminal interceptor[3] (the High Endoatmospheric Interceptor), which is not currently included in the Phase I design.

In April 1990, the Director of SDIO told the Congress that because of Brilliant Pebbles potential for independent operation, the Phase I architecture may not require the Boost Surveillance and Tracking System and the Space Surveillance and Tracking System or may require less capability from them. However, in May 1990, SDIO officials stated that the Phase I architecture will include Brilliant Pebbles and all the 1988 Phase I architecture elements, with the exception of the Space-Based Interceptor. The differences among such scenarios and the uncertain architecture point to the instability of basic concepts underlying the Strategic Defense System.

Unless the architecture is stabilized and the respective elements are developed, designed, and tested as an integrated system, SDIO will not

[3]Terminal interceptors are intended to destroy warheads after they have entered the earth's atmosphere.

know whether the system will work as planned. The process of interconnecting the Phase I elements so that together they can effectively accomplish the strategic defense mission is called system integration. Successful system integration should result in the design and delivery of complete elements that will work in concert with the other Phase I elements. Two of the elements, however, are preceding the rest of the system. Because of presidential guidance, SDIO has expedited the research and development of Brilliant Pebbles. Consequently, Brilliant Pebbles has been placed in an accelerated acquisition program. The Boost Surveillance and Tracking System, which may or may not be needed if Brilliant Pebbles is successful, is approaching a full-scale development decision. Defense has requested $265 million for full-scale development of the Boost Surveillance and Tracking System in fiscal year 1991. The Boost Surveillance and Tracking System is a multi-missioned satellite that supports other Defense programs. Defense documents show that SDIO will provide $1.3 billion (or 99 percent) of the system's funding through fiscal year 1991. The Boost Surveillance and Tracking System's specific functions for the Strategic Defense System are to detect missile launches, acquire and track boosters, and assess the number of boosters and warheads that have been destroyed. If Brilliant Pebbles and the Boost Surveillance and Tracking System are allowed to advance before the requirements of the other elements are clearly defined, significant integration problems and costs could emerge.

Phase I System Test Plans and Results May Be Moot

SDIO test and evaluation officials claim that including Brilliant Pebbles in Phase I has destabilized the architecture and that a firm design will not be available before 1991. For example, they have stated that a Preliminary Systems Requirements Review that was scheduled for May 1990 will be deferred for at least a year. Furthermore, SDIO test and evaluation officials are rewriting test plans to incorporate Brilliant Pebbles. Because most of the test and evaluation efforts have been based on the 1988 Phase I architecture, much of the data and analysis may no longer be relevant. For example, if, as mentioned above, the Space Surveillance and Tracking System's mission is changed and it no longer provides tracking information, then all of the modeling and simulation done so far is useless because all the interfaces and data paths have changed. Any change to one element causes this rippling effect across the system.

Further, system-level tests and the resulting requirements have not included Brilliant Pebbles. Accordingly, system tests must be rewritten and actual simulations rerun to include them. Because the other Phase I elements have not included Brilliant Pebbles in their tests, analyses, and development, element test plans and simulations must also be reassessed.

SDIO Will Not Perform Integrated System-Level Testing Prior to 1993

SDIO-funded studies and test plans cite the importance of conducting integrated system-level tests in real time, using actual system hardware and software with human intervention. For example, the Advanced Simulation Framework Study recommended that component hardware and software models at various geographic locations be tested and evaluated to see how they work in real-time operations. Moreover, SDIO's Integrated Test Plan notes the importance of such tests before making a decision on full-scale development. According to the plan, integrated system testing minimizes costs by integrating and building upon existing experiment assets, data, and results, and sharing a common test bed. However, an integrated system-level test in real time using hardware and software and a human-in-the-loop will not be demonstrated prior to the planned 1993 decision on deployment. SDIO officials feel they will be able to support a presidential deployment decision with less information than was originally desired, but state that this will be done at increased risk.

