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Strategic Defense Initiative

May 1991

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This report details progress and changes in SDI during the past year. It examines SDI's role in the changing international threat environment, particularly the use of SDI technologies in global protection against limited strikes (GPALS). This report also details current research and development strategy, allied participation in the program and compliance of SDI with the ABM Treaty. The report summarizes program funding and provides Congressional Descriptive Summary Extracts in the appendix.

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Chapter 1

SDI and the Changing World

Chapter 1
SDI and the Changing World

This chapter describes the policy associated with the Strategic Defense Initiative (SDI) Program, including the implications of the evolving international security environment, the role that defenses can play in responding to the threats we foresee in the 1990s and beyond, and recent presidential policy decisions regarding the SDI Program. The interrelationship of strategic defenses and U.S.-Soviet arms control is also discussed.

1.1 SDI in Perspective

The dramatic changes within Eastern Europe and the Soviet Union and, more recently, events in the Persian Gulf have served to underscore the fact that the strategic environment the United States will confront in the 1990s will differ significantly from that which we faced in the early 1980s when the SDI Program was established. Because of these changes, which include the continued proliferation of ballistic missiles and weapons of mass destruction on a global scale, ballistic missile defense has become far more urgent and relevant than could have been projected from the perspective of the early 1980s.

In light of these developments, the Department of Defense undertook a thorough review of the policy objectives toward which the SDI Program has to date been directed. That review helped inform a subsequent decision by the President, announced in his State of the Union address on January 29, 1991, that the SDI Program should be refocused, with an emphasis on accomplishing a revised set of policy objectives. The President stated,

> Now, with remarkable technological advances like the Patriot missile, we can defend against ballistic missile attacks aimed at innocent civilians. Looking forward, I have directed that the SDI Program be refocused on providing protection from limited ballistic missile strikes, whatever their source. Let us pursue an SDI Program that can deal with any future threat to the United States, to our forces overseas, and to our friends and allies.

This new focus has been named Global Protection Against Limited Strikes (GPALS).

1.2 SDI and Changes in U.S. National Security Planning Assumptions

The changes that have taken place in the international political and security environment over the last 2 years have caused us to revise the planning assumptions on which our overall military strategy is based.

1.2.1 New National Defense Strategy

In January 1990, while visiting Lawrence Livermore National Laboratory, President Bush concluded that "In the 1990s, strategic defenses make much more sense than ever before." The President's statement was made in the context of an ongoing review of U.S. defense policy and military strategy, generally, and, specifically, a review of the strategy and rationale for the SDI Program. Those reviews resulted in significant changes in our military strategy and the decision to refocus the SDI Program.

Changes in the Strategic Planning Environment

A fundamental assumption of U.S. military policy in the post-World War II era has been the need to prepare for global war with the Soviet Union that would begin with a short-warning attack into Western Europe. Furthermore, our strategy to contain regional instability and conflicts derived directly from Moscow's expansionist strategy and our own efforts to counter that expansionism. In the realm of strategic systems, the growth in Soviet strategic capabilities appeared to be unconstrained by resource limitations.

The past 2 years have seen historic changes in the strategic environment that have transformed our primary security concerns. The Soviet empire has been weakened economically and politically; communism has collapsed in Eastern Europe; Germany has been unified and is a member of the North Atlantic Treaty Organization (NATO); and the Warsaw Pact has been formally dissolved. The threat of a short-warning, conventional attack against Western Europe leading to global war is now less likely than at any time in the last 45 years.

Our optimism in these areas is tempered by recent unconstructive Soviet actions in arms control and the apparent political instabilities associated with the Soviet leadership's struggle for centralized control in response to the pressures in the various republics for greater autonomy and independence. There is enormous uncertainty about the ultimate results of these developments in the Soviet Union, and this should be reflected in our planning.

This uncertain political environment is accompanied by continuing Soviet efforts to modernize its strategic nuclear arsenal. Not only do the Soviets still possess a significant strategic capability; it is expected that Soviet nuclear forces will be fully modernized by the mid-1990s, including Typhoon/Delta IV submarines, SS-24 and SS-25 missiles, and a new highly accurate version of the SS-18 missile. In all, we see five or six new Soviet long-range ballistic missiles under development. Even after the Intermediate-Range Nuclear Forces (INF) and expected Strategic Arms Reduction Talks (START) Treaty reductions, the Soviets will likely be able to satisfy their critical nuclear targeting requirements with their current arsenal due to ongoing force modernization. The Soviet Union also continues to modernize its strategic defenses. In light of these uncertainties, we must recognize the continued importance of sustaining our strategic offensive modernization effort and of developing appropriate defensive capabilities.

While the Soviet conventional threat has declined and therefore the threat of global conventional conflict has receded, the potential for major regional threats to U.S. interests is growing. Although a new era holds the prospect for treating regional issues independent of the East-West context, we have witnessed the sobering truth that local sources of instability and oppression will continue to foster conflict. These conflicts, as the Gulf War has illustrated, can arise suddenly, unpredictably, and from unexpected quarters. The Gulf War presages very much the type of conflict we are most likely to confront in this new era—major regional contingencies, often very far from home, against foes well armed with advanced conventional and unconventional weaponry. The proliferation of ballistic missiles, and of weapons of mass destruction, increases the danger associated with these potential conflicts.

By the year 2000, it is estimated that at least 24 developing nations will possess ballistic missiles, nine of which either have or are near to acquiring nuclear capabilities. Thirty countries may have chemical weapons, and 10 may have biological weapons as well. A major implication for future regional conflicts that clearly emerges from the Gulf War is the military and political importance of possessing a capability to counter defensively the threatened or actual use of ballistic missiles and weapons of mass destruction. Future Secretaries of Defense are going to have to be able to deploy defenses against ballistic missiles—whether against the kind of theater threat we face today, or the far more sophisticated threats we anticipate in the future.

1.2.2 Strategic Defense in the New Strategy

The Annual Report of the Secretary of Defense to the President and Congress outlined the key elements of our defense strategy for the 1990s. Two points bear repeating. First, in response to the dramatic changes in the strategic environment, the United States has implemented a new strategy in which regional conflict has replaced global war as the major focus of its conventional defense planning. Second, this change in focus will result in a force structure strengthened, but significantly smaller than that which exists today.

The forces we develop and deploy to implement our new strategy must support several major tasks ranging from maintaining credible deterrent forces, through verifying arms control agreements, to developing comprehensive plans and programs for low intensity conflicts. The capability of our existing military forces to fulfill these tasks, and the plans for their further improvement, are generally well understood. The role missile defenses will play in supporting these tasks, particularly ***forward presence***, ***crisis response***, and ***force reconstitution***, was previewed in Desert Storm and is as follows:

- ***Forward Presence***: Our new strategy emphasizes the importance of U.S. presence abroad, albeit at reduced levels. Presence can take many forms. The stationing of forces in selected forward bases is perhaps the most tangible demonstration of U.S. commitment in key areas. Our missile defenses, in combination with those our allies and coalition partners might deploy, would protect us and them in maintaining a forward military presence in those areas threatened by ballistic missiles, and would support our aim of continuing to play a leadership role in international events.
- ***Crisis Response***: The need to respond to regional contingencies and crises, and do so on very short notice, is one of the key elements of our new strategy. The regional contingencies we might face are many and varied, including differences in the nature of the threat and distance from the United States. Defensive elements operating continuously from space and those resident with forward deployed, mobility, or power projection forces would provide protection, on short notice, of ports and airfields for arriving forces and their reinforcement. These defenses would also be capable of protecting population centers. In addition to protecting targets, they could also serve to defuse regional crises by deterring the employment of ballistic missiles. This combination of defense and deterrent capabilities increases the likelihood that, in regional crises, potential adversaries cannot threaten or use ballistic missile attacks to gain an advantage or to prevent the United States and its allies or coalition partners from pursuing political, diplomatic, or military initiatives designed to resolve the crisis on favorable terms.
- ***Force Reconstitution***: Our new strategy also provides options to respond to a major reversal in Soviet intentions or the emergence of a major new threat by incorporating into our planning the concept of reconstitution of our forces. It calls for timely reconstitution that requires that we take care to preserve the longest-lead elements of our security. This includes particularly our forward deployments and the technological and doctrinal edge that comes from vigorous innovation and development. This also includes particular weapons systems or capabilities that take a long time to rebuild, such as large weapons platforms that require long production or

recommission times. Moreover, within our new strategy, the reconstitution concept is not necessarily simply to recreate or expand existing forces, but to consider what new forces are most needed for a specific reemerging threat consistent with our strategic concept.

With respect to missile defenses, GPALS should provide the base level of capability to carry us into the next century in support of our forward presence and crisis response missions. A GPALS deployment represents an appropriate level of defense within our strategic forces structure, based on our current planning assumptions. It is consistent with preserving the potential for meeting the broader objectives of existing military requirements stemming from significant remaining Soviet strategic capabilities. Consistent with the underlying premise of the reconstitution task, if the United States decides that it needs to achieve more ambitious mission objectives at some point in the future, or if changes in the international environment result in a requirement to expand U.S. strategic defense efforts, the SDI Program will have developed the systems and technologies required to do so.

1.3 Considerations for the GPALS Threat

While the requirement for the United States to deter a Soviet strategic nuclear attack remains, the evolving world situation discussed above also leads to a requirement to provide protection against limited strikes by ballistic missiles. The design of a GPALS system to provide such protection must consider the possibility of unauthorized or accidental launches, whatever the cause or source.

1.3.1 Accidental and Unauthorized Strikes

Senior Soviet political figures have expressed their concerns about the implications of increasing instability for the security of Soviet nuclear weapons. Specifically, former Foreign Minister Shevardnadze stated "No one can calculate the consequences of a social explosion capable of igniting not only befogged minds but also the giant stockpiles of nuclear and chemical weapons and nuclear power stations and the zones already weakened by environmental and natural disasters and regions shaken by interethnic strife." Reflecting these concerns, there have been press reports that steps have been taken by the Soviet military to strengthen controls over their nuclear weapons, particularly in areas where there is significant political instability.

The effect of prolonged political instability on the probability of an accidental or unauthorized use of a ballistic missile is unknown. Nevertheless, this is a contingency of concern given the statements of Soviet President Gorbachev who, on December 18, 1990, commented "We are already in a state of chaos" on a government-run television news show and, on other occasions, has talked about the danger of civil war.

The concern for accidental and unauthorized launch increases as well with the proliferation of ballistic missiles. Concern that loss of positive control over ballistic missile forces might occur in third world countries is real due to their lack of experience with the weapons system, nonexistent or inadequate weapon release procedures, the absence of adequate physical and organizational safeguards, and the possibility of political instability.

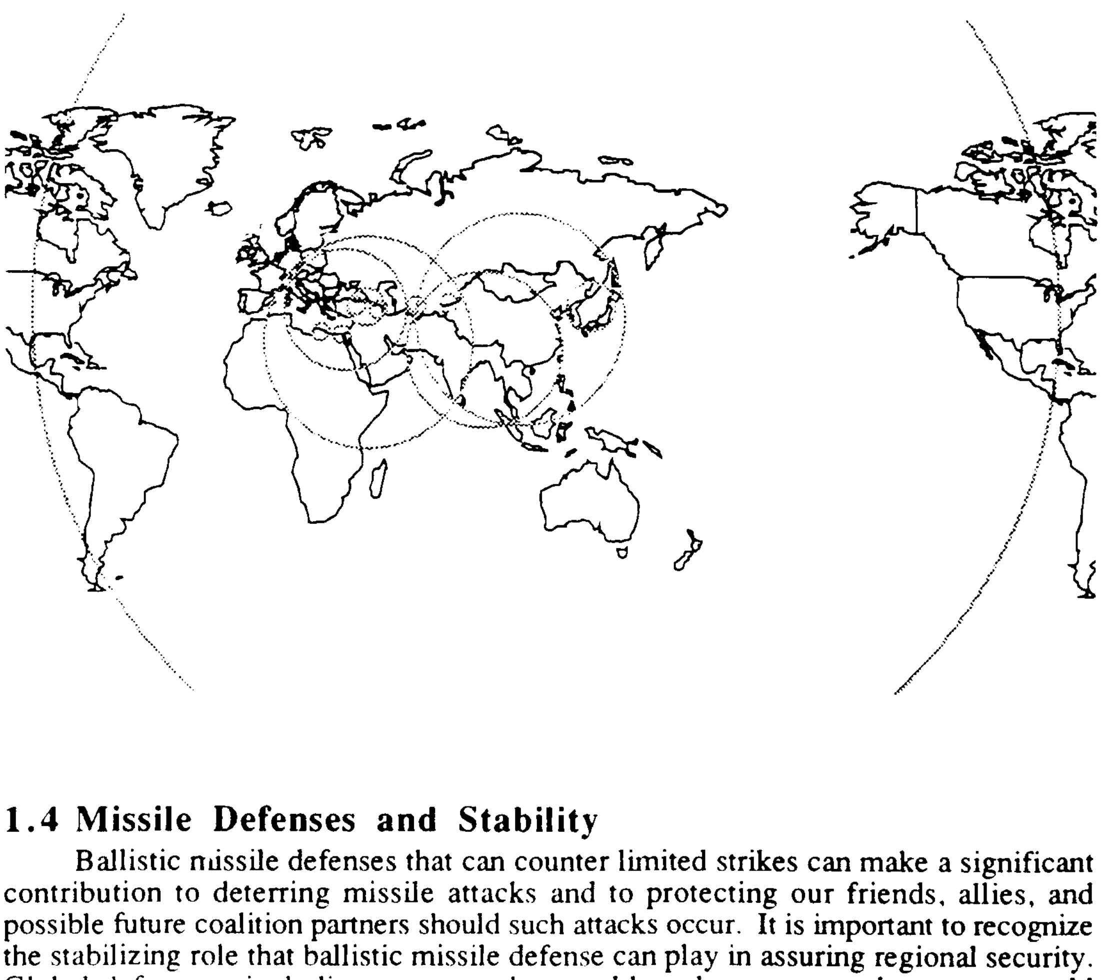
1.3.2 Ballistic Missile Proliferation as a Threat to the United States and Its Forces

The spread of military technology of increasing sophistication and destructiveness is a trend that must be considered as we develop military forces to be fielded in the 1990s. A prime example of this is the proliferation of ballistic missiles and weapons of mass destruction, including the capability to design, test, and fabricate chemical, biological, and nuclear weapons. One of the factors that mandated refocusing of the SDI Program is the increased threat posed by the spread of ballistic missile capability around the world.

The United States cannot accept a situation in which these capabilities are allowed to constrain a U.S. president's flexibility in pursuing the nation's global interests and responsibilities. In its role as a leader of worldwide alliances, this nation also cannot ignore the growing threats posed to our friends and allies around the globe.

Figure 1-1 represents an illustrative look at ballistic missile proliferation. These technologies pose a threat today that is regional in character (e.g., shorter-range missile systems). However, the trend is clearly in the direction of systems of increasing range, lethality, and sophistication. It is clear that some third world countries are striving to acquire or develop missiles capable of delivering payloads primarily at short and medium ranges, although a few countries could achieve intercontinental ranges through the conversion of space launch vehicles. This is a matter of concern in a world that may be increasingly affected by diverse geopolitical considerations.

Figure 1-1
Ballistic Missile Proliferation—An Illustrative Look



1.4 Missile Defenses and Stability

Ballistic missile defenses that can counter limited strikes can make a significant contribution to deterring missile attacks and to protecting our friends, allies, and possible future coalition partners should such attacks occur. It is important to recognize the stabilizing role that ballistic missile defense can play in assuring regional security. Global defenses—including space- and ground-based weapons and sensors—could protect the United States from limited ballistic missile attacks and also protect U.S. forces deployed overseas, U.S. peacekeeping and power projection forces, and the homelands and military forces of our friends and allies. An ability to extend such protection to our allies becomes an increasingly important indicator of American military strength, as well as a very tangible indicator that we remain committed to providing security assistance to our friends and allies.

Lastly, and perhaps most importantly, defenses can save lives and prevent massive societal damage. As President Bush said, "Thank God that when the Scuds came—the people of Israel and Saudi Arabia, and the brave forces of our Coalition had more to protect their lives than some abstract theory of deterrence. Thank God for the Patriot missile." The ballistic missile threats we will face in the future will be more sophisticated than the Scud, and we will require more advanced and capable defenses to counter them.

The war in the Gulf has served to underscore the stabilizing role that defenses against limited attacks can play in a regional conflict. First, such defenses reduce the effectiveness of blackmail threats based on the threat of ballistic missile strikes against coalition partners or other nations. And, despite the fact that only a few third world countries possess longer-range ballistic missiles, the trend clearly is in the direction of more nations possessing longer-range systems potentially armed with conventional and mass-destruction weapons. Thus, even if a conflict is hundreds or even thousands of miles away from the United States or the capitals of our allies or coalition partners, those capitals may be held at risk by belligerent nations. Without a capability to defeat these attacks, ballistic missiles could give regional aggressors the means to impact the political stability of a coalition or alliance. This stabilizing effect extends to military planning as well.

Defenses also reduce the incentives for anticipatory or preemptive attacks by allied, coalition, or other national forces against those countries threatening attack with ballistic missiles. The stabilizing effect of deployment of U.S. Patriot batteries to Israel following the first Iraqi ballistic missile attacks on Tel Aviv and Haifa was clearly evident. The provision of an active defense by the United States to an American friend —and, importantly, in this case a nonbelligerent—is tangible evidence of our continued commitment to assuring the security of our friends, allies, and coalition partners. In addition, such deployment permitted Israel to continue its policy of "reserving the right" to respond at a time and place of its choosing, while actively responding to a threat to its citizens.

In the same vein, the decision to send Patriot batteries to help in the defense of U.S. and Saudi forces and population centers in Saudi Arabia not only saved lives, but helped to blunt the political objectives the missile attacks sought to achieve.

We should also recognize that it may not be possible to deter some ballistic missile attacks. For example, the use of both offensive forces and Patriot defenses did not deter Iraq's Scud attacks on the Saudi cities of Dhahran and Riyadh. In the case of the attacks on Israel, these were intended to prompt escalation. The success achieved with Patriot, which is a point defense system, suggests that advanced systems capable of defending larger areas would be even more effective in extending protection to our friends and allies. Had such defenses been available in the recent war, loss of life and property damage would certainly have been reduced.

Active defenses also reduce pressures on U.S. military and political leaders involved in a regional conflict to alter their campaign or war plans because of the threat (or actual use) of ballistic missiles. In the absence of effective defenses, such carefully laid plans could be disrupted or delayed. With an effective defense in place, our military leaders are better able to follow their well-constructed plans, thereby retaining the initiative in battle.

1.5 Revised SDI Program Focus

The SDI Program's new focus was named Global Protection Against Limited Strikes because, consistent with the President's State of the Union address, the Department of Defense is developing capabilities to protect U.S. forward deployed forces, power projection forces, U.S. friends and allies, as well as the United States itself against limited ballistic missile attacks, irrespective of their source.

1.5.1 Global Protection Against Limited Strikes

A GPALS deployment could provide an appropriate level of ballistic missile defense within the U.S. strategic force structure for the foreseeable future. The decision to proceed with GPALS satisfies valid military needs. Any decision to proceed beyond GPALS would occur in the future and would ultimately require consideration of the following factors:

- Status of Soviet military power, and in particular Soviet strategic capabilities
- Political developments in the Soviet Union
- Progress in concluding and implementing U.S.-Soviet arms reduction agreements
- Changes in the threat due to ballistic missile proliferation.

Options for qualitative defense improvements will be pursued through research and development activities.

By focusing on ***protection*** as the objective, the concept for GPALS is significantly different from that of Phase I. The Phase I concept focused on deterring massive, deliberate attacks by the Soviet Union. Protection of the United States against limited strikes is a goal of Phase I and would have been provided by a defense system sized to enhance deterrence posture by substantially increasing Soviet attack uncertainty. Under the GPALS concept, the defense system would be capable of assuring protection against limited strikes, but, at less than half the size of the Phase I architecture, would not pose a threat to Soviet retaliatory capability. The primary responsibility for maintaining deterrence of an intentional, massive Soviet strategic offensive strike against the United States and its allies will remain with U.S. and allied strategic offensive forces for the remainder of the century.

1.5.2 Elements of GPALS

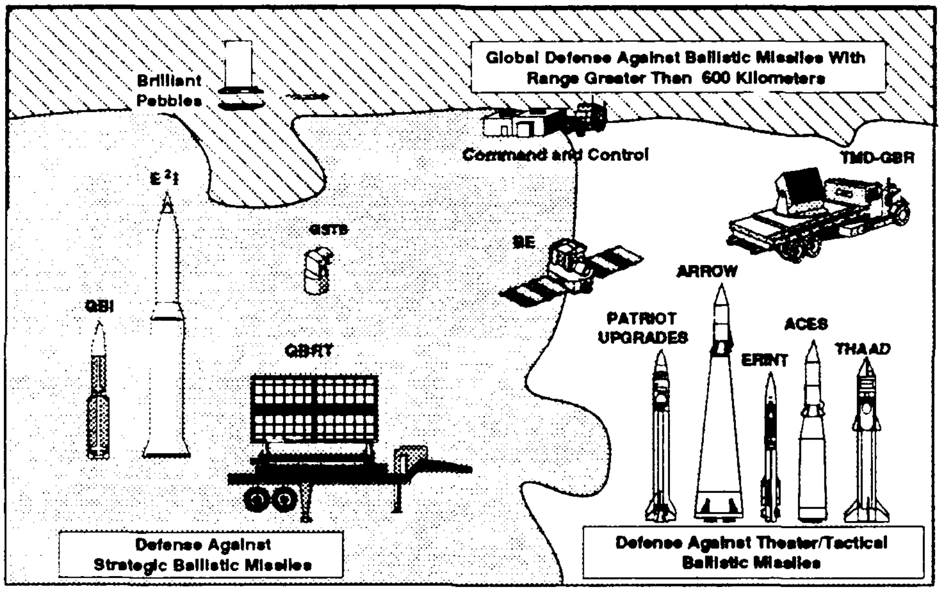
GPALS would consist of surface- and space-based elements to ensure continuous global detection, track, and intercept of ballistic missiles and their associated warheads, including theater missile threats. The defensive elements that comprise GPALS could be deployed sequentially, and need not await the deployment of an entire system. Nor would the deployment of a GPALS system be contingent on the technical maturity of follow-on systems. A GPALS defensive system would consist of the following:

- Space- and surface-based sensors capable of providing global, continuous surveillance and track, from launch to intercept or impact, of ballistic missiles of all ranges. The use of space-based sensors would allow for a reduction in the size, cost, and number of the surface-based weapons and sensors, while increasing their performance. In combination, the sensors would provide information to U.S. forces and, potentially, to those of our allies as well.

- Interceptors, based both in space and on the surface, capable of providing high confidence protection to areas under attack. Space-based interceptors could provide continuous, global interdiction capability against missiles with ranges in excess of 600 kilometers. The surface-based interceptors, located in the United States, deployed with U.S. forces and, potentially, deployed by U.S. allies, would provide local point and area defense.

To illustrate the GPALS concept, Figure 1-2 depicts an integrated system consisting of three interlocking pieces. The size of each piece reflects the relative investment projected for the three main parts of the GPALS system. Pictured on each piece are the key elements of the corresponding parts of GPALS. (These elements are described later in this report.)

Figure 1-2
GPALS Integrated System and Key Elements



Common to all the GPALS interceptors is the use of non-nuclear, hit-to-kill technology for destruction of all types of warheads—nuclear, chemical, biological, and conventional. These interceptors are designed to permit destruction of both missiles and warheads well away from the targets being defended. The employment of multi-layered defenses will ensure multiple opportunities to engage hostile ballistic missiles, thereby providing a high level of defense effectiveness.

The Theater/Tactical elements of GPALS will be able to be deployed globally by the United States. These forward elements of our ballistic missile defense will be transportable and could be deployed with ground-based or sea-based units. Friends or allies may also choose to deploy theater defenses that could be interoperable with those of the United States. It is important to note that the space-based ballistic missile defense sensors will support theater as well as strategic defense operations.

1.5.3 GPALS and the Theater Missile Defense Program

To attain maximum military effectiveness and economic benefits in closely related technologies, the Department's Theater Missile Defense (TMD) and SDI Programs have been integrated. This will permit the United States to deploy significant surface-based theater defenses by the mid-1990s and, beginning in the late 1990s, to deploy surface- and space-based elements of a global defense capable of detecting, tracking, and intercepting ballistic missiles of all ranges. Additional data on the U.S. TMD effort were provided in the Theater Missile Defense Report to Congress dated March 30, 1991.

With the refocusing of the SDI Program towards GPALS, we have significantly increased the priority assigned to theater missile defenses. The U.S. Congress has appropriated funds to accelerate TMD, and improved theater missile defenses would be the first elements of GPALS to be deployed.

The GPALS concept includes mobile, surface-based (ground and sea) theater missile defenses, owned by the United States and those potentially owned or operated by allies. These theater defenses could be deployed to a region by the United States during times of heightened tensions, or they could be permanently deployed by a government on its own territory. Under current plans, it would not be necessary to station U.S. TMD on allied territory for the GPALS system to perform its mission, unless U.S. forward forces had TMD assets included in their force structure.

While direct allied involvement is not required, we believe that a number of friends and allies will be interested in the TMD aspects of GPALS, particularly since third world country ballistic missile proliferation is a growing concern to them. Theater missile defense is a logical area in which the United States can cooperate with friends and allies to exploit technologies SDI has been developing to meet our mutual security needs expeditiously, and we are actively encouraging expanded cooperation with our allies.

A number of friends and allies (through direct contracts, subcontracts, and government-to-government agreements) are already involved in TMD work with the United States under the SDI Program, such as in the following areas:

- Theater architecture studies to develop a better understanding of the missile threat, the need for missile defenses in various theaters, and the possibility of developing these defenses
- Computer-based TMD test beds designed to evaluate TMD components as they are developed from concept definition through hardware development
- Interceptor experiments, such as the Arrow project with Israel
- Technology development, e.g., hypervelocity guns, radars.

We would anticipate that these kinds of activities would continue and even expand. If friends and allies decide to deploy their own theater missile defenses, we would envision them as being autonomous systems potentially capable of being interoperable with elements of U.S. defenses.

1.5.4 Programmatic Implications of GPALS Focus

Although our goal is to field advanced theater defenses in the mid-1990s, the President has not made a decision to deploy the remaining elements of GPALS. Rather, he has directed that the Department of Defense place priority within the SDI Program on research and development of capabilities to provide global protection against limited ballistic missile strikes. The SDI Program is being conducted in full compliance with all U.S. international legal obligations, including the ABM Treaty. An important result of the new GPALS policy approach is that the outyear funding requirements for SDI have been reduced substantially. Even with the addition of theater ballistic missile defense requirements, total Fiscal Years 1992 to 1997 funding costs for the SDI Program will be approximately 20 percent less than previous estimates when Phase I was the focus. Research on follow-on technologies will continue to be funded to provide a hedge against future potential threats in the post-Cold War era. (The research and development strategy for pursuing GPALS is discussed in Chapter 3.)

1.6 Arms Control

The new GPALS approach is consistent with U.S. objectives in U.S.-Soviet arms control talks, including the Defense and Space Talks (DST) currently under way in Geneva. Concerning future arms control talks with the Soviets, the June 1990 Joint Statement on Follow-on Negotiations noted that an agreed objective of those talks is to "implement an appropriate relationship between strategic offenses and defenses."

The United States continues to seek agreement in the Defense and Space Talks on a cooperative transition to the deployment of strategic defenses, should they prove feasible, while preserving our options to deploy such strategic defenses when they are ready. We also seek greater transparency and predictability into each side's research and follow-on work on such systems and have proposed regular exchanges of data, meetings of experts, briefings, visits to laboratories, and observations of tests. Although the Soviet Union has committed itself to continued discussions of the relationship between offensive and defensive forces, and itself is engaged in internal discussions about defenses, it has thus far not supported our approach in the DST. Nevertheless, we will continue to seek agreement, believing that conditions in the world today make it more necessary than ever.

Because it addresses a threat of mutual concern—accidental and unauthorized launches and third world proliferation—GPALS may facilitate progress in the future at the Geneva Defense and Space Talks. At the June 1990 Washington Summit Meeting, the United States and the Soviet Union committed to follow-on strategic negotiations aimed at "implementing an appropriate relationship between strategic offenses and defenses." We believe GPALS provides a basis for success in such negotiations.

1.7 Conclusion

Preserving our security in changing circumstances depends in part on the nation's willingness to commit to a new role for ballistic missile defenses. As envisioned by the President, this revised SDI Program, known as GPALS, would provide global protection against limited strikes, whatever their source. The policy objectives for GPALS can be summarized as follows:

- The objective of GPALS is to provide protection against accidental, unauthorized, or limited ballistic missile strikes by third world countries or the Soviet Union directed against U.S. power projection or forward deployed forces, U.S. friends and allies, and the United States itself.
- Options for qualitative defense improvements will be pursued as research and development activities.
- A future decision to deploy additional defense capability beyond that required to meet the objective of GPALS will depend upon the international security environment in the future. Key factors in this assessment will be the status of Soviet military power, and in particular Soviet strategic capabilities; political developments in the Soviet Union; progress in concluding and implementing U.S.-Soviet arms reduction agreements; and changes in the threat due to ballistic missile proliferation.
- The primary responsibility for maintaining deterrence of an intentional, massive Soviet strategic offensive strike against the United States and its allies will remain with U.S. and allied strategic offensive forces for the remainder of the century.

- The concept known as GPALS, designed to satisfy these objectives, will provide the policy and planning guidance for the conduct of SDI research, development, and demonstration and validation activities.
- The GPALS concept consists of surface- and space-based elements to ensure continuous global detection and track of missiles of all ranges and the capability to intercept ballistic missiles and their associated warheads, including theater missile threats. The defensive elements that make up GPALS could be deployed sequentially and need not wait for the deployment of an entire system. The deployment of a GPALS system would not be contingent on the technical maturity of follow-on systems.
- Enhancing the security of our friends and allies has always been an objective of the SDI Program, and we will pursue even more active participation on their part in GPALS.

Chapter 2

Defense Concepts and Architectures

Chapter 2
Defense Concepts and Architectures

This chapter summarizes the key ballistic missile defense (BMD) concepts underlying a system that will provide global protection against limited strikes (GPALS). The objective of a GPALS system, its architecture, and its estimated cost and effectiveness are also addressed.

2.1 Ballistic Missile Defense Concepts

In the 1980s the Defensive Technologies Study, or Fletcher Study, concluded that the most effective strategic defensive systems would have multiple layers. The concept of multilayered defense continues as the conceptual cornerstone for GPALS. Specifically, the GPALS system consists of layers referred to as boost/post-boost, midcourse, and terminal. These layers correspond, respectively, to (1) the period of a ballistic missile's flight while the booster is thrusting through the time its reentry vehicles (RVs) and possible decoys are deployed, (2) the relatively long period of time RVs and decoys coast along their ballistic trajectories in space, and (3) the final period when the RVs reenter the atmosphere near their targets. These layers exist when considering defense against strategic and theater ballistic missiles with ranges greater than a few hundred miles. Some shorter-range missiles may have trajectories that remain in the atmosphere and are too low to permit their intercept from space; such missiles would be susceptible to ground-based defenses, including anti-tactical ballistic missile defenses (ATBMs).

Although the phenomenology and required technologies for defense differ from layer to layer, the basic BMD system functions remain the same: (1) detection, acquisition, tracking, and discrimination (that is, sensing); (2) interception and destruction of threatening objects; and (3) battle management, command, control, and communications. Thus, as new technologies continue to emerge, they can provide better ways to accomplish the essential functions in the defensive layers without changing the overall system concept. These technologies involve both space- and surface-based defensive weapons and their associated sensors and command and control capabilities.

For ballistic missiles with multiple RVs, the region that potentially has the highest defense payoff is the boost/post-boost layer. Viable technical approaches now exist for intercepting from space a ballistic missile during the boost portion of its flight. Inclusion of a boost-layer defense would substantially discount the value of highly "MIRVed" ballistic missiles (i.e., missiles with independent reentry vehicles) and provide the Soviets with incentives to agree to our long-standing arms control objective of reducing their MIRVed intercontinental ballistic missiles (ICBMs). Intercepts in the boost phase also offer multiple engagement opportunities to ensure high levels of defense effectiveness, and, through the synergism provided by layers of the defense, significantly increase the task of designing and deploying effective offensive countermeasures.

If fast-burn boosters are employed to counter initial boost-layer defenses, the task of releasing decoys is more complicated, mitigating the requirement to design means of discrimination in the midcourse layer. Furthermore, follow-on defensive system concepts could block the fast-burn approach. Intercepts in the boost/post-boost layer also can destroy the post-boost vehicle (PBV) before it releases decoys and other penetration aids to confuse the defenses, should such decoys and penetration aids be present.

The major technical challenge in the midcourse layer is to develop a capability to discriminate RVs from accompanying decoys or other penetration aids. There are, for example, beneficial effects gained by using sensors in space to observe from nearby the operation of a PBV as it starts to release its payload. Such "bus-watching" observations could permit early identification of RVs among the clouds of objects, or at least identification of which clouds contain RVs. This early identification, in turn, could mitigate the problems associated with tracking and intercepting RVs from either space or the surface.

In the terminal layer, the atmosphere helps the defense discriminate because heavy RVs would be decelerated by atmospheric drag less than their accompanying lighter penetration aids. The key technical challenges for endoatmospheric interceptors are accommodating the severe interceptor heating caused by friction with the atmosphere and achieving a high degree of interceptor maneuverability.

2.2 Mission Objective

The President's remarks in his 1991 State of the Union address provide the basis for the GPALS mission objective. This objective is to provide protection against accidental, unauthorized, or limited ballistic missile strikes by third world countries or the Soviet Union directed against U.S. power projection or forward deployed forces, U.S. friends and allies, and the United States itself.

The pursuit of GPALS provides a technical foundation for evolutionary growth in future BMD capabilities should a decision be made to do so in the future. A decision to go beyond GPALS and achieve more ambitious mission objectives would be based on a number of future factors, including the Soviet and third world ballistic missile threats, developments in arms control, and more.

Previous SDI proposals involved relatively large defensive deployments with a mission to deter large attacks (thousands of RVs) by the Soviet Union. In contrast, the GPALS concept is aimed primarily at defeating limited attacks (e.g., up to a few tens of missiles with 1 to 10 RVs per missile).

2.3 GPALS Architecture

The discussion that follows addresses the complete GPALS architecture to defend against limited ballistic missile attacks regardless of their source. Both surface-based and space-based elements are included in the GPALS architecture.

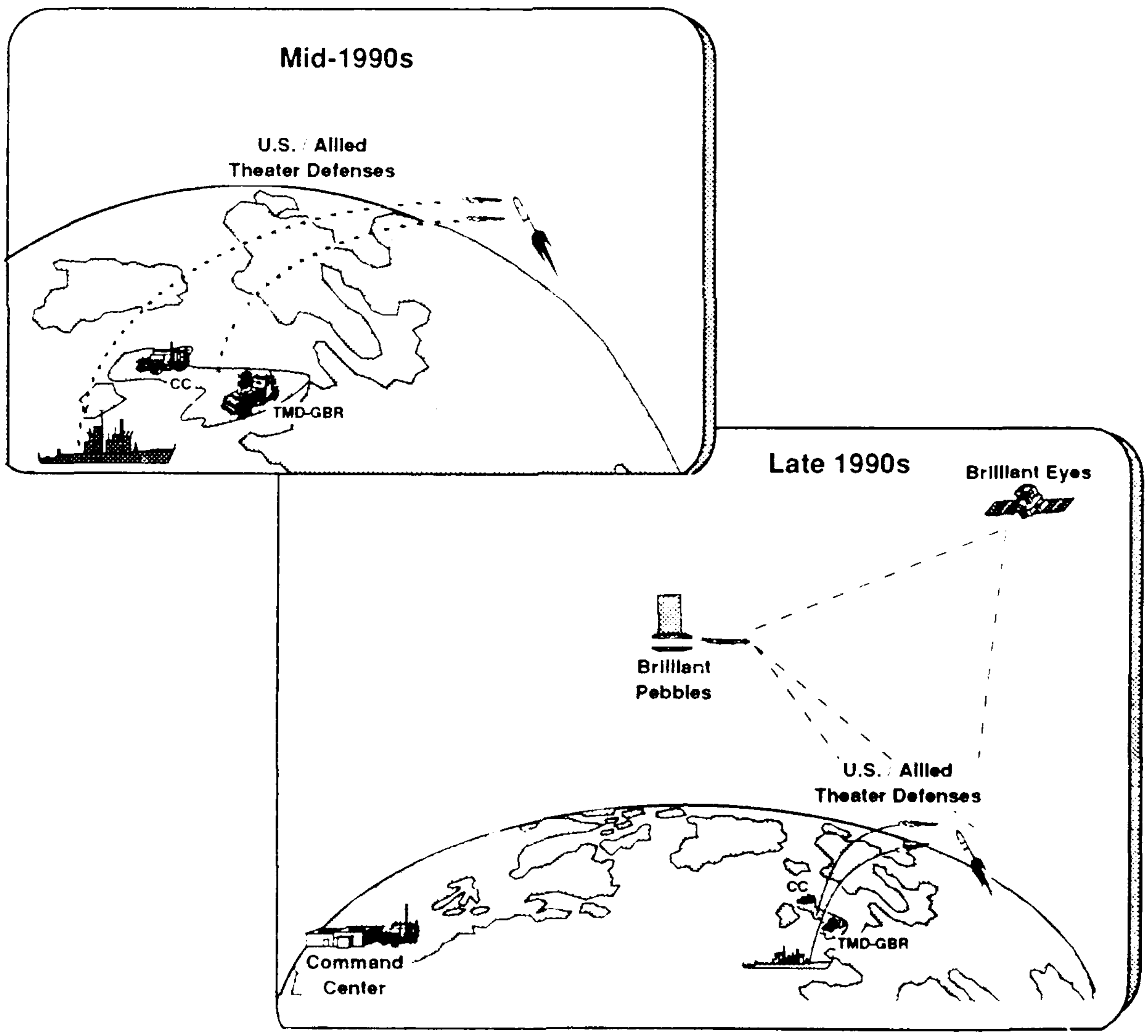
The strategy for fielding an effective GPALS defense, per the President's direction, follows an orderly progression of testing the most promising technologies as they come from the laboratory and deploying defensive systems as their capabilities are proven. Thus, as a consequence, the nearest-term deployment options will involve improvements to and modernization of our theater missile defense systems. Following a significant improvement in U.S. theater missile defense capabilities in the mid-1990s, our strategy calls for deployment of Brilliant Pebbles and U.S. ground-based defensive systems (made up of GBI/E^{2}I, GBRT, Brilliant Eyes, GSTS, etc., which are described later in the report) in the late 1990s.

2.3.1 Theater Missile Defense

Given our experience with theater ballistic missile threats in the Persian Gulf War, and the fact that these threats will become more sophisticated in the future, we are pursuing the development and deployment of advanced theater defenses by the mid-1990s as an urgent priority. These ground-based theater defense interceptor systems would provide midcourse and terminal defense capability. Interceptors could be based in-theater continuously (or moved to "hot spots" as needed), on ships, or on aircraft. These interceptor systems would be cued and supported by space-, air-, and ground-based sensors.

When Brilliant Pebbles and the ground-based U.S. defense systems are also deployed, the ultimate GPALS capability would be as indicated in Figure 2-1. Brilliant Pebbles would detect and track the launch of ballistic missiles, and Brilliant Eyes, ground-based and, perhaps, ship- and aircraft-based sensors, would provide midcourse acquisition and tracking. Radars would support the terminal defense. Brilliant Pebbles could intercept those missiles with trajectories that have ranges greater than about 600 kilometers.

Figure 2-1
GPALS Architecture: Protection Against Theater and Tactical Ballistic Missiles



The missile threat facing U.S. forces and our friends and allies is complex in terms of technical sophistication, armament, numbers, and concept of operations. Differences exist with respect to capability, intent, and value among the various nations that might try to use or defend against such threats. For example, emerging third world users of ballistic missiles may be more inclined to attack population centers to terrorize an adversary's populace. On the other hand, as missile accuracies improve in the future, these nations might choose to use theater missiles to attack critical military targets.

Theater ballistic missile defenses should serve to complement U.S. and allied defenses against cruise missiles, aircraft, or terrorists. Theater missile defenses must be integrated with counteroffensive operations and also must be balanced with respect to other ways to limit damage from missile attacks, e.g., by hardening and mobility.

The Strategic Defense Initiative Organization (SDIO)-led projects are now examining options for improved theater ballistic missile defense capabilities that will build on the performance of the Patriot air defense system demonstrated in Desert Storm. The goal of these projects is to provide layered defenses to achieve true area defense and high probability of success by employing improved (longer-range) interceptors and sensors. Part of the program is evolutionary in that it begins with near-term improvements to Patriot as identified in the Patriot preplanned product improvement plan. Alternatives being considered in this plan include radar power upgrades, missile radar receiver improvements, remote control of Patriot launchers, and new missile guidance systems using multimode seeker technologies. New active defense missile designs being evaluated through demonstration and validation programs include the U.S.-Israeli long-range, area-defense missile (Arrow) and its follow-on Arrow Continuation Experiments (ACES); a U.S. wide-area, high-altitude interceptor and sensor known as the theater high altitude area defense (THAAD) system; a "hit-to-kill" autonomous missile called the extended range interceptor (ERINT); and a complete replacement of the Hawk anti-aircraft system with an anti-missile, anti-aircraft capable system.

The theater missile defense and strategic defense programs have been fully integrated into the GPALS system architecture. Initial estimates of the research and development and procurement costs of a theater defense architecture for a single theater are about $9 billion (in constant 1988 dollars). This estimate does not include operations and support costs or an allowance for modifying existing ship or aircraft weapon platforms if those theater missile defense basing modes are employed. The $9 billion figure is based primarily on preliminary estimates for upgraded Patriots, the ERINT and THAAD interceptors, and associated sensor capability. Activities to formally validate all TMD requirements are running in parallel with SDIO development of technical alternatives to meet these requirements. More complete information on the TMD requirements process and on the concepts being developed by SDIO can be found in the Theater Missile Defense Report to Congress, dated March 30, 1991.