Value of Integrated System-Level Testing

Integrated system-level testing will help confirm whether the individual elements and the strategic defense commander can successfully interact in real time. Actual hardware and software in the test environment will provide significantly more information about system performance than a model. Such testing would put system components in a realistic system environment for detecting problems early during design and development. SDIO officials decided that such testing will be performed in the System Simulator (or some other simulation framework) and will provide the basis for system design studies and end-to-end validation of overall system performance. Simply put, the System Simulator will increase SDIO's confidence that when the independently designed and developed elements become operational, they will integrate effectively into a Strategic Defense System.

In 1988 SDIO established the Stellar Task Force to address the question of how best to evolve to such an integrated system test environment. While the task force fully supported the use of the System Simulator for system-level tests, it concluded that trying to start off using only one test environment was too complex an undertaking. It recommended breaking the problem into pieces and developing several test beds.[4] By using several test beds, the system could be broken into units, each focusing on a different part of the system. For example, a communications test bed would enable SDIO to conduct a series of tests on all of the elements' abilities to effectively communicate.

The task force's rationale for this approach was that detailed test results from each test bed could be entered into the System Simulator's data bases for more accurate system-level testing. The elements will be represented at the System Simulator by software models rather than actual element hardware and software. SDIO does plan to use several test beds and then evolve to integrated system-level testing at the System Simulator, incorporating actual element hardware and software in a real-time environment. However, integrated testing will not occur before the President's scheduled 1993 decision.

System-Level Test Results Based on Immature Element Models

A stable architecture with defined system and element requirements is required before software models can be developed to validate each of the elements and the system as a whole. However, even prior to the inclusion of Brilliant Pebbles, the SDIO Phase I System Engineer had stated that detailed system requirements for all Phase I elements will probably not be set until 1994 or 1995. Therefore, element software models cannot sufficiently demonstrate how the various elements will work until detailed requirements are defined. As things stand, test results available in 1993 will be based on limited software representations of the elements. For example, Air Force officials have stated that they have not been provided detailed ballistic missile defense requirements for the Boost Surveillance and Tracking System. Without such requirements, system developers cannot develop an accurate software representation for system-level testing. Consequently, it is unclear whether detailed requirements will be determined, a model developed, system testing completed, and results analyzed in sufficient time to support the 1993 deployment decision. Therefore, not only will system-level tests not be conducted in real time or be integrated with pieces of hardware and software, but the tests will be based on simulations involving immature, possibly inaccurate element models.

[4] These test beds are the Surveillance and Tracking Test Bed, the Communications Network Test Bed, the Pilot Command Center, the Gaming Test Bed, and the System Simulator, all of which are described in appendix III.

SDIO Asserts Funding Cuts Will Reduce Information Needed for an Informed Decision in 1993

According to SDIO, an informed executive decision on deployment is contingent, in part, on minimum funding levels. At one time, this decision was to occur in the same time frame as Defense's formal, full-scale development decision. In most major acquisitions, a deployment decision is made after full-scale development is completed and the system has moved into the next stage. (See app. I.) According to SDIO's Director, an informed decision on deployment is contingent on funding levels of $4.6 billion for fiscal year 1990 and $33 billion over fiscal years 1990-1994. He stated that any funding reduction would reduce confidence in the deployment decision and would have increasingly serious consequences for the SDI program. For example, the Director stated that a 20 percent funding cut would reduce the confidence in making a decision on deployment due to cutbacks in research. He further stated that emerging concepts, especially Brilliant Pebbles, would not be fully explored. Hence, the space-based architecture would not be completely defined, and initial system development and deployment schedules would be delayed at least 2 years.

The Congress reduced SDIO's fiscal year 1990 budget request by 20 percent (from $4.6 billion to $3.6 billion) because of congressional concern for overall fiscal constraints and SDIO's major uncertainties for fiscal year 1990. Consequently, SDIO initiated a major replanning and restructuring strategy to identify program priorities and impacts, and SDIO delayed its full-scale development decision for 2 years. Many contracts were reduced, delayed, or cancelled, resulting in scaled-back demonstration and validation activities that, according to SDIO, will provide less information than was originally envisioned to support an informed 1993 deployment decision. For example, the identification of system-level demonstration and validation requirements in support of system-level tests will not be established until fiscal year 1992; and by 1993, testing on command and control functions will not be as thorough as originally planned. Further, because the new Phase I architecture will not be defined until 1991, the elements will be less developed and their designs less detailed, therefore, less able to support system-level testing. Finally, the system's communications network will not be tested for real-time operations. Nevertheless, SDIO officials have stated that they will be able to support a presidential deployment decision but with increased risk.