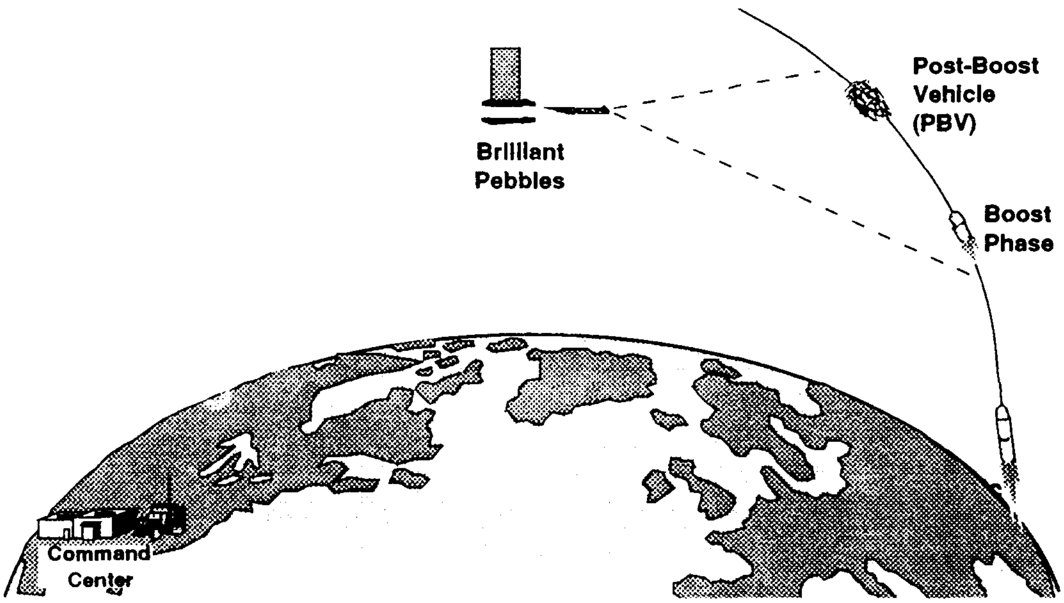
The program will develop options to allow a layered approach to theater defense—longer-range systems like THAAD and Arrow, and shorter-range or point defense systems like Patriot PAC II. This layered approach will ensure that overall high system performance would be further enhanced once space-based sensors (Brilliant Eyes) are coupled to the theater defense because of the added early warning and target tracking information. Capable space-based sensors, able to provide high-quality track information directly to the THAAD or Arrow interceptors, could increase severalfold the defended radius of one battery. The use of space-based interceptors

(Brilliant Pebbles) would complete the defense layering providing the ability to engage missiles with ranges greater than 600 kilometers early in their trajectories.

2.3.2 Brilliant Pebbles

The space-based Brilliant Pebbles (BP) element in combination with a ground-based command center is illustrated in Figure 2-2. Brilliant Pebbles, after receiving weapon release authority, is an autonomous space-based kinetic energy interceptor. The BP would provide global detection of an attack and a means to destroy ballistic missiles with ranges greater than about 600 kilometers. In the GPALS architecture, BP operates against both strategic and theater ballistic missiles.

Figure 2-2
GPALS Architecture: Space-Based Protection Against Ballistic Missiles with a Range Greater Than 600 Kilometers



Developing space-based BP interceptors as part of GPALS is important for the following:

- Brilliant Pebbles interceptors would have the potential for continuous worldwide coverage.
- The sensing capability of Brilliant Pebbles will provide additional tactical warning information to the National Command Authorities in the event of a ballistic missile attack as well as provide cueing to the Brilliant Eyes satellites and other elements of the GPALS system.
- Brilliant Pebbles exploits U.S. technological strengths and provides leverage both against proliferation of theater ballistic missiles of longer ranges and in U.S.-Soviet arms control negotiations (e.g., to provide incentives to the Soviets to "de-MIRV" their strategic offensive forces).

BP obtains its greatest leverage as a boost and post-boost interceptor. It detects a launch with its infrared sensor, tracks the hot plume, computes the trajectory, then homes in on the heat signature. BP also has the potential to engage theater ballistic missiles, depending on the characteristics of such missiles (e.g., their burn time and apogee) and on the BP design, basing, and operations concept.

However, BP cannot reach some theater and tactical ballistic missiles during boost because their burn time is very short and burnout altitude is very low. For these and other single-warhead missiles, the precise tracking of the booster trajectory during powered flight can be used by the BP to project ahead to an intercept point in space. The BP can fly toward this point and, with the currently planned sensor capability, acquire the target from a sufficient range, even when dark, and home in to intercept.

The role of BP in the midcourse layer is being studied. It is clear, however, that BP could have a greater midcourse capability against a limited attack than against a massive Soviet strike. First, a limited strike is not anticipated to include a preemptive anti-satellite strike. This means that survivability requirements would differ significantly between the two situations. Second, because the number of threat objects in a limited strike scenario is anticipated to be a fraction of what would be included in an all-out strike, the need for discrimination of RVs from penetration aids is less acute.

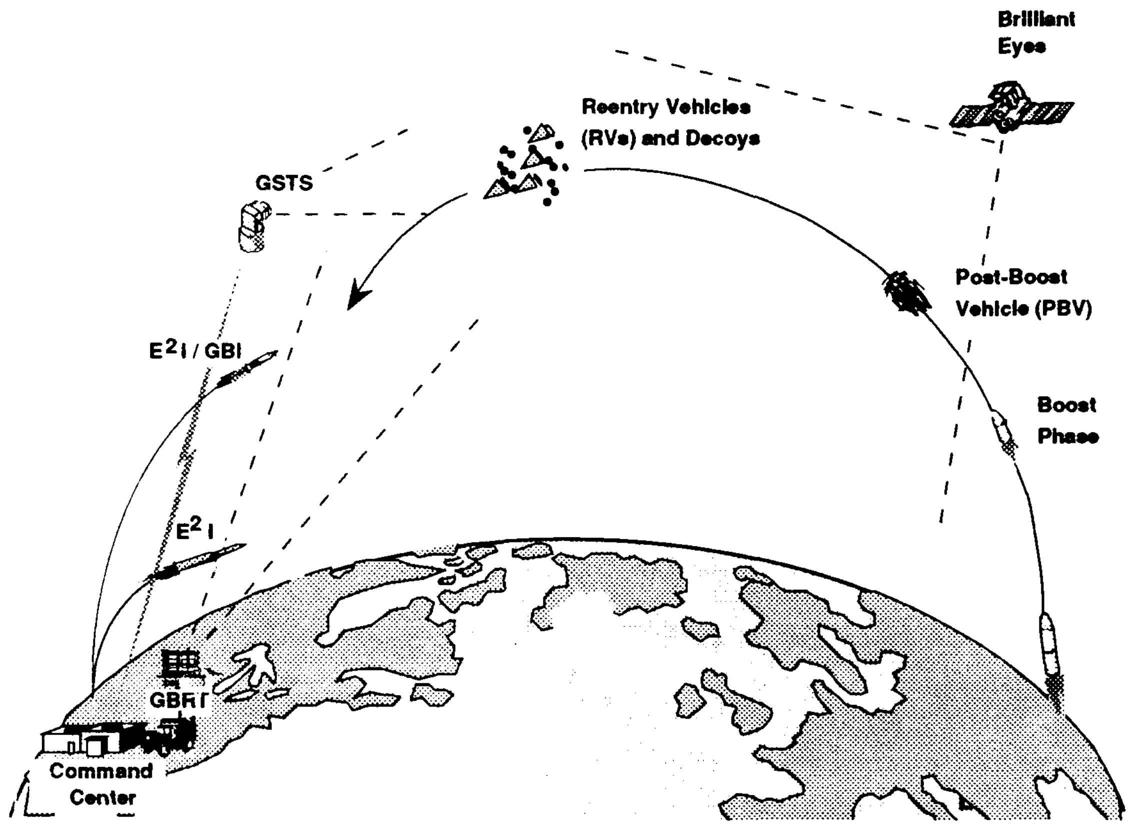
The 1,000 or so BPs needed for GPALS would cost approximately $10 billion (in constant 1988 dollars), including research and development, procurement, and launch costs. If additional BPs are required to respond to more stressing future threats, the subsequent BPs would be less expensive. For example, deploying an additional 1,000 BPs would cost an additional $2.8 billion (in constant 1988 dollars), including launch costs.

2.3.3 U.S. Ground-Based Tier

The architecture for ground-based defense against strategic ballistic missiles is depicted in Figure 2-3. The ground-based architecture consists of a command center and a combination of Brilliant Eyes (BE) satellites, terminal phase ground-based radars (GBRTs), and terminal phase endo-exoatmospheric interceptors (E3I) and/or midcourse phase exoatmospheric ground-based interceptors (GBIs). An option also exists to add the ground-based surveillance and tracking system (GSTS) to the architecture. The Brilliant Eyes satellites are derivatives of the previous space-based surveillance and tracking system (SSTS) satellites, and the E^2I is a derivative of the previous high-endoatmospheric defense interceptor (HEDI). For planning purposes, we have estimated $22 billion (in constant 1988 dollars) for acquisition of approximately 750 ground-based interceptors and six ground-based radars, acquisition and launch of approximately 60 Brilliant Eyes, and acquisition of appropriate command and control for the ground-based tier.

If E^2Is are used, BEs would provide post-boost and midcourse surveillance, and GBRTs would support terminal intercepts. The BE satellite would track the PBVs, clusters of RVs, and, in some cases, individual RVs to provide the data to commit the E^2I. The GBRT would acquire, track, and discriminate the RVs and decoys in the late midcourse and terminal portions of their trajectories, providing kill assessment and additional target selections to the E^2I. If GBIs are used, either BE, GSTS, or some combination of each will be used to provide cluster tracks for the GBIs. GBIs may require GBRT for commit against short time of flight submarine-launched ballistic missiles (SLBMs), but this requirement remains to be validated as the program matures.

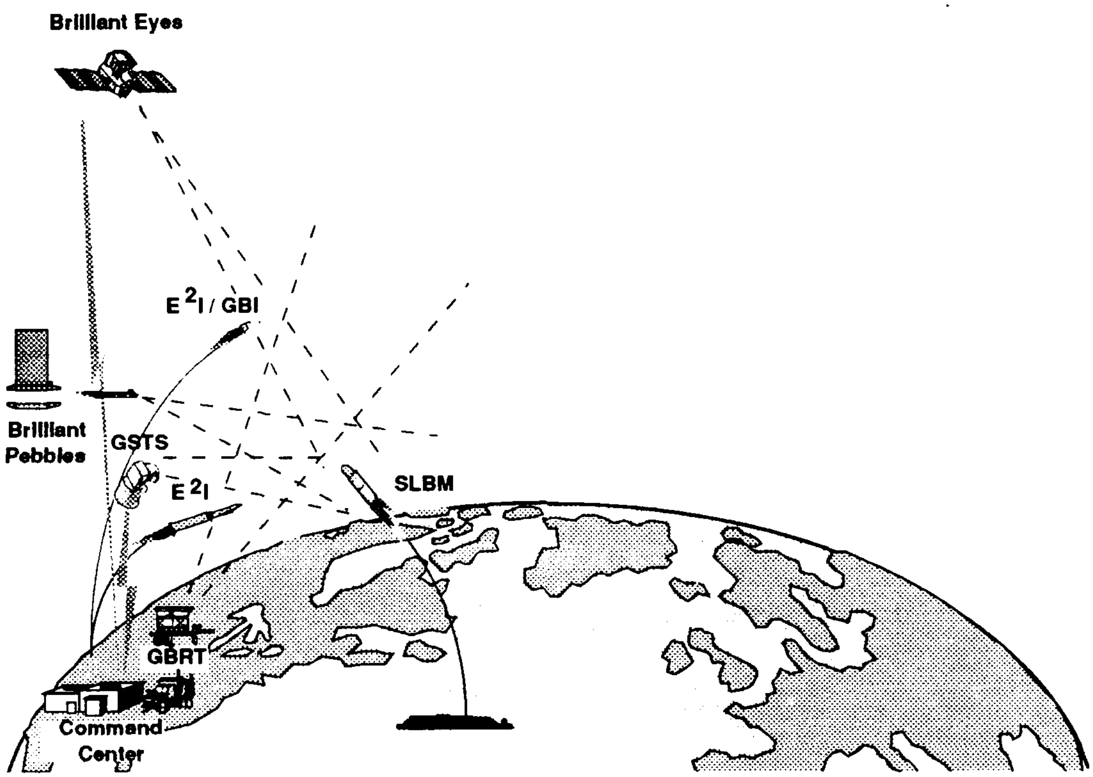
Figure 2-3
GPALS Architecture: Ground-Based Protection Against Strategic Ballistic Missiles



The choice between E^2I and GBI, or possibly whether to continue with both, will be made prior to full-scale development and will depend on the status of resolution of several issues at that time. Terminal defenses can benefit from the robust discrimination of RVs from decoys by atmospheric slowdown at the expense of requiring a more complicated interceptor that can withstand the heating and mechanical stress environment of operation in the upper atmosphere. Midcourse interceptors are inherently simpler and can be used much more flexibly throughout the long midcourse portion of the RV's flight trajectory. However, the defense must have confidence in its ability to discriminate RVs in midcourse in the expected threat environment.

The same elements discussed above could counter SLBM attacks. The functions of the elements would be very similar to those performed in defending against ICBMs. This capability is shown in Figure 2-4. However, an SLBM attack launched from a submarine very close to our coasts would constitute a more stressing threat, especially if flown on a depressed trajectory. While BP has effectiveness against such an attack, those RVs not engaged by BP would require intercept by ground-based interceptors to completely counter such an attack.

Figure 2-4
GPALS Architecture: Protection Against SLBMs



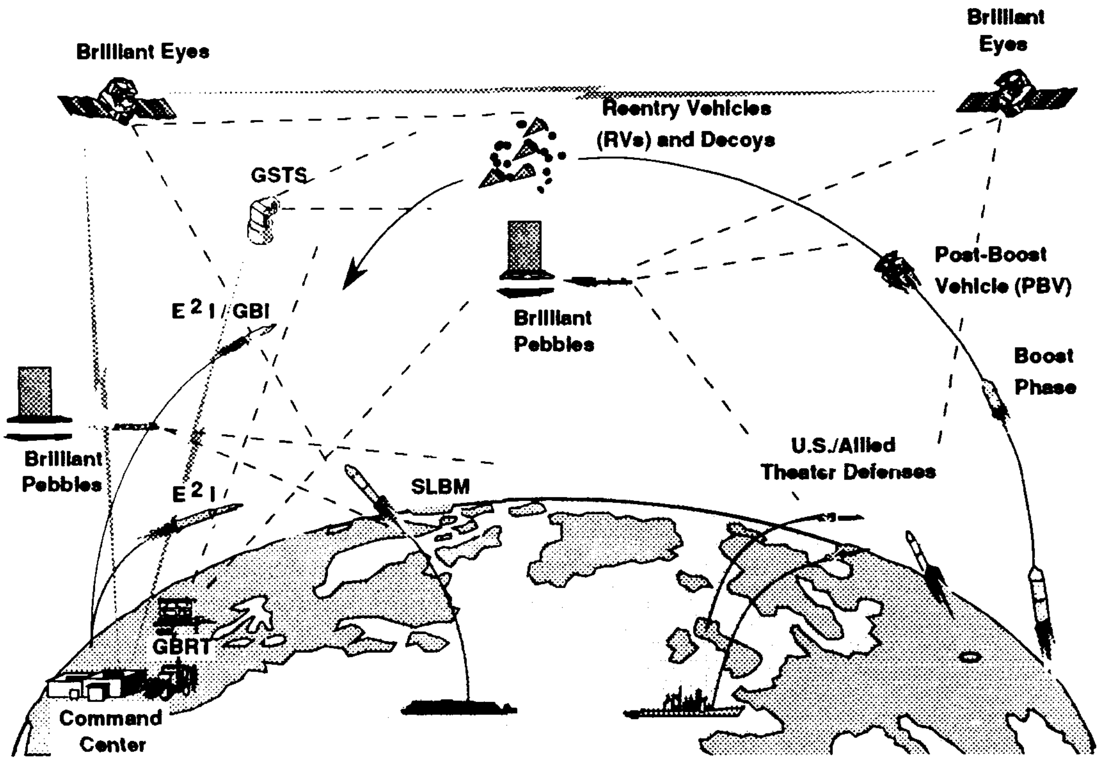
2.3.4 Summary

The complete GPALS system is portrayed in Figure 2-5. The effectiveness, survivability, and testability of this architecture are made possible in large part by the autonomy of its constituent parts. As described above, the total cost, in constant 1988 dollars, is approximately $41 billion.

2.4 Follow-on Systems

The selection of an evolutionary path to increasingly capable defenses beyond GPALS, should such a decision be made in the future to do so, will depend heavily on how the threat may change in the future, the mission desired, and the technologies available and their costs. The SDI Program is examining a variety of concepts for advanced weapon and sensor elements and is developing the required technologies to support them. Possible follow-on architectures have been analyzed for several years.

Figure 2-5
Complete GPALS Architecture



Preliminary observations suggest that the following approach could be adopted, if a decision is made to expand defense objectives beyond GPALS:

- Build on the GPALS infrastructure by increasing the concentration of and improving sensors, kinetic energy interceptors, and command and control.
- Add directed energy weapons, i.e., lasers (space-based or ground-based) and/or neutral particle beams, either sequentially or concurrently, to provide the capability to interactively discriminate RVs from decoys and other penetration aids during the midcourse phase of ballistic missile flight and/or to provide multiple capabilities to destroy boosters, PBVs, and RVs. Choices for missions, directed energy development timing, and directed energy types depend on the nature and timing of threat changes that require expansion beyond GPALS.

Another promising element under investigation is the hypervelocity gun for situations where high firepower is required. Also under study is the potential to combine the inherent sensor capabilities of different weapon platforms. This combination could yield a more complete picture of the battle, thereby enhancing the effectiveness of the architecture and possibly reducing certain technical requirements on the weapons.

2.5 Cost and Effectiveness of Limited Strategic Protection Systems

In the 1991 Defense Authorization conference report, the conferees requested that the Secretary of Defense provide in his annual report to Congress on SDI, in addition to the material previously required, "an evaluation of the cost and effectiveness of a limited strategic defense system, both with and without regard to ABM Treaty limitations, that could provide protection against accidental, unauthorized, or deliberate terrorist/Third World threat ballistic missile attacks of limited scope." The following discussion responds to the conferees' request in the context of the President's call for a refocused SDI Program aimed at providing global protection against limited ballistic missile strikes.

2.5.1 ABM Treaty Background and Evaluation Definitions

The conference report refers to evaluation of a limited protection system both with and without regard to Anti-Ballistic Missile (ABM) Treaty limitations. The conference report does not identify what area would be protected by a limited system. The ABM Treaty prohibits deployment of all ABM systems except certain types that are explicitly identified. The Treaty allows deployment of a fixed land-based, traditional ABM system (consisting of ABM interceptor missiles, ABM launchers, and ABM radars) in the vicinity of a party's national capital or in the vicinity of a party's field of ICBM silo launchers.

Continuing architectural analysis is being performed in the context of the GPALS objective. However, in addressing the conferees' questions regarding systems constrained and not constrained by the ABM Treaty, we have also set aside the issue of "other physical principles." As amended by the 1974 Protocol, the ABM Treaty permits a single site deployment of 100 ABM interceptor missiles along with supporting ABM radars. In addition, the Treaty constrains deployment of ABM systems based on other physical principles. No determination has yet been made on whether or not SDI near-term defensive system concepts, such as the hit-to-kill GBI and E^2I interceptors and supporting sensors, are based on other physical principles. Notwithstanding this fact, these systems were used in the following evaluation of the cost and effectiveness of various Limited Protection System (LPS) concepts. This approach is consistent with the clarification provided by the Congress in the conference language accompanying the FY 1991 Authorization Act, which permits SDIO to fund the development of certain ground-based components under the LPS program element. It is also consistent with President Bush's November 5, 1990 statement accompanying the signing of the FY 1991 Authorization Act which, among other things, put forth his understanding that "the Congress did not intend that obligation of funds for the ground-based interceptors and sensors identified in the conference report on H.R. 4739 be dependent on a determination at this time that these systems are deployable under the ABM Treaty."

In order to have some basis for evaluating alternatives for providing this capability, it is necessary to discuss what we mean by protection. By ***protection***, we mean very effective defenses which afford high confidence capability to <u>defeat</u>

accidental, unauthorized, or deliberate ballistic missile attacks of limited scope, whatever the cause or source. This definition not only places a strong requirement on the number and quality of the interceptors to provide a high combined probability of kill, but also places very strong demands on the sensor and battle management systems that must "see" all parts of the threat with high confidence. Protection puts a premium on negating the warheads as far away and at as high an altitude as possible to minimize effects of "debris," a very serious concern for chemical, biological, and nuclear warheads, and, as we have seen in the Gulf War, even for conventional missiles that are not completely destroyed as a result of a successful intercept. A multiple-shot opportunity defense is essential to achieve the level of protection desired against attacks involving tens to a few hundred reentry vehicles.

It is also necessary to discuss the limited strike threats that such a system should be capable of negating. The scale of limited strikes depends on their source. For third world threats we might expect one to a few tens of warheads arriving within a short time. For a Soviet accidental launch, we might be concerned with the launch of a single ICBM having around 10 nuclear warheads or with the launch of a few such missiles. For an unauthorized launch, a reasonable expectation might be the launch of a regiment of ICBMs (e.g., 10 ICBMs with 10 warheads each) or of a full boatload of SLBMs (e.g., 20 SLBMs with 10 warheads each), launched within a short time. For the Soviet missiles, penetration aids could accompany the nuclear warheads. Missiles from some third world countries might have primitive penetration aids, or none at all.

2.5.2 Defense of the United States

We discuss here preliminary conclusions that have emerged from analyses still in process.

Ground-Based Defenses Only

It appears that six ground-based interceptor sites, including sites in Alaska and Hawaii, are necessary for near-100 percent coverage of the United States against the variety of threats. For very close-in SLBM attacks, it is possible that additional interceptor sites might be necessary. A deployment of several hundred ground-based interceptors per site would be necessary to provide protection against the full range of potential threats. Multiple shot opportunities per RV are necessary to provide the desired combined system probability of kill.

A single site with ground-based interceptors, while providing some protection against a few long-range ICBMs or SLBMs launched from the Soviet Union or waters nearby, is not able to protect the entire continental United States (CONUS) against the full range of plausible accidental or third world launches of even a single ballistic missile no matter where the single site is based. In addition, neither Alaska nor Hawaii can be covered by a CONUS-based defense. This limitation is due to the fundamental physics of how long it takes the interceptor to fly to where it is aimed versus how long the missile takes to get there. The limitation is especially evident for interceptor flyout against close-in SLBMs and depressed trajectory ballistic missiles. For example, a single site in the center of the country leaves both coasts unprotected against out-of-bastion submarines (i.e., not in the waters north of the United States and close to the Soviet borders). Even when kinematic coverage is feasible, a 100- interceptor single site can be overwhelmed by an unauthorized launch of a boatload of SLBMs or a regiment of ICBMs that saturate the 100-interceptor deployment.

Protection requires space-based tracking sensors such as Brilliant Eyes to cue and otherwise to support the ground-based interceptors and ground-based radars.

Ground-based radars, even long-range midcourse radars, are horizon limited (and therefore can not see lower-altitude targets at long range) and thus have difficulty against some classes of threats. Ground-based, probe-launched infrared sensors (i.e., GSTS) could significantly enhance the performance over radars alone for longer-range threats by seeing over the horizon, but they add little to performance against short-range threats due to timeline limitations.

Space- and Ground-Based Defenses

One key to high levels of protection is a multilayer defense with multiple-shot opportunities at each missile, post-boost vehicle, and RV warhead. The addition of space-based Brilliant Pebbles interceptors to the defense of the United States would provide the highly effective boost and post-boost intercepts against long-range missiles and additional shots in the midcourse against shorter-range missiles. This more robust space- and ground-based defensive system would reduce the requirement to accomplish multilayered defense from only ground sites. Also, the addition of the space-based Brilliant Pebbles interceptors to a ground-based defensive system significantly complicates the development of countermeasures.

Cost and Effectiveness

High-confidence layered defense of the continental United States, Alaska, and Hawaii against limited attacks can be achieved by either deploying a multiple-shot opportunity ground-based system or a two-layered space- and ground-based system. Preliminary analysis suggests comparable costs for the two types of systems. On the one hand, the space- and ground-based system would require development and deployment of Brilliant Pebbles and a ground-based tier. On the other hand, the all ground-based system would require development and deployment of more ground-based interceptors and associated sensors.

2.5.3 Global Defense

Brilliant Pebbles would provide continuous, "global" capability, always in position to respond to surprises and accidents, and, for rapid contingency deployments, to defend ports and airfields for arrival of forces, to reduce the deployed forces required, and to provide critical space-based sensor and command and control support. Brilliant Pebbles could provide broad area coverage for many areas at once. The equivalent coverage from surface-based defenses would be considerably more expensive. In concert with surface-based defenses deployed in theaters of operation, it would assure a multilayer defense to provide high-confidence ***protection*** against limited ballistic missile strikes.

Protection of the United States would be provided by Brilliant Pebbles and U.S.-deployed ground-based defenses. Protection of U.S. forces and U.S. friends and allies would be provided by Brilliant Pebbles and theater-deployed surface-based defenses. In addition, some defense of territory against longer-range threats where surface-based defenses are not deployed could be provided by Brilliant Pebbles. If provided solely by surface-based theater defenses, the cost of continuous worldwide coverage would be much higher.

2.5.4 Cost-Effectiveness at the Margin

In past years, when the focus of the SDI Program was deterrence of a massive intentional Soviet missile strike, the major issues were cost (affordability), military and operational effectiveness, and cost-effectiveness at the margin (CEATM), an important element of the so-called Nitze criteria. Because the focus required adoption of a phased deployment concept in order to maintain or increase system effectiveness against an increasingly responsive Soviet threat, CEATM was, among other things, necessary to provide incentives to the Soviets to move in the direction of a negotiated solution. As a result, SDIO pursued components and architectures that were inherently cost-effective at the margin.

During this earlier period, CEATM was consistently examined through a combination of red and blue costing analyses and force-on-force simulations. In that process, frequently referred to as the path-costing approach or methodology, advanced changes to the Soviet threat were postulated, designed, and costed, after which corresponding changes to the defense necessary to recover fully the original effectiveness were identified and costed. These procedures were monitored, evaluated, and refereed by an independent senior mediator group to ensure consistency and accuracy. For a wide variety of plausible scenarios, the ratio of increased offense costs to increased defense costs, which is our definition of CEATM, was consistently greater than unity, ranging from 1.5 to 7.5 in key cases.

For the new focus on the GPALS program, it will be necessary to review our treatment of CEATM. For example, the concept of incremental increases in force levels and costs associated with an unauthorized or accidental attack becomes less relevant. Moreover, when addressing ***protection***, vice deterrence, one logically focuses more intently on the value of the objects being protected and on defense *performance* and *affordability* rather than simple cost ratios for defenses vs. offensive ballistic missiles. To bring this point into focus, countering the Scuds in the recent Gulf War certainly cost more than the Scuds. It is hard to imagine anyone arguing that we should not have developed Patriot as a result. In the year ahead, SDIO will probe these issues in depth and come forward with a concept of CEATM appropriate for the new focus of the SDI Program.

2.5.5 Affordability

The total acquisition cost estimated for GPALS is $41 billion in constant FY 1988 dollars (or about $46 billion in constant FY 1991 dollars). As discussed earlier, the breakout of the research and development, procurement, and launch costs, in FY 1988 dollars, is:

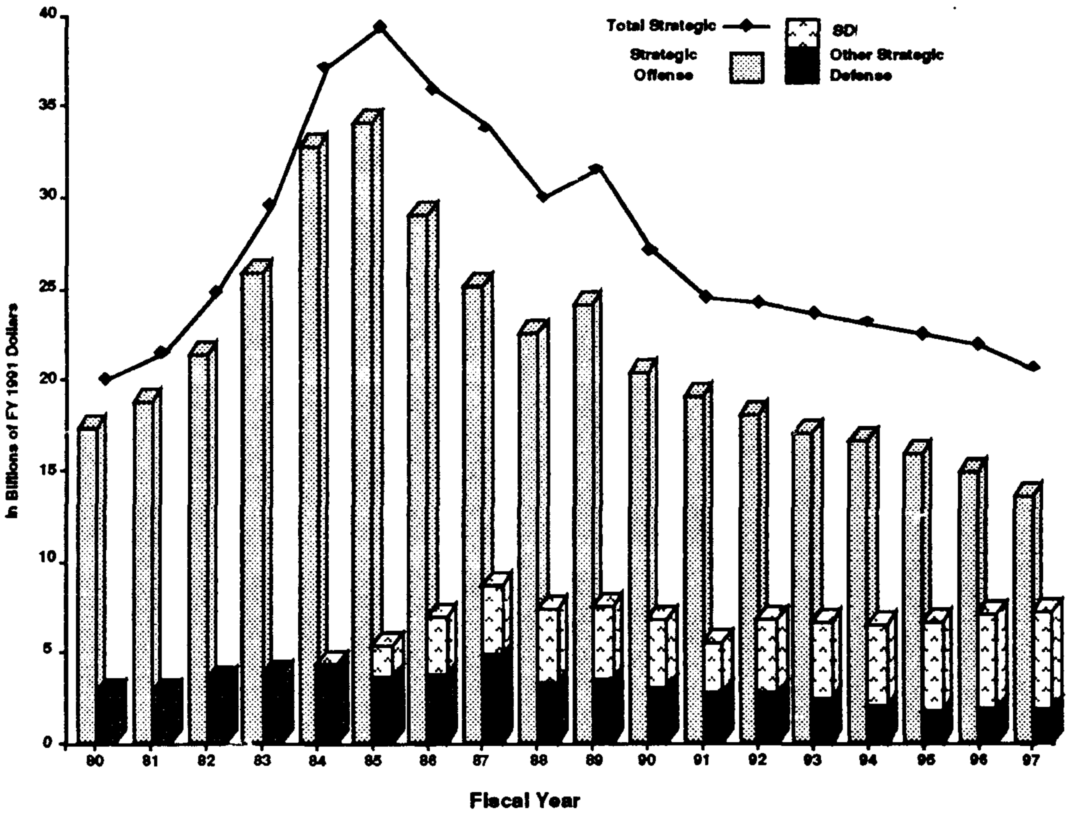
- $9 billion for ground-based theater defense components capable of concurrently defending one major area of operations at a time or multiple lesser contingency operations areas
- $10 billion for Brilliant Pebbles to provide the global overlay for defense of both the United States and theaters of operations (contingency operations)
- $22 billion for the ground-based interceptors and supporting sensors for the defense of the United States.

The strategic portion of the Department of Defense Future Year Defense Program for Fiscal Years 1992 to 1997 represents a rebalancing by the Department based on an assessment of strategic forces priorities for the 1990s. This funding is displayed in Figure 2-6. Despite a declining strategic budget over this period, the strategic portion of the GPALS program is fully funded and, at its peak, comprises only about 20 percent of the current strategic budget and less than two percent of total Department of Defense current funding.

2.5.6 Summary

A single-site, 100-ground-based-interceptor deployment does not provide coverage of the United States against the full range of limited ballistic missile attacks.

Figure 2-6
Past and Projected Strategic Programs Budget



With an all ground-based system, at least six sites in the United States would be necessary to provide near-100 percent kinematic coverage, including Hawaii and Alaska. At least several hundred ground-based interceptors at each site would be necessary to protect against the anticipated threats. Space-based, target-tracking sensors would be necessary to support the ground-based interceptors against the full array of threats.

Multiple-shot opportunity defense against limited ballistic missile attacks is necessary to provide protection. Deployment of Brilliant Pebbles could provide shot opportunities in the boost and post-boost phases and against non-decoyed threats in the midcourse phase.

The deployment of Brilliant Pebbles makes countermeasures much more difficult to implement. The use of Brilliant Pebbles would also allow a decrease in deployment of ground-based interceptors and associated sensors.

Preliminary analysis suggests that, for protecting the United States against a fixed threat, the cost for an all ground-based system is not greatly different than the cost of a system employing both ground-based and space-based interceptors.

However, Brilliant Pebbles also would provide global capability to GPALS, serving as the space-based overlay to deployed theater defenses and providing continuous global intercept capability at any location where surface-based defenses have not been deployed. If Brilliant Pebbles were not deployed, substantially increased funding would be required to deploy surface-based theater defenses and to provide critical cueing and warning support to those defenses. Indeed, global defensive coverage may not be affordable without Brilliant Pebbles.

Chapter 3

Research and Development Strategy

Chapter 3
Research and Development Strategy

This chapter describes the research and development (R&D) strategy of the revised SDI Program in light of the new focus on global protection against limited strikes (GPALS): specifically, the acquisition of a non-nuclear defensive capability to provide protection against accidental, unauthorized, or limited ballistic missile strikes by third world countries or the Soviet Union directed against U.S. power projection or forward deployed forces, U.S. friends and allies, and the United States itself. The new structure of the SDI Program also is explained, showing the relationship among projects, program elements, and possible deployments.

3.1 Strategy

The basic strategy is to reduce the cost and complexity and improve the performance and autonomy of the elements associated with a GPALS defense, while conducting research into promising systems and technologies that could achieve more ambitious mission objectives than GPALS, should a decision be made to do so. Because of the immediacy of the threat and because the technical challenge is less stressing, options to improve the effectiveness of U.S. surface-based theater and tactical ballistic missile defenses will be available by the mid-1990s. Concurrent with the development of improved theater missile defense options, high-priority research will focus on demonstrating the feasibility and affordability of Brilliant Pebbles (BP); surface-based interceptors; associated space- and ground-based sensors; and the necessary command, control, and communications to provide global protection against limited ballistic missile attacks. The combination of theater-based, U.S.-based, and space-based defenses is the GPALS system. These defenses could be enhanced if conditions warrant.

The strategy explicitly recognizes the security environment described earlier—U.S. plans to develop ballistic missile defenses are in response to the proliferation of ballistic missile technology in the third world, as well as the continuing Soviet threat, particularly with respect to unauthorized or accidental attack.

The strategy must address key technology issues involving GPALS sensors, interceptors, and command and control. It is also extremely important that credible cost estimates and schedules be developed for R&D as well as production of a GPALS system, should a deployment decision be made.

Parallel research, technology development, and support activities will focus on finding cost-effective solutions to current development challenges. Examples would include possible future sensor and interceptor block improvements for GPALS. These activities will also develop new kinetic or directed energy follow-on capabilities; acquisition, tracking, and pointing technology; and battle management, command, control, and communications (BM/C^3) technology to provide options to enhance defense performance in the 21st century.

Major decision points to measure progress of the GPALS program will be established. These decision points will occur regularly and as required to support SDI Program planning, programming, and budget execution, and to support replanning to accommodate national defense requirements.

The overall strategy encompasses both the acquisition of the defensive capabilities described above and the research and support effort. Each aspect of the strategy is discussed in the following sections.

3.1.1 Acquisition Strategy

The acquisition strategy is the overarching blueprint for planning, directing, and managing the GPALS program to achieve its objective within the resource constraints imposed. This strategy, centered on the GPALS system, defines the cost goals and program master schedule. More specifically, the near-term strategy is to refine performance requirements through architecture definition studies and complete development of space-based interceptors and sensors, ground-based interceptors and associated ground- and space-based sensors, and BM/C^3 to support the schedule outlined below.

Improvements in defenses against theater and tactical ballistic missiles armed with conventional, chemical, biological, or nuclear weapons could begin with Patriot upgrades. These would be followed by developments such as the Extended Range Interceptor (ERINT), Arrow (and an Arrow follow-on known as ACES), and Theater High Altitude Area Defense (THAAD), as well as possible sea-based and aircraft-based interceptors. All of these elements would operate with associated sensors (e.g., the advanced contingency theater sensor known as ACTS) and appropriate theater command, control, and communications. Cueing from space-based sensors would enhance these defenses.

Demonstration and validation work for concepts that are part of the Tactical Missile Defense Initiative (TMDI) is already under way. Full-scale development is planned to begin in FY 1992 for the Patriot upgrades, and in FY 1993 for ERINT, THAAD, and appropriate sensors.

The capability to protect the United States against accidental, unauthorized, or deliberate attacks by small numbers of ballistic missiles will be available in the late 1990s. Space-based BP interceptors and the endo- and exoatmospheric ground-based interceptor (E^2I) and/or the ground-based exoatmospheric interceptor (GBI) would be employed, along with the appropriate sensors (i.e., Brilliant Eyes [BE], ground-based terminal radar [GBRT], and possibly the ground-based surveillance and tracking system [GSTS]). (Funds are budgeted for full-scale development and deployment of E^2I. If it is decided to proceed with both into full-scale development, additional funding will be required in the FY 1995 time period.)

Brilliant Pebbles, the Command Center (CC), E^2I, GBI, BE, GSTS, and GBRT are being developed in parallel, with a goal of supporting deployment in the late 1990s. Development and deployment of a theater version of the GBRT (the TMD-GBR) is planned by the mid-1990s. The TMD-GBR will constitute a "module" of the U.S.-based version and will enable later development of the GBRT at low risk.

A decision on the specific elements and numbers of elements required to meet the GPALS mission objective will be made prior to full-scale development. At that time, an exact architecture, detailed performance requirements, more precise cost estimates, and a master acquisition schedule will be established. Current acquisition cost estimates for GPALS are approximately $41 billion in constant FY 1988 dollars (or about $46 billion in constant FY 1991 dollars). This estimate consists of about $9 billion for theater missile defenses and about $32 billion for the global coverage and U.S.-based defenses. Research and development and procurement funding have been budgeted to provide for the availability of theater defenses beginning in the mid-1990s (slightly earlier for Patriot derivatives). The remainder of GPALS could be operational beginning in the late 1990s.

The program just described is dollar limited, not technology limited. It could be accelerated with greater near-term expenditures while keeping the overall program costs approximately the same. The $41 billion acquisition cost estimate for GPALS is compared to previous acquisition cost estimates for a ballistic missile defense system in

Figure 3-1. These data illustrate how the costs of the previous Phase I defense declined as the estimate of the threat evolved and improvements were made to the architecture due to new technology. They also show that the GPALS system, including an effective theater missile defense component, is currently estimated to cost about 20 percent less than the cost of Phase I.

Figure 3-1
System Acquisition Cost Evolution

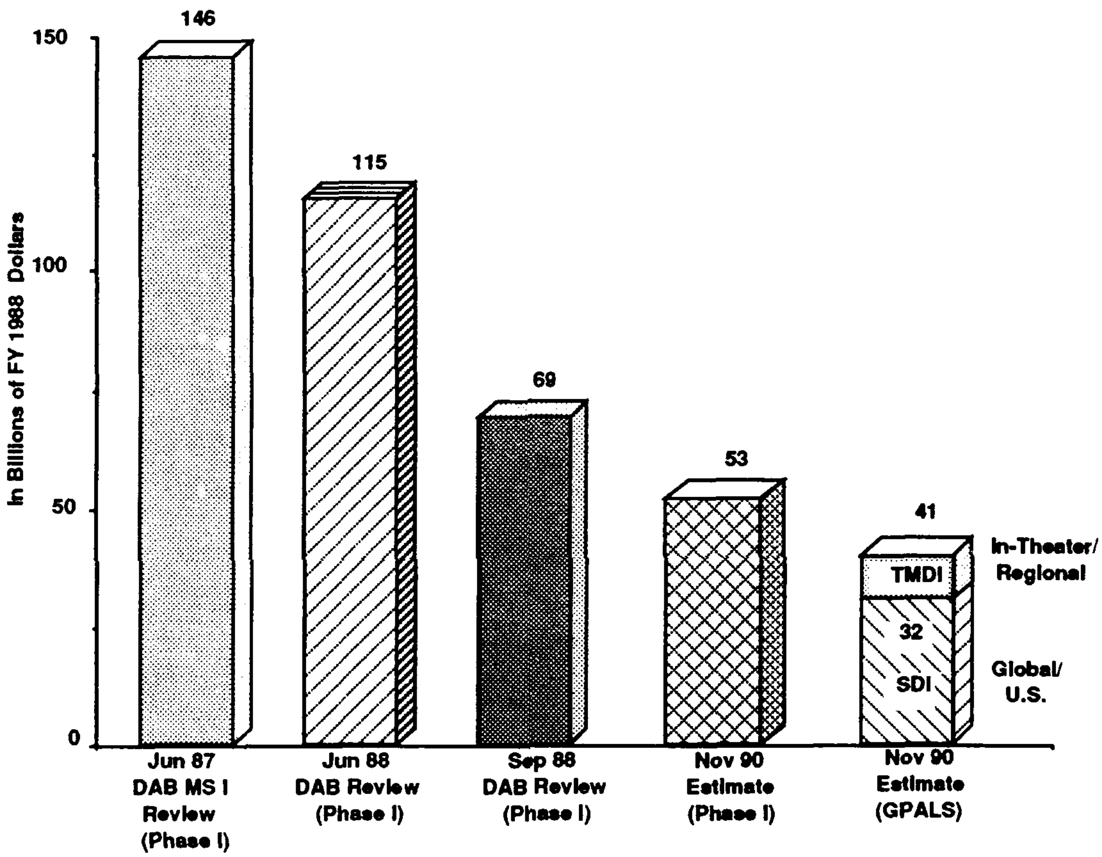


Figure 3-2 illustrates past and plann^d research and development investments in near-term space- and ground-based defensive systems. Space-based estimates include investments in developing specific space-based weapons, such as SBI and Brilliant Pebbles, and any supporting sensor and command and control elements. Likewise, ground-based estimates include R&D investments in ground-based weapons such as GBI and E^2I and their supporting sensor (such as GBRT, Brilliant Eyes, and GSTS) and command and control elements.

These estimates also include the respective technology base efforts that directly support the dev.:opment of space- and ground-based systems by providing timely enabling technology and pressing the state of the art to permit design by "interpolation" rather than "extrapolation." The SDI acquisition :nanagement plan provides for the integration of these technology programs with systems development schedules to ensure that critical technology is available at the least possible risk and cost, and when needed.