Program Management Oversight Has Been Reduced

SDI program decisions have been made without the formal review and approval of the Defense Acquisition Board (DAB), increasing the risk that program objectives will not be achieved. Defense, recognizing the complexity, uniqueness, and cost of the Strategic Defense System, required additional DAB oversight and directed additional monitoring of SDIO's operational test and evaluation activities. Despite the more stringent oversight requirements, the 1989 annual DAB review did not occur as planned. Consequently, fundamental changes to the Phase I architecture and reductions in test and evaluation requirements have occurred without formal DAB review and oversight.

Oversight for Phase I More Stringent Than Typical Acquisition

As discussed in chapter 1, the DAB oversees major Defense acquisition programs. As part of its oversight responsibility, the DAB conducts formal reviews at major program milestones to ensure that programs are ready to proceed into more advanced stages of development and that proposed program plans for later stages follow sound acquisition management practices. Among the issues typically considered in a DAB milestone review are cost, requirements growth, schedule delays, threat assessment, acquisition strategy, and test and evaluation plans and results. As part of the Defense acquisition process, DAB reviews are to help reduce the risks associated with major systems acquisitions.

Phase I, however, is not a typical acquisition. The complexity, cost, and uniqueness of the Strategic Defense System has prompted the need for a more stringent acquisition process. For example, in 1987 the DAB developed a guidance document called the Implementor which provides a framework for additional oversight. Although formal acquisition reviews by the DAB are usually only required at major milestones, the Implementor expanded the DAB's oversight responsibility to include yearly reviews, and lists additional documentation SDIO must submit to the DAB to ensure program goals are being met.

In addition to the increased DAB oversight, Defense also decided in 1987 to establish an oversight group under its Director for Operational Test and Evaluation to monitor SDIO's test and evaluation activities. Each stage of the acquisition process, as well as each milestone decision, is to be supported by test and evaluation. The purpose of test and evaluation is to help ensure the timely development, production, and fielding of systems that meet the users' requirements and perform as intended. The DAB relies on information from test and evaluation activities to determine whether a system is ready to enter the next stage of development.

1989 Annual DAB Review Did Not Occur; Decisions Have Been Made Without DAB Review and Approval

The Implementor the DAB imposed on the SDI program states that the Phase I program baseline must be reviewed annually by the DAB. These annual reviews were to include cost, schedule, technical performance, and operational assessments. The annual DAB review scheduled for October 1989 was delayed until December and later cancelled. According to Defense officials, the review was cancelled because the fiscal year 1990 budget had not yet been finalized, and because Defense was reassessing the amount of oversight needed for the Strategic Defense System acquisition. The review has been rescheduled for June 15, 1990. Further, significant issues have not been formally reviewed by the DAB as to their impact on the SDI program. These issues include the October 1989 Space-Based Architecture Study's conclusions and recommendations and the dramatic effect of incorporating Brilliant Pebbles into Phase I.

The Space-Based Architecture Study was initiated to review the feasibility and consequences of incorporating Brilliant Pebbles into Phase I with special emphasis on the space-based elements—the Space-Based Interceptor, the Boost Surveillance and Tracking System, and the Space Surveillance and Tracking System. The study concluded that Brilliant Pebbles was feasible, but recommended that research continue on both Brilliant Pebbles and the Space-Based Interceptor. Additionally, the study concluded that if Brilliant Pebbles were incorporated, major changes should be made to system requirements that could significantly affect program cost and schedule. For example, the study concluded that (1) the Boost Surveillance and Tracking System's ballistic missile defense requirements could be reduced; (2) the Space Surveillance and Tracking System is an essential asset for Phase I but may need to be modified; and (3) the Ground Surveillance and Tracking System's capability will have to be increased. While SDIO officials have considered the study's results, the DAB has not formally reviewed the study and determined its consequences on the program's design, cost, and schedule.