Figure 3-2
Space- and Ground-Based Investments
(In Then-Year Dollars)

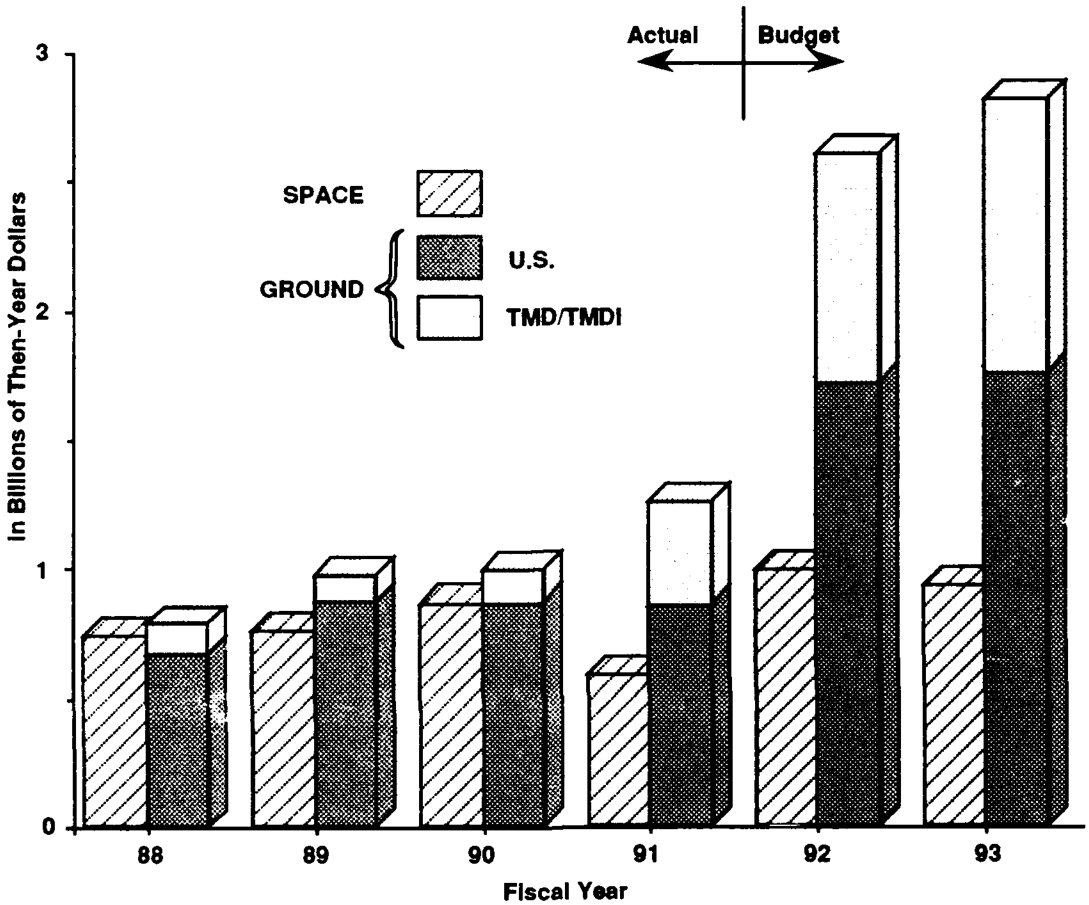


Figure 3-2 shows that, prior to FY 1991, the space- and ground-based defense systems were supported equally. In FY 1991, the investment in the space-based system (now Brilliant Pebbles) was substantially less than in previous years, reflecting the fact that Brilliant Pebbles, as an autonomous system, permitted an architectural simplification and removal of BSTS and SSTS from the architecture for the space-based system. At the same time, investments in ground-based systems increased due to the additional funding for theater missile defenses.

Figure 3-2 also demonstrates that the FY 1991 investment in ground-based systems increased somewhat while that in space-based systems (Brilliant Pebbles) was reduced by one-third. The FY 1992 and FY 1993 budget requests would restore space-based system (Brilliant Pebbles) investments to the FY 1990 level, while doubling the investment in ground-based systems. (Note that Brilliant Eyes is a space-based sensor which is an integral part of the ground-based U.S. defensive system.) This Fiscal Years 1992 to 1993 investment plan is consistent with the 3:1 (ground:space) total investment strategy for GPALS defensive systems.

3.1.2 Strategy for Follow-on Systems and Research and Support Activities

The technology research strategy is to preserve a strong technology base, consistent with funding constraints, to serve as a continuous source of support for the acquisition component of the SDI Program. The technology base will be exploited continuously for innovations that will increase the effectiveness of GPALS or reduce its cost and development risk.

The technology base will support four categories of research: (1) projects to support or upgrade the GPALS system, (2) projects that support candidate elements of follow-on systems, (3) projects to resolve key technology issues applicable to several ballistic missile defense elements, and (4) projects that encompass generic, long-term research that promises high payoff, albeit at high technical risk.

- The first category will influence the technical specifications of the elements that make up the GPALS architecture. It will include an extensive array of research that includes: signal processing; optical, laser, and radar sensing; phenomenology; interceptor propulsion; and guidance and control.
- The second category will focus on advanced concepts, such as the hypervelocity gun and other advanced kinetic energy concepts, and directed energy technologies.
- The third category of technology research will contain projects identified as key technologies. These research efforts will involve near- and long-term survivability, lethality, and target hardening; space power; space transportation; and materials and structures investigations.
- The fourth category contains SDIO oversight of basic research in the Innovative Science and Technology project that seeks new and innovative approaches to ballistic missile defense. Also, the Small Business and Innovative Research project will pursue work in diverse fields such as computers, sensors, semiconductors, and optics.

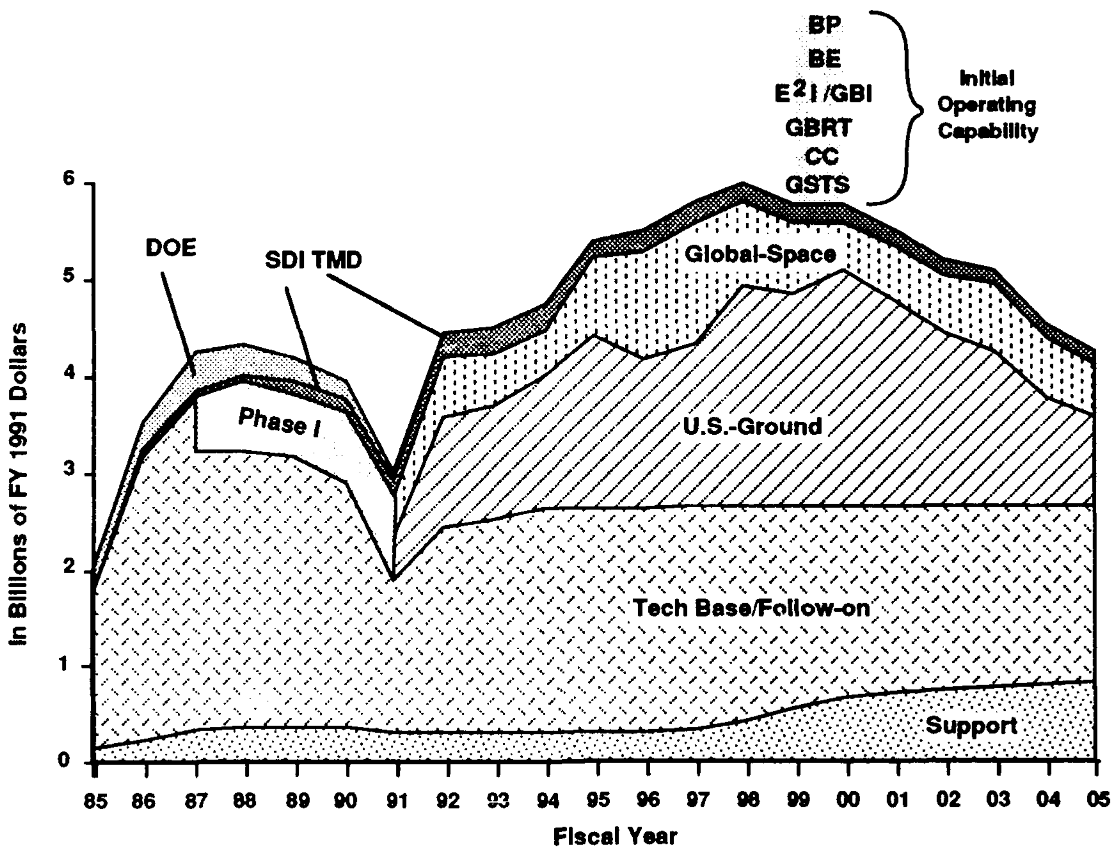
3.1.3 Top-Level Funding Profiles and Schedules

A time-phased funding profile that depicts past and current estimated levels of expenditure for the SDI Program over the 21-year period from 1985 through 2005 is shown in Figure 3-3. Department of Energy (DOE) funding for the SDI Program is shown for FY 1985 through FY 1990. The amounts labeled SDI TMD are discussed below.

As noted above, our investment strategy calls for two to three times as much on the ground-based system as on Brilliant Pebbles. The figure also indicates that initial operational capabilities are expected in the late 1990s for space- and U.S.-based elements of the GPALS system.

Figure 3-3 reveals that, because of budget cuts imposed by Congress over the past 3 years, the FY 1991 technology base was reduced to less than the level of the technology base in FY 1985, the first SDI appropriation. In effect, the President's FY 1992 budget request, if approved, would return the SDI constant dollar funding level to that appropriated by the Congress in FY 1988. Our outyear budgets project a relatively constant funding level for the technology base, follow-on research, and support elements of the SDI Program. This level is about $2.5 billion annually in constant 1991 dollars. The program set forth in Figure 3-3 has been balanced with

Figure 3-3
SDI Top-Level Funding Profiles and Schedules



respect to near-term and far-term technologies. In particular, the follow-on technologies are proceeding at a pace appropriate for their current maturity and the time frame when they might be needed to counter potential future threats.

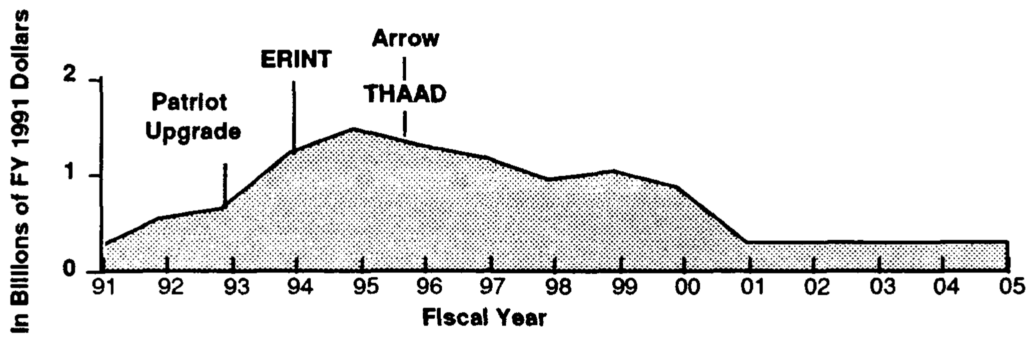
The peak annual funding requirements occur in the late 1990s, where a level of about $6 billion (in FY 1991 dollars) is reached. This amount represents about 2 percent of the current U.S. defense budget and about 20 percent of the amount currently spent on strategic programs.

Because GPALS incorporates consideration of regional protection against theater and tactical ballistic missiles, the thrust of certain SDI program areas (e.g., Systems Engineering and Integration, Command and Control, Architecture Studies) has been modified to address more fully theater missile defense (TMD) requirements and integration with strategic defenses.

During the FY 1991 budget process, Congress directed the Secretary of Defense to centralize and accelerate theater and tactical ballistic missile defense efforts with a view toward fielding a system "as soon as technologically and fiscally feasible." Management responsibility for the resulting program, the Tactical Missile Defense Initiative, was assigned to the SDIO by the Deputy Secretary of Defense.

Figure 3-4 depicts the funding requirements and the timing of initial operational capability for this program over the 15-year period from FY 1991 to FY 2005. Peak funding requirements of approximately $1.5 billion occur in FY 1995.

Figure 3-4
TMDI Top-Level Funding Profiles and Schedules



TMDI budgets and expenditures are accounted for by a new program element, which is separate from the five SDI program elements established by the Congress during the FY 1991 budget cycle. Pre-FSD TMDI efforts are categorized in the Advanced Technology Development Budget Activity (BA), within the Research, Development, Test and Evaluation (RDT&E) Major Defense Program. FSD efforts will move to BA 4, Tactical Programs, also within the RDT&E Major Defense Program. Production of theater/tactical defenses would be accomplished under the General Purpose Forces Major Defense Program.

Although funding for this new program is accounted for separately, TMDI efforts are complemented by and are fully integrated with ongoing SDI TMD efforts.

3.2 Impact of Funding Constraints

Congressional actions have produced approximately $7 billion in budget cuts over the past several years, resulting in years of delay, a number of project cancellations, and premature down-selects between competing technologies. The $1.6 billion cut in FY 1991 funding led to at least a 2-year delay. If this trend is not reversed in FY 1992, it will not be possible to deploy ballistic missile defenses for the United States in this century.

The President's budget makes it possible to deploy defenses to protect the United States by the end of this decade. It should be emphasized that the President's budget was constructed to be affordable. The pace of the program is constrained by dollars, not technology. If funding were adequate to constrain progress only by the pace of technology, then the initial operational capability dates could be accelerated.

3.3 Program Structure

During the FY 1991 budget process, the Congress established five program elements (PEs) for the SDI Program:

- Phase I Defenses (0603214C)
- Limited Protection Systems (0603215C)
- Theater and Anti-Tactical Ballistic Missile Defenses (0603216C)
- Follow-On Systems (0603217C)
- Research and Support Activities (0603218C).

For each PE, the Congress set fiscal limits for FY 1991 and provided both general and specific guidance regarding the activities that could be conducted and funded within each PE. Efforts that directly, or potentially, support GPALS can be found in most, if not all, PEs.

The current PE structure was devised by the Congress in the context of program objectives that have now changed fundamentally. Consequently, the potential for confusion and misunderstanding has been increased. The following paragraphs present the rationale followed by SDIO in assuring that the current program is consistent with the FY 1991 Defense Authorization Act. To minimize problems in the future, SDIO and the Department of Defense stand ready to work with the Congress to devise a more appropriate structure for the FY 1992-1993 budget in light of the advent of GPALS.

The reassignment of the 60-plus project management agreements (PMAs) to the new PEs could not be accomplished on a one-for-one basis, even though the PE definitions were reasonably broad. Some PMAs had to be split between two or more PEs to comply with both fiscal and programmatic Congressional direction. This outcome is reflected in the project funding summaries and explained in the appropriate project descriptions.

With regard to the new PEs, one source of potential misunderstanding needs to be discussed. The PE titles selected by the Congress could suggest specific independent efforts within the several PEs. For instance, the title "Phase I Defenses" could suggest that the activities within this PE are focused exclusively on development and deployment of a system that would meet the Joint Chiefs of Staff requirements for a Phase I Strategic Defense System. However, the projects within the Phase I Defenses PE need to be viewed within the context of the PE definition provided by the Congress. That definition provides for efforts directed at developing defenses against a large-scale Soviet attack. However, it also includes "*an early deployment option to counter limited attacks, including accidental, unauthorized, or deliberate launch of a small number of ballistic missiles.*" Therefore, SDIO is directing the activities under the Phase I PE toward deployment against limited strikes with the full Phase I deployment as a growth option. Furthermore, while the specific sensor, weapon, and command and control projects within the Phase I Defenses PE may provide the "skeleton" of an architecture to meet Phase I requirements, there are competing concepts and critical, supporting projects being conducted within the other PEs that might be deployed to meet the Phase I requirement should a future decision be made to do so.

With regard to the Limited Protection Systems (LPS) PE, the potential for misunderstanding is even greater. The term LPS suggests an interest in limited protection—which is not the case; full protection against limited attacks is the objective. Furthermore, LPS has often been assumed to mean a ballistic missile defense system that complies with the 1972 Anti-Ballistic Missile (ABM) Treaty. However, the defining Congressional language for this PE clarifies that, for "purpose of planning, evaluation, design, and effectiveness studies, such programs, projects and activities may take into consideration both the current numerical limitations of the 1972 ABM

Treaty *and modest changes to those numerical limitations*" [emphasis added]. Thus, in fact, the Congress acknowledged that an effective LPS could require deployment levels beyond the limits of the ABM Treaty. The issue of whether modern ground-based interceptors and probes such as GSTS are "based on other physical principles," which would prohibit deployment unless the ABM Treaty was modified, was addressed by language within the FY 1991 Authorization Conference Report specifically permitting the use of LPS PE funding to support the GBI and GSTS projects. When the President signed the National Defense Authorization Act for Fiscal Year 1991, the President stated,

> I sign this Act with the understanding that the Congress did not intend that obligation of funds for the ground-based interceptors and sensors identified in the conference report on H.R. 4739 be dependent on a determination at this time that these systems are deployable under the ABM Treaty.

It should also be understood that the GBI may not ultimately be the interceptor of choice. There is, in fact, to be a competition between the E^2I (funded in the Phase I Defenses PE) and GBI interceptors to determine whether one or the other, or both, will be carried into full-scale development for use in GPALS. The proposed budget provides funding for demonstration and validation of both the GBI and E^2I, but funding for full-scale development and deployment has been budgeted only for E^2I. If there is a later decision to carry both systems into full-scale development, some additional funds will be required for the ground-based defensive system in the mid-1990s.

The midcourse discrimination problem must be resolved before the GBI could be judged effective against penetration-aided threats. The E^2I is a terminal layer interceptor that finesses the midcourse discrimination issue by using the atmosphere to discriminate between decoys and reentry vehicles. The E^2I key technical challenge to be met during demonstration and validation is to cope with atmospheric heating during the critical intercept stage. If both technical problems are solved, development and deployment of a mix of GBIs and E^2Is may be desirable; in this case, additional funds would probably be needed in the mid-1990s.

Thus, final selection of GPALS elements will depend on the resolution of various technical issues (as illustrated with the above discussion of the GBI and the E^2I), as well as on the cost and effectiveness of the competing elements. In the future, ballistic missile defense system architectures may evolve and require the introduction of new elements or the reallocation of functions among existing elements. Additionally, the proportions in which a single project is divided among the five program elements may vary from year to year due to a changing level of support provided to other projects within the PEs. The projects being pursued within the five new PEs, and the proportion in which certain projects are allocated among the PEs, therefore, may change in future budgets.

The relationship among GPALS functional areas and SDI Program support activities, projects, program elements, and possible deployment phases is shown in Figure 3-5. Chapter 4 discusses the progress and plans of key projects. The Appendix provides a discussion of all the projects in greater detail.

Figure 3-5

Correlation of GPALS Functional Areas and SDI Program Support Activities With Projects, Program Elements, and Possible Deployment Phases (1 of 3)

GPALS Functional Areas and SDI Program Support Activities	Projects	FY 1991 Funding Program Element: Phase I	LPS	TMD	Follow-On	Research & Support	Possible Deployment Phases
Sense an Attack	1101 Passive Sensors	●					
	1102 Microwave Radar Technology	●					
	1103 Laser Radar Technology	●			●		
	1104 Signal Processing	●					
	1105 Discrimination	●	●				
	1106 Sensor Studies and Experiments	●	●	●			
	1601 Innovative Science and Technology					●	
	1603 New Concepts Development				●		
	2102 Space Based Sensor	●					GPALS
	2103 Ground-Based Surveillance and Tracking System		●				GPALS
	2104 Ground Based Radar	●		●			GPALS
	3111 Surveillance Engineering	●	●				
	3307 Midcourse Experiment		●	●			
Control, Operate, and Integrate (BM/C3)	1403 Computer Engineering					●	
	1405 Communications Engineering				●	●	
	1601 Innovative Science and Technology					●	
	1603 New Concepts Development				●		
	2300 Command Center	●	●	●			GPALS
Engage and Destroy (Strategic Interceptors)	1201 Interceptor Component Technologies				●		
	1202 Interceptor Integration Technology	●			●		
	1204 Interceptor Studies and Analysis				●	●	
	1601 Innovative Science and Technology					●	
	2201 Space-Based Interceptor		●				
	2202 Ground-Based Exoatmospheric Interceptor Development		●				GPALS
	2203 HEDI (Endo/Exoatmospheric Interceptor [E^2I])	●		●			GPALS
	2205 Brilliant Pebbles (also has a sensing function)	●					GPALS

Figure 3-5

Correlation of GPALS Functional Areas and SDI Program Support Activities With Projects, Program Elements, and Possible Deployment Phases (2 of 3)

GPALS Functional Areas and SDI Program Support Activities	Projects	FY 1991 Funding Program Element					Possible Deployment Phases
		Phase I	LPS	TMD	Follow-On	Research & Support	
Engage and Destroy (Theater Interceptors)	1205 Foreign Technology Support			●			
	1206 Theater Interceptors			●			GPALS
Engage and Destroy (Follow-on Advanced Concepts)	1203 Hypervelocity Technology				●		Follow-on
	1301 Free Electron Laser Technology				●		Follow-on
	1302 Chemical Laser Technology				●		Follow-on
	1303 Neutral Particle Beam Technology				●		Follow-on
	1304 Nuclear Directed Energy Technology				●		
	1305 Acquisition, Tracking, Pointing, and Fire Control Technology				●		
	1601 Innovative Science and Technology					●	
	1603 New Concepts Development				●		
	2204 DEW Concept Definition				●		
Support With Key Technologies	1501 Survivability Technology	●	●	●		●	
	1502 Lethality and Target Hardening			●		●	
	1503 Power and Power Conditioning				●	●	
	1504 Materials and Structures				●	●	
	1505 Launch Planning, Development, and Demonstration	●			●		
	1601 Innovative Science and Technology					●	
	1603 New Concepts Development				●		
	4102 Sandia Construction				●		
Perform System Analysis, Engineering, and Testing	1701 Launch Services	●			●		
	1702 Special Test Activities					●	
	2304 System Software Engineering	●	●				
	3102 System Engineering	●	●	●		●	
	3104 Integrated Logistics Support					●	
	3105 Producibility and Manufacturing					●	
	3107 Environment, Siting, and Facilities					●	

Figure 3-5
Correlation of GPALS Functional Areas and SDI Program Support Activities With Projects, Program Elements, and Possible Deployment Phases (3 of 3)

GPALS Functional Areas and SDI Program Support Activities	Projects	FY 1991 Funding Program Element					Possible Deployment Phases
		Phase I	LPS	TMD	Follow-On	Research & Support	
Perform System Analysis, Engineering, and Testing (Cont'd)	3108 Operational Environments					●	
	3109 System Security Engineering	●	●				
	3110 Survivability Engineering					●	
	3201 Architectures and Analysis					●	
	3202 Operations Interface					●	
	3203 Intelligence Threat Development					●	
	3204 Countermeasures Integration					●	
	3205 Theater Missile Defense (TMD) Special Studies			●			
	3206 System Threat					●	
	3207 System Architecture	●	●	●			
	3302 System Test Environment					●	
	3303 Independent Test and Evaluation (T&E) Oversight and Assessment					●	
	3304 Test and Evaluation Resources					●	
	3305 Theater Test Bed			●			
	3306 Advanced Research Center					●	
	3308 Systems Simulator, Level II	●	●				
	4302 Technology Transfer					●	
	4305 Miniaturized Accelerators for PET				●		
Manage	4000 Operational Support Costs					●	

Chapter 4

Significant Progress and Plans

Chapter 4
Significant Progress and Plans

The SDI Program continues to make significant technical progress across a broad range of technologies that include both near- and longer-term applications. This chapter addresses the significant technical achievements that have occurred since last year's report and the plans of major SDI projects.