Under Defense's current approach, major changes to Phase I have occurred without high-level Defense oversight and management review. Although the study recommended that research continue on both space-based weapons, SDIO decided to include Brilliant Pebbles in the Phase I architecture. This fundamental change to the program baseline was made without formal DAB review and oversight. As noted in chapter 1, this addition will have far-reaching impacts that will ripple across the Strategic Defense System; system interfaces, sensing capabilities, communications, and element requirements will all change significantly.

SDIO has also reduced the testing requirements for both the System Simulator and the Pilot Command Center without DAB review. SDIO initially established stringent System Simulator requirements that would demonstrate an end-to-end, real-time system test with hardware-, software-, and human-in-the loop in support of a full-scale development decision. However, the System Simulator is now only required to demonstrate an end-to-end simulation using software representations of the system elements instead of actual pieces of hardware and actual system software operating in real time. Further, the Pilot Command Center, SDI's test bed to demonstrate battle management and command, control, and communications functions in real time, was to include actual sensor and weapon hardware-in-the-loop testing. Current test plans do not include actual sensor and weapon interfaces. Since these significant reductions in demonstration and validation requirements have not been subject to DAB review, high-level Defense Department officials have not passed judgment on whether this proposed approach will provide sufficient information to make an informed deployment decision.

Congress Cuts Funding for Operational Testing and Evaluation Until Architecture Is Solidified

The Congress has shown long-standing interest in how major weapon systems perform and the adequacy and timeliness of operational test and evaluation. As early as 1971, the Congress enacted legislation requiring Defense to provide the Congress with data on operational test and evaluation results of major weapon systems before committing major production dollars.

In 1983, Congress enacted additional legislation creating the Office of the Director of Operational Test and Evaluation. Defense directed this office to provide an independent assessment of system-level testing for the Strategic Defense System. This office is to provide independent oversight, coordinate the military services' planning and execution of operational tests, and objectively report on test results to Defense and congressional decision-makers.

The Congress expects independent oversight and objective reporting of operational test results before it is willing to commit to production decisions. However, the Congress, in November 1989, expressed concern about the constantly changing design of the Strategic Defense System and, given these changes, questioned what value the Office of Operational Test and Evaluation could provide to the Strategic Defense

System at that time. According to the 1990 Authorization Act conferees,[1]

> ...the need for a Strategic Defense Initiative operational test and evaluation activity is premature in view of the shifting SDI architectures, plans and priorities. Accordingly, the conferees agree to reduce the operational test and evaluation authorization by $12.415 million from the requested amount and direct the Department of Defense not to obligate any appropriated funds for such an activity until it has been formally authorized in law.

We agree that such testing is premature given the fluid and constantly changing nature of the Strategic Defense System architecture. However, once the architecture is set, early system-level operational test and evaluation will help ensure that the acquisition process, which includes system-level test plans and methodologies, is not only monitored but also assessed. Furthermore, such oversight will help ensure that complex system-level test results, justifying a full-scale development decision, will be understood.

[1] Authorizing Appropriations for Fiscal Year 1990 for Military Activities of the Department of Defense, House of Representatives Report No. 101-331, 101st Congress, 1st Session (Conference Report).

Conclusions and Recommendations

The Strategic Defense Initiative Organization is engaged in one of the most complex and technologically challenging efforts ever undertaken. Tens of billions of dollars will be needed to develop and deploy the first phase of a Strategic Defense System. The first phase is designed to protect the United States from only a portion of a massive Soviet nuclear ballistic missile attack.

The Phase I architecture of the Strategic Defense System remains in a state of flux, primarily because Brilliant Pebbles, a new space-based weapon, was added to the system. The importance of a stable architecture cannot be overstated. An architecture that is not well defined runs the risk that system requirements will not be met and that the system will not perform as intended. Unless the individual Strategic Defense System elements are designed, developed, and tested as an integrated system, SDIO will not know whether the system will work as intended.