4.1 Global Protection Against Limited Strikes

This section discusses the studies related to the global protection against limited strikes (GPALS) system and the evolution of the system elements in the GPALS architecture. Also described are the progress and plans of the elements that comprise the space- and U.S.-based segments of GPALS as well as the underlying theater missile defense components.

4.1.1 Studies and Evolution of Elements

During 1990 several major studies of ballistic missile defense were performed within the Department of Defense. These studies helped form the basis for the GPALS approach. They also provided a basis for the evolution of some of the elements in the GPALS architecture.

Studies

An independent review of the SDI Program, conducted by Ambassador Henry Cooper, was completed in the spring of 1990. The Independent Review recommended increased emphasis on the Joint Chiefs of Staff requirement for high defense effectiveness against attacks of limited scope. Retention of both ground- and space-based elements was advocated for countering large-scale and limited attacks. It was recognized that a system that could provide protection against limited strikes also could constitute a first step toward meeting the Phase I objectives of defending against a massive Soviet attack. Continued emphasis on exploiting Brilliant Pebbles technology was urged along with infusion of the Brilliant Pebbles approach (autonomous operation; miniaturized, light-weight components; proliferated, distributed system) into ground-based interceptors and into sensor satellites.

In response to the Independent Review, a GPALS study was conducted by the Office of the Secretary of Defense. It examined the feasibility and contribution of layered defenses like GPALS against third world ballistic missiles and Soviet accidental or unauthorized limited strikes.

Also in response to the Independent Review, the Midcourse and Terminal Tiers Review (MATTR) was performed by the Strategic Defense Initiative Organization (SDIO) to address the intercept of reentry vehicles (RVs) in the midcourse and terminal layers with a view toward simplification, cost reduction, and increased effectiveness of Phase I. The scope included an examination of proliferated low-altitude sensor satellites and the application of Brilliant Pebbles concepts (e.g., miniaturization, autonomy, and proliferation) to ground-based defenses. The MATTR concluded that defenses should be built in an evolutionary manner, starting with protection against limited attacks. The elements recommended for defending against limited attacks were Brilliant Pebbles, an endoatmospheric and exoatmospheric interceptor known as E^2I, a ground-based terminal radar (GBRT), Brilliant Eyes (BE), and a command center. Additionally, for large-scale threats, and depending on progress in solving the midcourse discrimination problem, a ground-based exoatmospheric interceptor (GBI) with lower cost than E^2I should be added along with a ground-based surveillance and tracking system (GSTS).

Finally, there was a study known as TPALS, for theater protection against limited strikes. Commissioned in the early stages of Desert Shield, this study examined options for rapid deployment of a TPALS capability to answer the questions: What if the President wanted something now? What could we have as soon as technically feasible? The conclusions were that Patriot is the only system currently deployable, and Patriot upgrade is the only option for 1992 to 1994. However, by 1995 to 1996, given a national priority, the Theater High Altitude Area Defense (THAAD) and complementary Extended Range Interceptor (ERINT) could be available.

The results from those studies were synthesized, as the FY 1991 budget cuts were assimilated and as the outyear budget was planned. In particular, the TPALS study was used as a basis for formulating the Tactical Missile Defense Initiative (TMDI) acquisition strategy discussed in Chapter 3. However, the MATTR recommendations were not completely followed.

For example, MATTR would have deferred GBI/GSTS development in favor of E^2I, primarily because of anticipated difficulty in resolving the midcourse discrimination problem. After review of the MATTR recommendations, the SDIO Director decided to continue GBI/GSTS on a concurrent development path with E^2I until tests over the next several years permit an informed evaluation of our ability to solve the difficult midcourse discrimination problem. If the results of these tests are favorable, a GBI/GSTS system could be less expensive than an E^2I system.

The MATTR also called for Brilliant Eyes to cue Brilliant Pebbles for midcourse intercepts for follow-on Phase I operations. Instead, the Director, SDIO decided to focus Brilliant Pebbles on its autonomous capability—boost/post-boost phase intercepts against MIRVed Soviet missiles and midcourse intercepts against single RV missiles, which include those from all third world countries for the foreseeable future. If it turns out that Brilliant Eyes can provide a state vector sufficient to localize a single threat RV in a cloud of decoys, that information could, of course, be used by Brilliant Pebbles or the ground-based interceptor of choice. Future block changes to Brilliant Pebbles could also enhance its midcourse discrimination and intercept capability.

Advanced interceptors must be integrated with advanced sensors and command and control capabilities to create the complete GPALS system. In early 1991 a detailed architecture integration study for GPALS was begun. This study builds on the above-mentioned studies to develop more specific and detailed definition of the elements and complete description of the battle management, command, control, and communications (BM/C^3), along with the performance, schedule, and cost of a baseline system. Alternative system elements will be analyzed in terms of performance, schedule, cost, and risk trade-offs. The entire study is expected to be completed by the end of FY 1991.

Evolution of Elements

Several of the elements in the GPALS architecture have new names but are derivatives of elements discussed in last year's Report to Congress on the SDI. These elements are the BE, a derivative of the space-based surveillance and tracking system (SSTS); the GBRT, a derivative of the ground-based radar; and the E^2I, a derivative of the high endoatmospheric defense interceptor (HEDI). The remaining elements—Brilliant Pebbles (BP), GBI, GSTS, and command center—are relatively unchanged from their descriptions in last year's report. Therefore, only the BE satellites, the GBRT, and the E^2I will be described below.

An artist's concept of the BE satellites compared to the SSTS is provided in Figure 4-1. BE satellites offer increased survivability through proliferation of smaller, lighter, and cheaper platforms. In addition to capitalizing on SSTS technology, it also takes advantage of BP and GSTS technology. The BE sensors are less capable than those of the SSTS, but the satellite orbits at lower altitudes, thus putting it closer to the targets. This closer proximity provides greater possibilities for exploiting "bus-watching" discrimination procedures.

Figure 4-1
Comparison of Brilliant Eyes and SSTS

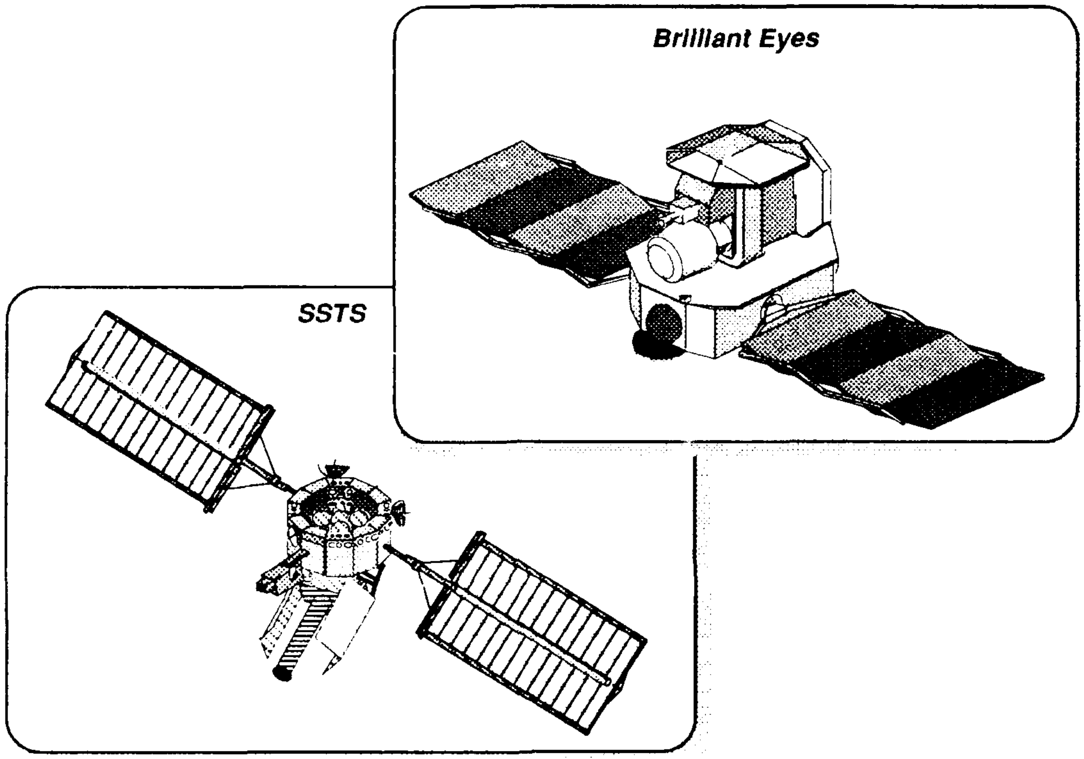


Figure 4-2 portrays last year's GBR concept in contrast to the current GBRT. The GBRT offers increased survivability through greater mobility, rapid deployability, and lower weight and power requirements. It leverages off of the development effort of the GBR-X which was the demonstration and validation radar for the deployable GBR. GBRT will be modular and part of a family of X-band radars. The basic building block is the theater ground-based radar (TMD-GBR), which uses a single phased-array antenna module and is the smallest and least capable radar of the family.

Figure 4-3 depicts an artist's concept of E^2I versus the HEDI. The E^2I will reduce the weight of the HEDI kill vehicle by almost an order of magnitude, will have a multicolor sensor to enhance discrimination, and will have improved maneuvering capability. The E^2I footprint radius will be increased by a factor of 15 over that of HEDI. It will key off of BE sensor data for late midcourse (exoatmospheric) and terminal (endoatmospheric) intercepts and will be supported by the GBRT for terminal intercepts. The E^2I will finesse the midcourse discrimination problem by using the atmospheric effects to differentiate RVs from decoys and debris.

Figure 4-2
Comparison of GBRT and GBR

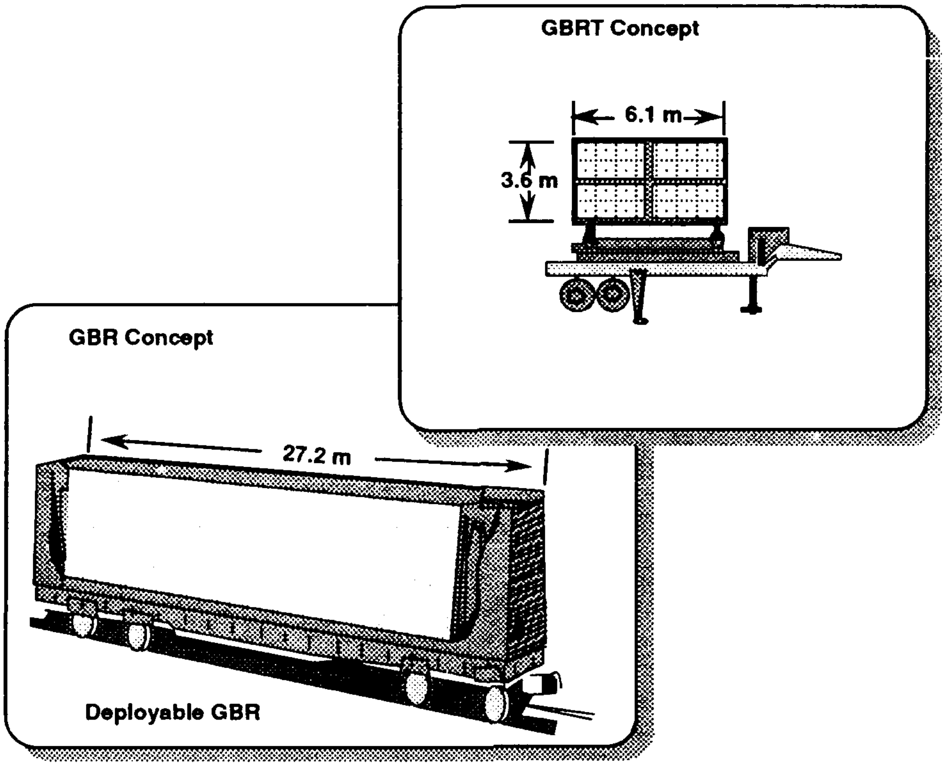
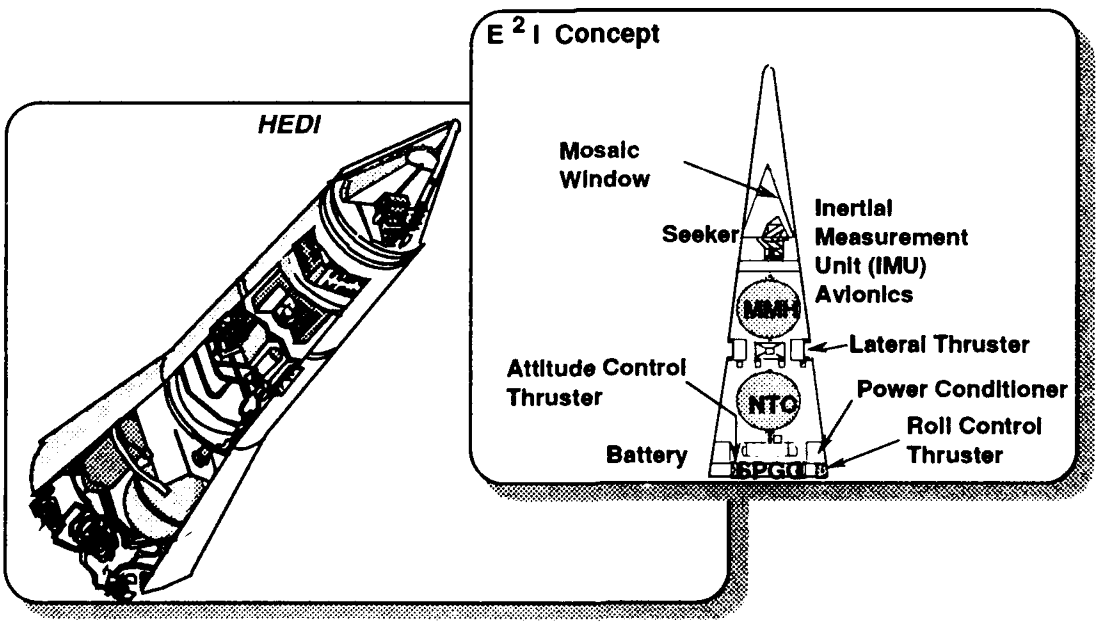


Figure 4-3
Comparison of E^2I and HEDI



4.1.2 Theater Missile Defense

Theater missile defense (TMD) concepts encompass active defense; passive defense; counterforce; and command, control, communications, and intelligence (C^3I) and will build on existing systems as quickly as technical and fiscal realities allow. The active defense elements of TMD will be built upon proven systems such as Patriot, Aegis, and space-based surveillance systems. This will ensure that a cost-effective baseline is maintained while supporting defense improvements. The ultimate system will provide: prelaunch intelligence and warning; nearly instantaneous launch detection and accurate launch point determination and impact point prediction; threat trajectory for interceptor cuing; improved anti-missile lethality and keepout range; and real-time tactical data links between all sensors and defensive elements.

Theater missile defense architecture studies demonstrated that layered point, area, and population defenses are required for regional defenses and contingency operations. The near-term goal is to deploy a transportable system, the components of which could be used as the underlay to the global protection system, to counter limited contingency threats, and to provide population defense against ballistic and cruise missile threats. To this end, SDIO will continue to develop the following components and technologies.

Patriot

Theater/tactical ballistic missiles (TBM) with significantly improved accuracy have increased the threat against Patriot air defense sites and defended assets. This will result in the destruction of air defense sites and provide the enemy air superiority once an attack is initiated. Patriot must be able to acquire, identify, track, engage, and destroy incoming TBMs as an element of active defense and unit survivability. Patriot near-term anti-tactical missile capabilities (PAC) consisted of two phases: modifications to the system software, PAC-I, and modification to missile hardware (warhead and fuze assembly), PAC-II. The PAC-I software changes fielded in June 1988 provide a self-defense capability. The PAC-II changes, which extend the self-defense capabilities to a limited, corollary point-defense capability, were fielded in January 1991. The Multi-Mode Seeker (MMS) project, a cooperative development with Germany, expands the limited critical asset defense capability of the PAC-II by incorporating an active seeker into the Patriot missile. The MMS also includes changes to the missile autopilot to improve data handling and improvements in signal-to-noise performance in the missile receiver. These system changes are needed to counter TBMs with low radar cross section, high terminal velocity, and high angle of attack. MMS is targeted for full-scale development in FY 1992. Other modifications including increased data rate processing, radar power and sensitivity, and reduced size are also being evaluated.

Extended Range Interceptor

The Extended Range Interceptor is designed to be a small, agile, fire-and-forget, hit-to-kill interceptor that could be deployed with Patriot as part of the contingency forces or as a point-defense weapon in the underlay for area defense against incoming maneuvering and nonmaneuvering TBMs. An ERINT secondary objective is to provide defense against the air-breathing threats. The missile features an on-board active millimeter-wave seeker that provides endgame guidance, advanced flight control technologies for agility in terminal maneuvers, lethality enhancement technologies, and a lightweight, composite case solid rocket motor. The ERINT flight test project will begin in FY 1992 and will be completed in FY 1993. Two ERINT flights will be conducted against threats armed with simulated chemical submunition warheads.

Arrow

Arrow is a cooperative U.S.-Israeli research and development project that responds to tactical ballistic missile threats proliferating throughout the Middle East. The project demonstrates an Israeli concept for long-range interceptor engagements and large area and population defense. Key technologies include seeker development, warhead development, and aerodynamic guidance and control. The three remaining proof-of-principle flight tests will be completed in FY 1991.

The Arrow Continuation Experiments (ACES) interceptor (a follow-on to the Arrow) is also being developed under a joint U.S.-Israeli project and will provide Israel with an area tactical ballistic missile defense capability. A Memorandum of Agreement (MOA) between the U.S. and Israeli Governments, which will be used to direct the project, has been agreed to in principle with some details, such as cost sharing, yet to be determined. The ACES project will be initiated in FY 1991 with the design of an ACES experiment and a new interceptor vehicle. The Israeli-designed ACES interceptor will be smaller and lighter than the Arrow, with an extended range and enhanced lethality. The research, development, and flight test of the ACES is scheduled to be completed in FY 1996.

Theater High Altitude Area Defense

The Theater High Altitude Area Defense interceptor system is being developed as a hypervelocity, ground-launched tactical weapon capable of engaging reentry vehicles in the upper atmosphere and over large ground regions to provide area defense in contingency operations. THAAD will be designed as an overlay to planned point defense systems such as Patriot or ERINT. A system concept definition for THAAD has been initiated with the goal of a deployable demonstration system of several tens of interceptors and associated system components (e.g., sensors, BM/C^3) in the mid-1990s. The THAAD interceptor will provide the area defense weapon system for possible future integration as the theater underlay to GPALS.

Ground-Based Radar

The TMD-GBR will be the first recipient of the development progress made under the midcourse GBR project. TMD-GBR satisfies the requirement for a more capable theater missile defense radar that would double the search area of the improved Patriot air defense system against theater ballistic missiles and be the primary initiation and fire control radar for the THAAD interceptor. Immediate plans require new contracts that will produce a demonstration and validation (Dem/Val) TMD-GBR available for testing with Patriot in FY 1993 and with THAAD in FY 1994. The deployable version will be transportable in C-130 aircraft.

Advanced Contingency Theater Sensor

Concept definition began in FY 1991 for a rapidly deployable, survivable sensor system to support defense against a theater missile threat (tactical air-to-surface missiles, ballistic missiles, cruise missiles, and aircraft) in a variety of contingency theaters of operation. Project options are to include the use of existing assets and the integration of ongoing SDIO sensor programs. The required sensor suite is to be available to begin deployment in FY 1995.