Brilliant Pebbles has greatly changed the Phase I architecture and highlights the instability of SDIO's design for the Strategic Defense System. Instead of the highly integrated, interdependent architecture envisioned for Phase I, Brilliant Pebbles is to provide more autonomy and require less interdependence among elements. As a result, element interfaces, surveillance and tracking capabilities, communications, and the numbers of elements will change. According to the Phase I System Engineer, even before the addition of Brilliant Pebbles to the architecture, detailed system requirements for all Phase I elements would probably not be completely defined until 1994 or 1995. Nevertheless, Defense has requested $265 million for full-scale development of the Boost Surveillance and Tracking System in fiscal year 1991. While the system is being developed to meet other Defense missions, we believe that a decision to enter full-scale development for the Boost Surveillance and Tracking System before the Phase I architecture had been solidified and its ballistic missile defense requirements defined would be premature. Such decisions in other Defense programs have led to significant cost increases, schedule delays, and performance shortfalls.

Phase I system-level test and evaluation activities will be significantly affected as well. System-level testing and evaluation are critical to making decisions on the continued development and deployment of a Strategic Defense System. However, the majority of system test and evaluation efforts so far have been based on an earlier Phase I architecture that did not include Brilliant Pebbles. Consequently, much of the current test data and analyses will not be applicable to the new architecture, and many of the tests will likely have to be redesigned and repeated. Even though initial SDIO test plans required that real-time integrated system-level tests be performed prior to a full-scale development decision and a presidential deployment decision, SDIO officials now claim such tests will not be conducted prior to either decision. We believe SDIO's initial plans could significantly reduce the risks involved in making critical development and deployment decisions for such a costly and technically complex system.

The President is scheduled to make a decision in 1993 on deploying Phase I of the Strategic Defense System. The President will have a range of options including deploying, delaying, or cancelling the Phase I system. Public Law 99-145 states that the system may not be deployed unless the President determines that the system is sufficiently capable of fulfilling its mission. Given that the architecture continues to change, the program is falling behind schedule, and the amount of test and evaluation data has been reduced, we do not believe that SDIO will be able to give the President enough information to support a 1993 decision to deploy Phase I.

We are not alone in raising concerns about the Strategic Defense System's changing architecture. The Congress has been troubled by the constantly changing design of the Phase I system and has questioned the value of operational test and evaluation oversight at this time. The Congress was so concerned that for fiscal year 1990 it not only reduced SDI program funding by 20 percent (from $4.6 billion to $3.6 billion), but also cut funding for the Office of Operational Testing and Evaluation, citing such activities as premature in view of the shifting Strategic Defense System architecture, plans, and priorities.

The federal government has repeatedly found that major acquisitions such as the Strategic Defense System are extremely difficult and complex undertakings, fraught with high risks. Indeed, many have floundered. A principal element needed to successfully design and develop highly integrated systems is the commitment and oversight of agency leaders. To provide that oversight they must have the information they need—such as program cost, requirements growth, schedule delays, acquisition strategy, and test and evaluation plans and results—to effectively guide the acquisition effort.

High-level oversight of the SDI program, however, is not occurring. The Defense Acquisition Board, which oversees major Defense acquisition programs, has not reviewed major changes to the Phase I architecture and to the system's test and evaluation requirements. The DAB's

1989 annual program review was cancelled. According to Defense officials, the review was cancelled because the fiscal year 1990 budget had not yet been finalized, and because Defense was reassessing the amount of oversight needed for the Strategic Defense System acquisition. We do not believe these reasons justify cancelling scheduled oversight reviews considering the dramatic, fundamental changes in the Phase I design and the significant reductions in system-level test and evaluation requirements. As a result, significant changes, such as the addition of Brilliant Pebbles to the Phase I architecture and the results of the October 1989 Space-Based Architecture Study, have not been subject to formal review.

Recommendations to the Secretary of Defense

We recommend that the Secretary of Defense advise the President to defer a decision to deploy any element of the Phase I system until SDIO has stabilized the architecture and has demonstrated the effectiveness of the system through integrated system-level tests in real time, using system hardware and software prototypes with human intervention. Additionally, the Secretary should ensure that required oversight by the Defense Acquisition Board be followed. The Board should more closely monitor system design, development, testing, and evaluation. Finally, when the program's architecture is stable, the Secretary should request that the Congress reinstate funding for the Director of Operational Test and Evaluation to provide an independent system-level assessment for the Strategic Defense System.