4.1.3 Brilliant Pebbles

The BP project is continuing to investigate the technologies and concepts for a highly autonomous, proliferated, space-based, kinetic hit-to-kill interceptor. The autonomous proliferated BPs result in a highly survivable BP constellation. Additionally, because the BPs are autonomous, how a single BP operates in any given situation is similar for all BPs. By testing single, or a few, BPs, confidence can be established in the effectiveness of the BP constellation as a system. Modeling legacy from other interceptor projects has been employed and modified to support development of the algorithms required to support BP autonomous operation. The project exploits the complementary capabilities of the national laboratories and industry to develop an innovative, low-cost system. The accomplishments and plans of Concept Demonstration and Concept Definition activities are described below.

Concept Demonstration

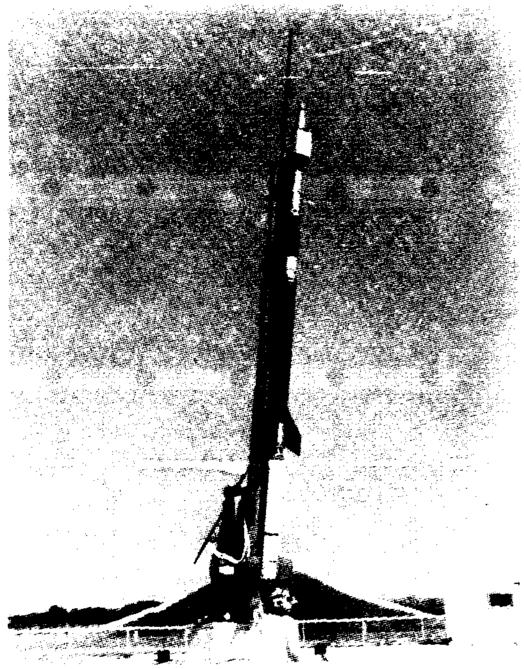
Concept Demonstration consists of an extensive set of laboratory, ground test, and flight experiments that support the development of technologies, resolution of critical issues, and system design. To date, the BP project has participated in two major underground tests that evaluated the effects of radiation on BP materials and components. Cooperation with other projects has also advanced critical technologies. Several key components such as sensor, navigation, and communication subsystems have been tested in "piggyback" fashion aboard the Delta Star space experiment. Another project tested the ability of a space-based interceptor to focus on a dim missile body and not the extremely bright rocket plume. Free-flight ground tests such as the advanced integrated hovering series have successfully demonstrated space-based interceptor capabilities relevant to BP.

The first Brilliant Pebbles flight experiment was launched from Wallops Island, Virginia, on August 25, 1990. Figure 4-4 illustrates the test configuration. The mission telemetry prematurely ended 81 seconds after liftoff, preventing the majority of the mission technical objectives from being achieved, however, the flight suitability of the Black Brant 10 sounding rocket system along with the payload support systems was demonstrated. The failure was due to an early release of a separation fastener. While the failure was not associated with the BP technologies or components, it did prevent gathering data from the payload. The cause of the failure has been investigated, analyzed, and corrected.

The second Brilliant Pebbles experiment was successfully launched from Wallops Island, Virginia, on April 17, 1991 on a Black Brant 10 sounding rocket. The payload, consisting of sensors, processor, and attitude control system, was successfully deployed at an altitude of 100 miles. All sensors (infrared [IR], ultraviolet, visual and star tracker) operated as expected and successfully collected phenomenology against a space and earth background. Preliminary results indicate that the star tracker images and subsequent star map matches were successfully accomplished. Using the star tracker images, the payload successfully stabilized the attitude control system. The payload then performed a series of maneuvers exercising the attitude control software. The IR sensor operated successfully and observed the nose fairing separation. The initial payload maneuver did not adequately position the IR sensor to observe and track the solid rocket booster, but sufficient data have been collected to analyze and correct the positioning anomaly.

Hardware and software integration experiments with a BP experimental vehicle have demonstrated the successful integration of the processor, software, sensors, and navigation subsystems. The series of hardware and software integration experiments has demonstrated the ability of BP hardware and software to meet the requirements of the experimental vehicle flight profile. A series of experimental vehicle flight experiments are planned for Fiscal Years 1991 through 1993. Each experiment is designed to have a few redundant objectives and to be able to accept some failures. The next experiment, scheduled for FY 1991, is designed to test more capable hardware in preparation for later intercept flights.

Figure 4-4
Brilliant Pebbles Flight Experiment



Concept Definition

BP Concept Definition was initiated in 1990 with six contractor teams to develop candidate concepts for high-quality, low-cost space-based interceptor systems. The contractors were asked to assess, using Lawrence Livermore National Laboratory's concepts as a point of departure, the existing BP design; to develop alternative designs to improve performance, reduce risk, and lower costs; and to develop detailed plans for subsequent project phases. Down-selection to no more than two contractor teams to conduct the pre-Full Scale Development (pre-FSD) phase will occur in the spring of 1991.

The objectives of pre-FSD are to focus the BP concept and continue the design process with appropriate demonstrations and documentation to proceed into FSD. Models, simulations, and testing will be used to validate the pre-FSD designs to ensure an acceptable level of risk before proceeding into FSD (risk management is a critical area of emphasis). The product of the pre-FSD phase will be an integrated, balanced, and proven design ready for a full-scale development decision in the mid-1990s, and deployment by the end of the decade. Specifically, the design must balance performance, producibility, operability, supportability, and affordability while meeting schedule goals.

4.1.4 U.S. Ground-Based Tier

As discussed in Chapter 2, the GPALS ground-based tier consists of a command center and some combination of Brilliant Eyes satellites, ground-based surveillance and tracking systems, ground-based terminal radars, endo-exoatmospheric interceptors, and exoatmospheric ground-based interceptors. The specific elements selected to proceed into full-scale development are dependent upon which of the following solutions is the more favorable: either discrimination of reentry vehicles from other objects in the midcourse layer or elimination of the atmospheric heating problem on the endoatmospheric terminal layer interceptor's sensor window.

Brilliant Eyes

The BE concept emerged in 1990 during the MATTR study. BE is intended to acquire and track targets in the post-boost phase and track and discriminate targets during the midcourse phase. BE data would be handed over to ground-based sensors or used directly by the interceptors to initialize target locations or provide in-flight updates. BE can be alerted by a boost-phase sensor to look for a particular target in a specified area.

While yet to be finalized, most design concepts envision approximately 60 BEs for GPALS and an additional 200 BEs would be needed to meet the Phase I requirement. The current design makes maximum use of technologies from SDIO-sponsored projects.

The Brilliant Eyes demonstration and validation objectives are to refine the BE concept and continue the design process with systems design and analyses, provide early resolution of the most stressing technology issues with proof-of-principle demonstrations, and demonstrate critical functions of BE with flight tests. During Dem/Val two BE flight test vehicles will be designed, fabricated, ground tested, and flown. Launch is planned for FY 1995 to provide on-orbit data collection and functional testing to support an FSD decision in the mid-1990s.

Ground-Based Surveillance and Tracking System

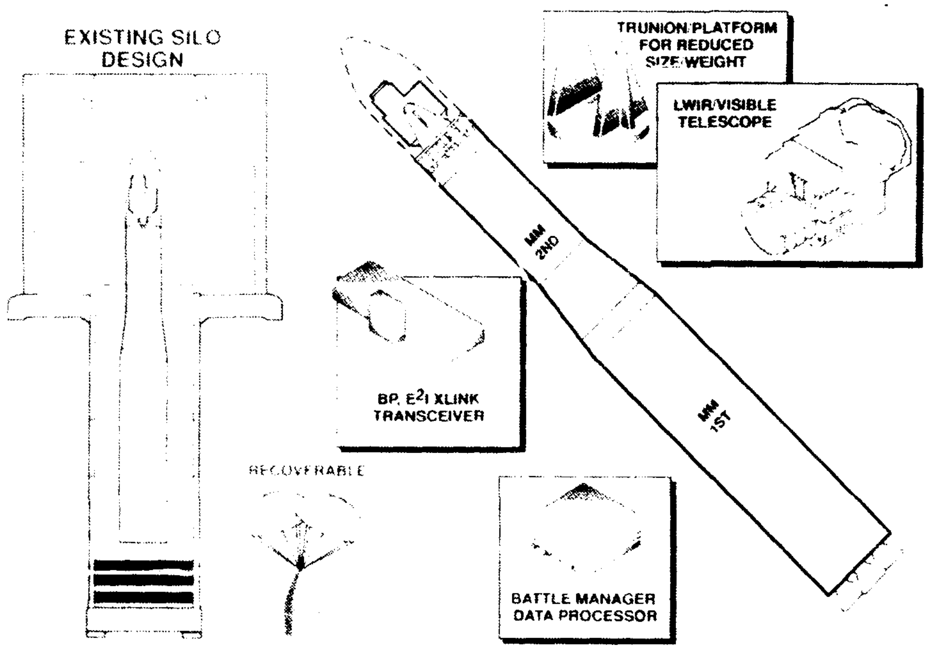
The GSTS was validated by the MATTR as a midcourse sensor element. Currently, the emphasis is to meet the GPALS mission objectives while retaining growth potential to meet Phase I requirements. GSTS provides a ground-based capability of performing the midcourse sensor role and also can be used on demand to supplement space-based sensors to give high-confidence protection against limited strikes. The GSTS Dem/Val project will design, fabricate, and ground test a flight vehicle as a technology validation experiment. System studies and analyses, including technology infusion and simulation and algorithm development, will fully support GSTS in the GPALS architecture. Figure 4-5 shows the GSTS design concept.

The GSTS project has made significant progress since its requirements were defined in 1989. A full-up design review was completed, and a dual source competition for the sensor was concluded with a down-select to one contractor in FY 1990. An interim preliminary design review will be conducted in FY 1991 followed by a preliminary design review and critical design review in FY 1992. The project remains on schedule for fabrication during Fiscal Years 1992 to 1994, a ground demonstration and first flight test in FY 1995, and additional flight testing and a Milestone II in the mid-1990s. The product of Dem/Val will be a low-cost GSTS design that optimizes performance, producibility, and supportability and also meets the GPALS schedule goals.

Ground-Based Terminal Radar

As a result of the MATTR review, Theater Missile Defense mission requirements, and GPALS threat definition, the radar project has been redirected from the Fiscal Years 1988 to 1990 radar design and development project. The previous single radar design thrust has been changed to a design that provides a family of radars related to each other through common antenna modules and components in order to meet each of the TMD, GPALS, and, if required, Phase I, ground-based radar requirements. The

Figure 4-5
GSTS Design Concept



radar's specifications will be baselined to support the ground-based interceptors in each of the three missions (TMD, GPALS, and Phase I). TMD-GBR, the smallest and least capable radar, is the basic building block and uses a single phased array antenna module (PAAM). The TMD-GBR PAAM, transmitter, power supply, processor, and other supporting components that are the basic building block will be designed and baselined against the most stressing operating environment of all three missions. Adding additional PAAMs and other power, transmit, and processing modules allows the design to grow to the GBRT to meet GPALS and GBR-M (midcourse) Phase I requirements.

The acquisition strategy for the GBRT GPALS radar in Dem/Val derives from modular growth of the TMD-GBR Dem/Val radar. The same Dem/Val radar contractor developing the TMD-GBR will also develop and integrate the GBRT. The TMD-GBR test at White Sands Missile Range (WSMR) will test many GBRT radar performance objectives. GBRT mission performance will be demonstrated at the U.S. Army Kwajalein Atoll range. The TMD-GBR will be tested in FY 1993 and the GBRT will be tested and ready for a full-scale development decision in the mid-1990s.

Endo-Exoatmospheric Interceptor

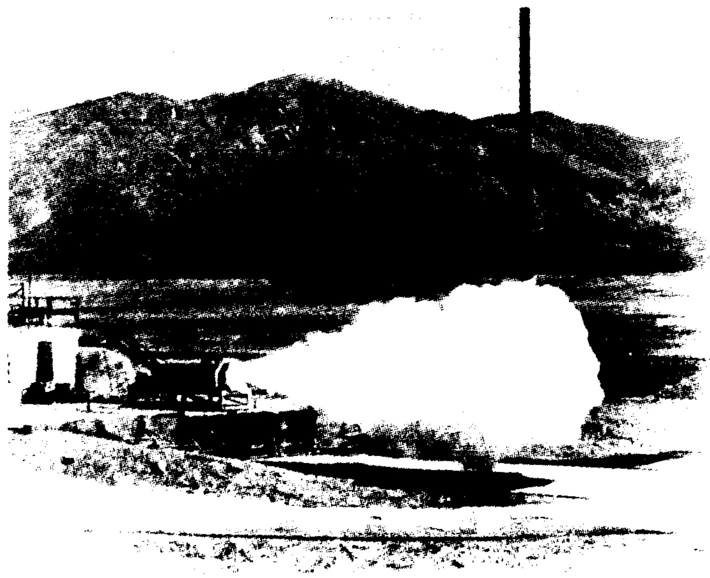
The benefits of the dual mode E^2I were established by the MATTR. The project evolves from the High Endoatmospheric Defense Interceptor and has progressed from the successful first technology demonstration flight of the Kinetic Energy Kill Vehicle Integrated Technology Experiment (KITE) on January 26, 1990 at White Sands Missile Range (WSMR), New Mexico, through preparations for the second KITE flight scheduled for the fourth quarter of FY 1991. The first flight showed our ability to cool the forebody and sensor window from the high temperatures generated by atmospheric heating. The test showed that at the interceptor's highest aerodynamic performance the cooling requirements are more than met. The second flight will verify target acquisition and tracking, control and guidance systems, and seeker window survivability with the interceptor homing on an air-dropped flare. A third KITE test in FY 1992 will gather data on behavior of RVs and decoys reentering the atmosphere by observing and tracking a cooperative target complex with a two-color, long-wavelength infrared seeker on board the KITE kill vehicle.

The next phase of the project, an E^2I Dem/Val, will be initiated in FY 1991 with multiple contract awards in early FY 1992. The objective of the Dem/Val phase is to examine at least three contractor designs for E^2I and to select two designs for a proof-of-principle competitive fly-off at WSMR. The winner of the fly-off will continue flight testing at the U.S. Army Kwajalein Atoll (USAKA) to demonstrate the full anti-ballistic missile capabilities of E^2I at operational closing velocities. A critical element of the USAKA tests will be the addition of a newly developed two-pulse second stage being developed for the project by the Air Force Astronautics Laboratory at Edwards Air Force Base (AFB), California. In association with the competitive portion of Dem/Val, a seeker development project is being conducted to test the seeker at the Kinetic Kill Vehicle Hardware-in-the-Loop Simulator (KHILS) at Eglin AFB, Florida, to validate the seeker concept and design. These design and test activities will resolve the Milestone (MS) II exit criteria by the mid-1990s and result in an E^2I design that is producible and fully hardened and can support a fully competed full-scale development.

Ground-Based Interceptor

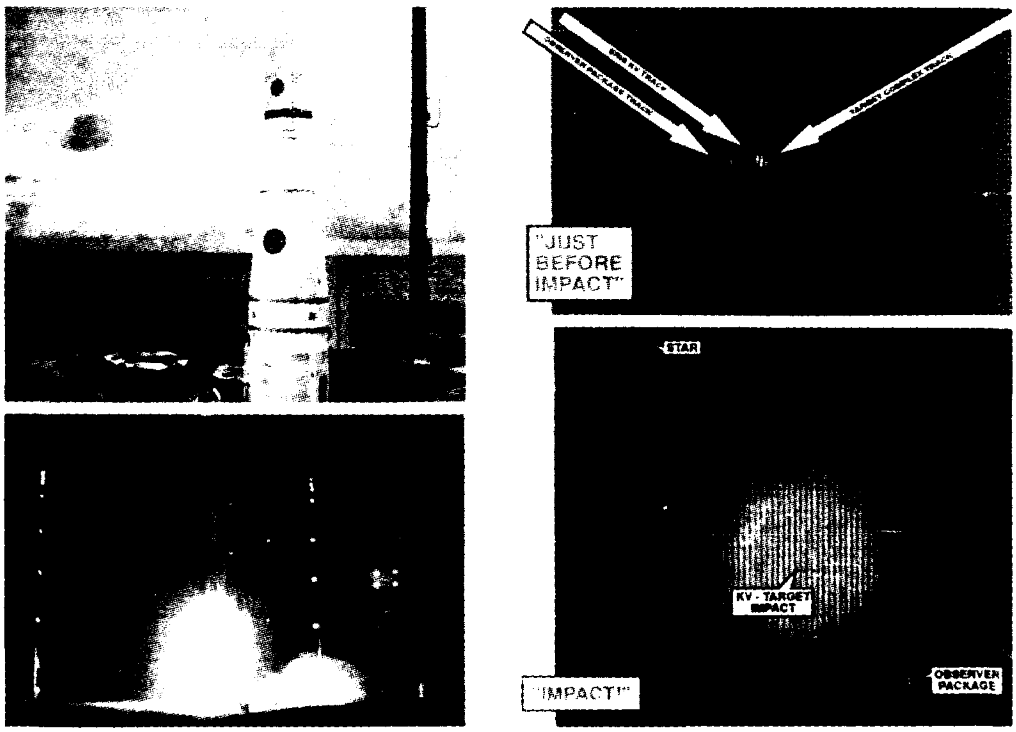
The GPALS ground-based segment may include the GBI, which is intended to work autonomously in space after launch to locate and destroy RVs during the midcourse phase of their flight. Figure 4-6 shows a high-performance booster that successfully completed all of its ground firings in 1990. Because the booster makes up most of the weight of the GBI, completing this technology development was critical. The current kill vehicle design is much smaller than the 1980's technology kill vehicle that was successfully flown on the exoatmospheric reentry vehicle interceptor subsystem (ERIS) in January 1991. The ERIS flight test was conducted on January 28, 1991, at USAKA. In this first test of an interceptor against a target accompanied

Figure 4-6
GBI Booster Technology Development



by decoys, the ERIS successfully intercepted a simulated RV launched from Vandenberg AFB. The ERIS correctly selected the target from among decoy balloons, diverted to the target, and intercepted it in a hit-to-kill collision. Figure 4-7 shows a closeup of the ERIS at the launch pad; launch during a violent rainstorm; the kill vehicle, observer package, RV, and balloon decoys just prior to intercept; and successful intercept of the RV by the ERIS kill vehicle. This extremely successful flight experiment validates the concept of performing midcourse intercepts using basic discrimination techniques, and enhances confidence in the GBI's ability to perform more advanced discrimination.

Figure 4-7
ERIS Flight Test



Another ERIS ballistic test is planned in FY 1991 at USAKA to investigate more advanced approaches to discriminating between RVs and decoys. This test should greatly increase confidence in an autonomous capability. Subsequent tests beginning in FY 1993 with advanced, lightweight hardware will increase confidence in a cost-effective GBI for GPALS.

Competitive selection of GBI concepts includes several phases. The initial phase, which was completed in FY 1990, included 15 studies performed under a Broad Agency Announcement. The GBI concept and technology integration phase began in 1990 and is ongoing. During this phase, the best interceptor concept(s) will be chosen from among the three concept and technology integration contractors, and realistic interceptor components and technologies will be identified. The focus will be on validating the concept of a semi-autonomous, discriminating interceptor to achieve the most effective defense at the lowest system cost. In FY 1991, following early exoatmospheric flight tests by two of the contractors and hardware development and ground testing by the third, there will be a down-select to two contractors. The two selected kill vehicle concepts will be flight tested in the mid-1990s to determine the optimum configuration. A full-scale development decision is planned for GBI in the mid-1990s.

Although the Space-Based Interceptor (SBI) concept has been replaced by Brilliant Pebbles, selected SBI hardware development and integration efforts and hover testing will be continued through FY 1992 because of direct applicability to GBI. Figures 4-8 and 4-9 show examples of the tremendous progress made in weight reduction. Figure 4-8 shows an 8-ounce interceptor computer system (ICS), which delivers about one-eighth of the processing capability of a giant scientific Cray computer but requires less power to operate than two outdoor Christmas lights. The ICS has been completed and flight tested. Figure 4-9 shows an August 1989 test of a 220-pound, 75-inch infrared (IR) sensor-controlled hover vehicle and a July 1990 test of a 40-pound, 23.5-inch visible sensor-controlled brassboard kill vehicle.

Command Center

During FY 1990, the Pilot Command Center (PCC) functional representation and requirements documents were developed. PCC experiments emphasizing human-in-control were conducted by the Army, Air Force, and National Test Facility.

In FY 1990, the Air Force Electronic Systems Division (ESD) conducted real-time human-in-control experiments that emphasized threat assessment, attack characterization, and preplanned response option/defense employment option selection. ESD started development of a test bed to analyze the effectiveness of selected defense options and to assist the U.S. Space Command in further defining tactics and concepts. The Air Force also initiated development of a standards-compliant Core Support Module (CSM) for future mobile command center development. The CSM will provide the common network and technical control capability to support modular command center development.

In FY 1990, the U.S. Army Strategic Defense Command (USASDC) conducted experiments demonstrating an integrated Army Space Command mock Regional Operations Center (ROC) capability at the Advanced Research Center using prototype software for hardware-in-the-loop tests. A fully functional representation of the command center was tested and evaluated. This capability allows development and evaluation of ground-based networks for the GBI, E^2I, and BE.

During FY 1991, information processing, command and control (C^2) decision, and communications requirements definition activities will support the initiation of prototyping beginning in FY 1992, evolving to command center and operations center prototypes during FY 1994, and full-scale development in the mid-1990s. This effort includes completion of first-order prototypes of the ROC for ground-based C^2, and of the Element Operations Center for space-based C^2 at the Air Force Space Systems Division. Both will evolve into an integrated Mission Operations Center.