Recommendation to the Congress

We recommend that the Congress not fund full-scale development for any element of Phase I until SDIO has stabilized the architecture and has demonstrated the effectiveness of the system through integrated system-level tests in real time, using hardware and software prototypes with human intervention. This would include not providing $265 million for the Boost Surveillance and Tracking System in fiscal year 1991. However, if Defense needs the Boost Surveillance and Tracking System for another mission, independent and separate from the Strategic Defense System, it should be justified and funded to meet that mission and should no longer be considered an element of the Strategic Defense System.

Department of Defense Major Systems Acquisition Stages

Mission area analysis and program initiation generally precede the five Department of Defense acquisition stages. Defense components continually analyze their assigned mission areas to identify deficiencies (needs) and determine if new systems or major upgrades to existing systems are necessary. These analyses often result in recommendations to initiate new acquisition programs through the validation of a need to correct the deficiency. Once a need has been identified and validated and Defense initiates an acquisition program, the program enters the concept formulation stage.

Concept Formulation Stage

In this stage, potential requirements and alternative approaches to satisfy the need are identified and evaluated. Various types of analyses considering trade-offs among performance, life-cycle cost, and schedule are conducted to select among possible concepts to satisfy the need. Once a concept has been selected, it is presented to Defense for approval.

Demonstration and Validation Stage

In this stage, feasibility and desirability of the selected requirements and the system concept are further analyzed, generally using techniques like computer simulation, hardware prototyping, development test and evaluation, operational test and evaluation, or a combination of test methods. When the feasibility of the concept has been convincingly demonstrated and validated, the program enters the full-scale engineering and development stage.

Full-Scale Development Stage

In this stage, the system, including every item necessary for its logistic and operational support, is designed, fabricated, and tested. At the conclusion of this stage, the system is ready to be produced.

Full-Rate Production and Initial Deployment Stage

During this stage the proposed system is built and released to the user. At this point, the system becomes operational.

Operations Support Stage

This stage immediately follows deployment and extends until the system is removed from Defense inventory. Two major Defense reviews are conducted in this stage. The first takes place 1 to 2 years after deployment to determine if operational readiness and support objectives are being achieved and maintained. The second, occurring 5 to 10 years after deployment, evaluates system capabilities and assesses whether major upgrades are needed or if the system should be replaced.

Strategic Defense System Elements of Phase I

System element	General function	Specific functions
Boost Surveillance and Tracking System	Sensor	Detect missile launches; acquire and track boosters, assess kills
Space Surveillance and Tracking System	Sensor	Acquire and track warheads and satellites; assess kills
Ground Surveillance and Tracking System	Sensor	Track warheads and decoys; discriminate warheads from decoys; assess kills
Ground-Based Radar	Sensor	Acquire and track warheads and decoys; discriminate warheads from decoys
Space-Based Interceptor	Weapon	Destroy boosters and warheads
Ground-Based Interceptor	Weapon	Destroy warheads
Command Center		Human decision-making, communications and guidance for defense system

Test Beds Supporting Demonstration and Validation of the Strategic Defense System

The Surveillance and Tracking Test Bed will evaluate tracking and discrimination function performance for accuracy, computational requirements, speed, robustness. It will also validate surveillance algorithms and integrated system performance.

The Communications Network Test Bed will validate communications network operations and management and validate security of the Strategic Defense System's communications design.

The Pilot Command Center will validate command structure, hardware-in-the-loop, and demonstrate proof of concept for mobile and fixed physical configurations with selected software performance.

The Gaming Test Bed will evaluate proposed command and control operational concepts, build operator and user confidence in hardware-in-the-loop decision tools to support the development of the Pilot Command Center.

The System Simulator will provide the basic vehicle for system design studies and end-to-end validation of overall system performance. It will also validate software and integration capabilities.

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