The U.S. Space Command will sponsor C^2 gaming at the National Test Facility to provide operational training and procedures definitions for the system user and to also support U.S. Space Command's ballistic missile defense Concept of Operations (CONOPS) definition and refinement. All efforts are focused on implementing the CONOPS. Human-in-control experiments will continue at ESD and USASDC with emphasis on decision aids development. Additional efforts include definition of BM/C^3 constructs that will assist in the integration of GPALS as the system evolves.

Figure 4-8
Interceptor Computer System

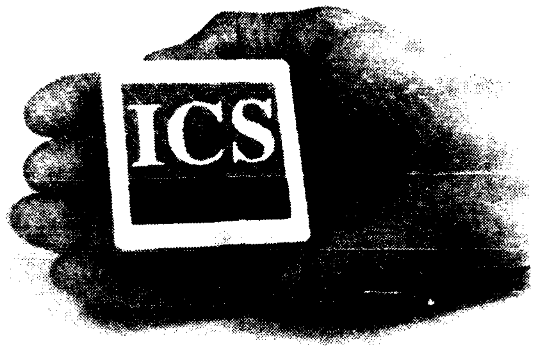
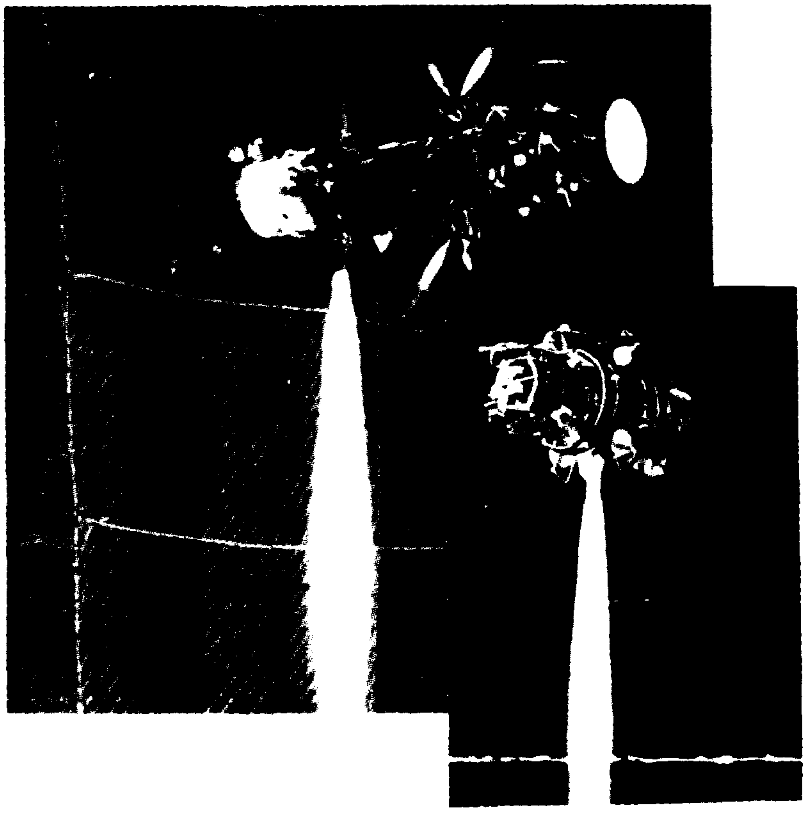


Figure 4-9
SBI Hover Vehicle Weight Reduction



4.2 Follow-on Systems, Research and Support

This section discusses the recent progress and future plans for technologies that support the development of follow-on weapons to a GPALS architecture, technologies such as producibility, survivability, lethality, power, and space transportation that support the development of all theater and strategic defense elements.

4.2.1 Kinetic Energy Technology

The technology projects discussed below are designed to support possible future FSD decisions for advanced follow-on interceptor systems deployable after the turn of the century. These technologies are being pursued to advance the state of the art of lightweight, low-cost components for both space-based and ground-based ballistic missile defense interceptors.

Interceptor Component and Integration Technology

Effective, low-cost interceptors, particularly those operating in the exoatmospheric environment, require hardened, miniaturized, lightweight components with improved performance. In 1990, several technology efforts evolved interceptor components with unprecedented characteristics and advantages.

The lightweight exoatmospheric projectile (LEAP) project has succeeded in integrating three separate miniaturized exoatmospheric kill vehicles ranging in weight from 3.5 to 17 kilograms. Recent hover tests, hardware-in-the-loop tests, and integrated propulsion tests of the kill vehicles have been highly successful. Because of these successes, a series of demonstration flight tests at WSMR and USAKA are currently being planned for Fiscal Years 1991 and 1992.

In the area of interceptor avionics technology, a high-throughput, high-density signal processor packaging design (SPPD) brassboard, shown in Figure 4-10, was designed and fabricated. The SPPD reduced mass by a factor of 30 and increased processor throughput by more than a factor of four over 1985 guided interceptor signal processor technology.

Interceptor sensors, reduced in size and weight by more than tenfold from their previous configuration, are being designed, fabricated, and tested. In 1990, a breadboard version of an ultraviolet seeker was manufactured and tested in the KHILS facility. This seeker provides enhanced discrimination capability in boost, post-boost, and midcourse and is inherently radiation hard. Plans for 1991 include breadboard integration with the SPPD processor and flight testing on board a LEAP fly-along sensor package. The flight concept hardware, to be delivered in 1995, will weigh approximately 1 pound.

During the past year, long-wavelength infrared (LWIR) focal plane arrays (FPAs), optics, and on-array processors have been designed to provide enhanced detection, tracking, and discrimination throughout all phases of flight for both ground- and space-based systems. In 1991, these lightweight, hardened components will be integrated into an evaluation unit called the LWIR Advanced Technology Seeker (LATS) illustrated in Figure 4-11.

Hardened LWIR focal plane arrays are presently not producible at low cost or high volume. The Pilotline Experiment Technology project was initiated in 1990 to address this problem. This project will demonstrate the production of over 1,000 focal plane arrays per year by 1995.

In 1990, a project was initiated to develop a micro-mechanical inertial guidance system (MIGS) weighing less than 30 grams. The MIGS is pictured in Figure 4-12. Breadboards for the MIGS will be fabricated in 1991 and later will be integrated with SPPD and an advanced stellar navigation sensor, another component development

Figure 4-10
Signal Processor Progress

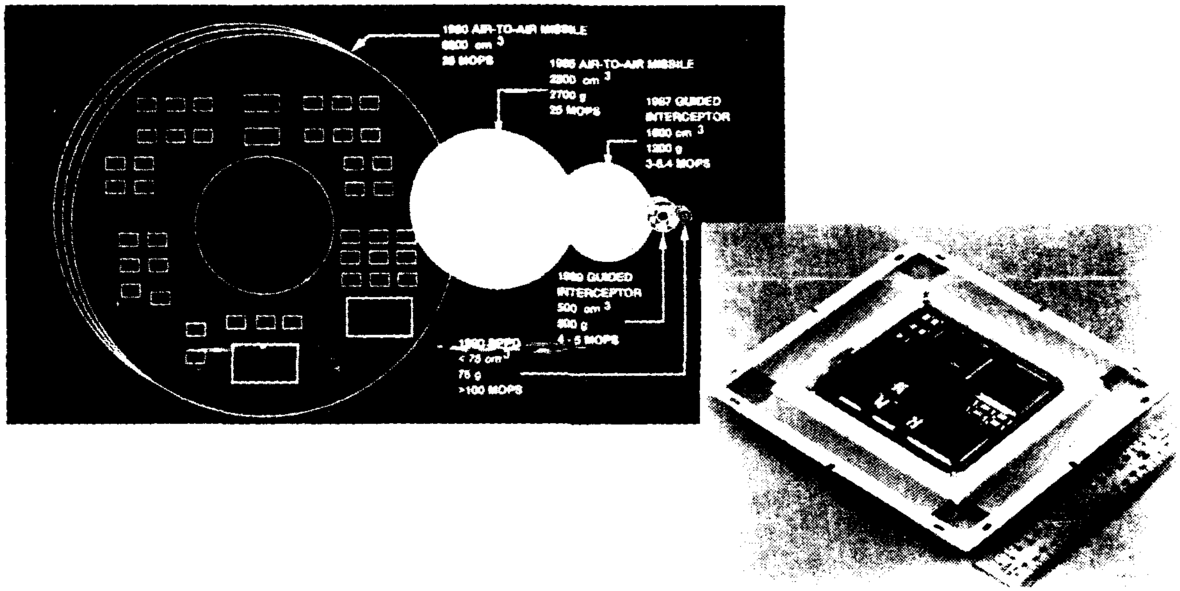


Figure 4-11
LWIR Advanced Technology Seeker

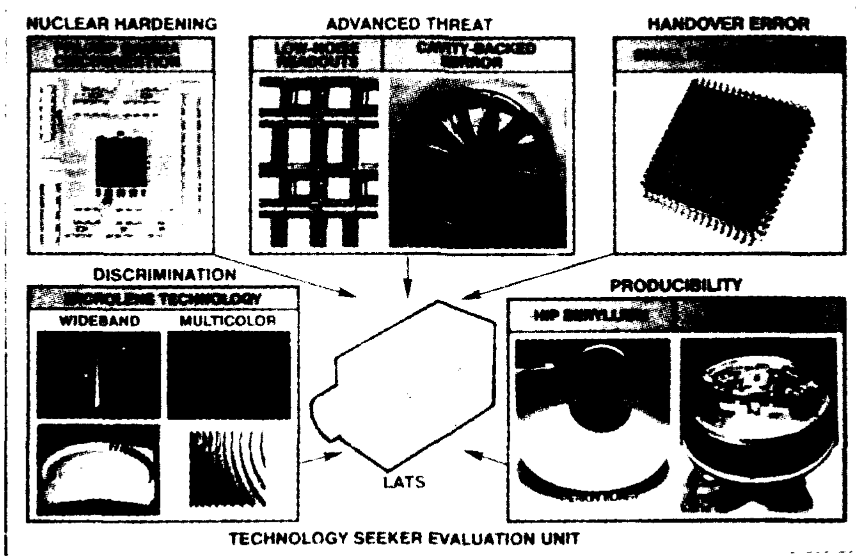


Figure 4-12
Micro-Mechanical IMU

AREA: INERTIAL MEASUREMENT

OUTSTANDING FEATURE

USES CURRENT MICRO MACHINING AND MICRO-ELECTRONIC TECHNIQUES TO BREAK WEIGHT BARRIERS OF FOG

MAJOR MILESTONES:

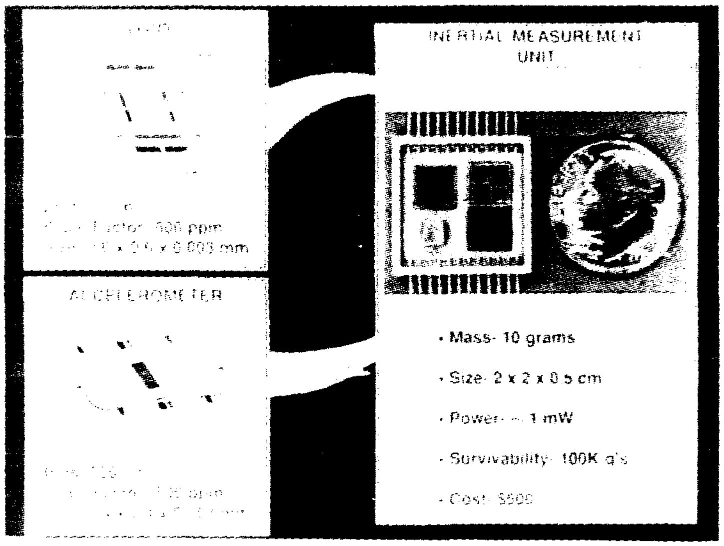
IN DEVELOPMENT AT DRAPER LABS
1QFY 93 - GROUND TESTING COMPLETE

KEY PARAMETERS

WEIGHT -- 10 GM
VOLUME -- 2 CC
POWER -- 1 mW
GYRO BIAS -- 10 DEG HR
COST -- $500

PRIMARY POC

LAURA STERRETT
AFATL SAI
(904) 882-4036



project initiated in FY 1991. The production unit cost goal of $500 is significantly less than current satellite inertial measurement unit (IMU) costs.

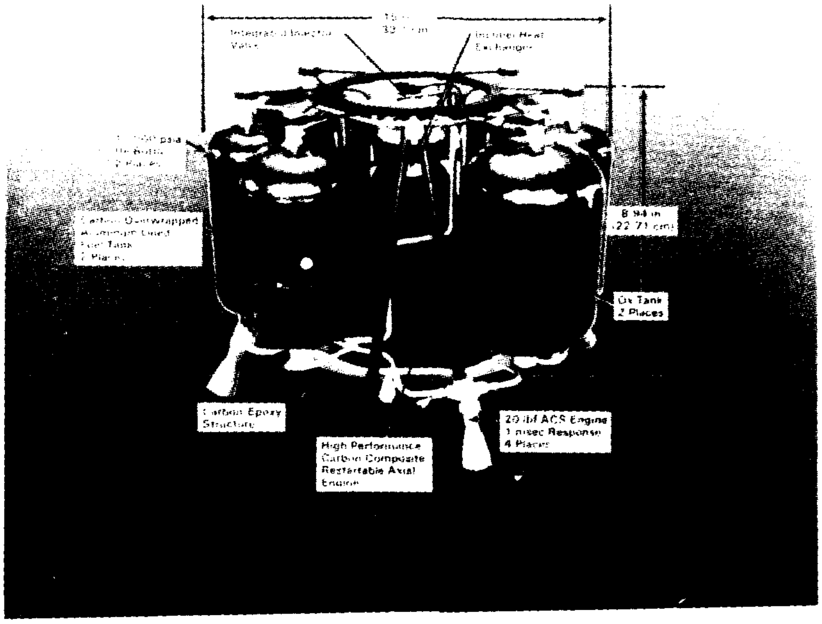
Improvements in interceptor propulsion systems have also been achieved during 1990. Development of a very high-performance, high-mass fraction advanced liquid axial stage, shown in Figure 4-13, has resulted in an eightfold weight reduction over current liquid propulsion systems. Ground flightweight component tests were completed in 1990, performing as expected. An integrated flightweight test was conducted in February 1991. A flight test is planned for early FY 1992. A missile low-cost solid booster for ground- or space-based applications while improving mass fraction and performance. The baseline design has been completed and nozzle insulation tests have been performed.

Near the end of 1990, several efforts were initiated to develop endoatmospheric seekers. One effort is investigating active millimeter wave (MMW) seeker and homing technologies that are critical to the development of advanced, follow-on theater missile defense (TMD) interceptors. The dual mode seeker project will develop concepts and designs for a combined MMW and IR seeker to enhance endoatmospheric homing capability. Hardware is scheduled for initial ground tests in mid-1993. Another effort started in 1990 will determine the viability and characterize performance of several electro-optical aperture concepts of hypersonic kill vehicles. Prototypes will be fabricated and ground tested in late 1992.

Hypervelocity Guns

Hypervelocity guns (HVG) utilize electromagnetic, electrothermal, or other advanced concepts instead of conventional chemical rocket propulsion to accelerate projectiles to ultrahigh velocities. The goal of the HVG project is to develop rapid-fire HVGs and compatible projectiles capable of supporting ground-based endoatmospheric and exoatmospheric defense missions. To accomplish the overall goal, an HVG must

Figure 4-13
Advanced Liquid Axial Stage Propulsion System



be developed that is capable of repeatedly launching flight-weight projectiles at acceptable velocities and efficiencies and has a reasonable barrel life. Supporting subsystems such as prime power, power conditioning, switching, and feeders must also be developed. Projectile development issues include highly sensitive seekers, divert propulsion, high-density electronics, and the ability to withstand the high acceleration launch environment (100,000 times the force of gravity). Fire-control hardware/software must be developed to handle multiple projectiles against high numbers of targets. The HVG project also includes SDIO sponsored research and development efforts with selected allies. The Netherlands provides research into advanced pulsed power and switching, while the United Kingdom provides complementary efforts in areas of barrel, armatures, and power supplies.

Transportable or fixed ground-based HVGs could be capable of intercepting endoatmospheric and exoatmospheric threats at both very short ranges (1 to 50 kilometers) and very long ranges (50 to 5,000 kilometers). HVG defenses promise much lower costs per shot, which could enable highly effective defenses at affordable costs. Current emphasis for the HVG project is placed on building and demonstrating a large-scale test bed. This test bed will establish the technical and conceptual basis for firing a projectile at velocities which will directly support mission requirements.

In mid-1990, active electronics packages were launched for the first time from railguns. The digital flight recorders that were launched collected extremely accurate acceleration data during the railgun launch with negligible electromagnetic interference. Electromagnetic interference was once considered a show stopper for a railgun launch of "smart" projectiles. Endoatmospheric interceptor subsystems were fired from light gas guns in mid-1990. The electronics, optics, propulsion and structural systems all demonstrated survival at 85,000 Gs. Taken together these tests completely validate the feasibility of gun launch of complex guided interceptors.

Throughout 1990, rapid fire and long duration railgun firings were accomplished. Thirty shot bursts at up to 7 hertz and up to 150 shots were demonstrated. Barrel lifetimes of up to 500 to 1,000 shots are expected in 1991 to 1992. These tests largely validate the lifetime and repeatability figures required for theater defense. These experiments have been conducted at small-scale (15-millimeter) bore size. Other Department of Defense (DOD) programs demonstrated 9 megajoules muzzle energy in 1990 and will demonstrate 15 to 20 megajoules muzzle energy in 1991 to 1992. Thus, all significant HVG parameters for TMD have been demonstrated at, or near, full scale.

4.2.2 Sensor Technology and Phenomenology

Sensor technology and phenomenology efforts provide required constituents of the sensor systems that must first detect, discriminate, acquire, and track targets under a variety of conditions before an intercept can be made. Technology projects in signal processing, passive sensors, laser radar, and microwave radar support the development of sensors. Passive, active, and interactive discrimination projects explore and develop this technology. A broad-based project to collect target signatures and background phenomenology was established early in the SDI Program and continues to be aggressively pursued. Signature data are collected by spaceborne, airborne, shipborne, and ground-based sensors. This project is supported by activities that build and test various decoys and penetration aids to see what will stress the system. Specific accomplishments and plans in these areas include the following:

- Reduced the cost per pixel by a factor of over 100 for both above- and below-the-horizon sensing focal plane arrays for sensor/interceptor applications.
- The Visible Light/Ultraviolet Experiment (VUE) was launched and collected data on visible and ultraviolet ballistic missile phenomenology.
- In 1992, sustained operation of an efficient X-band solid-state radio frequency power tray assembly producing 20 watts at 40% efficiency in each module will be performed.
- In 1994, the Midcourse Space Experiment (MSX), designed to address the outstanding issues concerning spacecraft operations and midcourse sensor functions; collect a large data set on targets, plumes, and backgrounds; and conduct a data decontamination experiment, will be launched.

Passive Sensors and Signal Processing

Significant progress occurred in passive sensors and signal processing. These accomplishments are described in Figures 4-14 and 4-15.

Laser Radar

Firepond laser radar observation of successful Firefly sounding rocket experiments in March and October 1990 demonstrated conclusively the utility of imaging laser radars for measuring target dynamics and performing a credible discrimination role at the required ranges for strategic defense systems. The Firepond laser radar performed range-Doppler imaging and precision tracking measurements on inflatable decoy targets launched from Wallops Island and viewed at 800-kilometer range from Firepond as shown in Figure 4-16. Two Firebird sounding rocket experiments, in which more complicated plume and target interactions will be observed, are scheduled for March 1991 and April 1992.

Figure 4-14
Passive Sensor Accomplishments

TECHNOLOGY AREA	ACCOMPLISHMENTS	IMPACT
Focal Plane Array	Demonstrated advanced hardened infrared detectors in doped silicon and mercury-cadmium-telluride devices for the mid wavelength, long wavelength and very long wavelength infrared Initiated pilot production of silicon impurity band conduction focal plane arrays Fabricated and demonstrated a very long-wavelength infrared absorption superlattice and high-temperature superconducting devices Continued the yield, cost, and production capacity improvements for below-the-horizon mid-wavelength detectors	Extremely sensitive, low-noise infrared detectors for acquisition, tracking, and discrimination of relatively warm ICBM boosters and cold midcourse reentry vehicles must be able to survive nuclear environments, utilize minimal power, act uniformly, and be cost reasonable.
Optics	Fabricated a 10-inch lightweight beryllium mirror using the hot isostatic press method. This mirror contained a channel that would allow fluids to pass to cool the mirror and thus lower the background noise Evaluated 4 beryllium mirror fabrication technologies for radiation hardness in an underground test Validated the jet spray decontamination technique for cleaning mirrors of particulate matter Fabricated large arrays of microlenses to be used with small area devices for enhancing of radiation hardness	New mirror materials and fabrication processes produce high-resolution, image-quality optics for space-based sensors that can be maintained contamination free and are survivable in nuclear environments
Cryocooler	Built and tested the components for the 10°K magnetic refrigerator. Completed 65°K Standard Spacecraft Cooler detailed design. Completed mixed gas analysis for Joule-Thompson coolers. This method enables high-efficiency quick cooldowns. Completed design of a diode heat pipe to provide thermal transfer Demonstrated a very novel thermo-acoustically driven pulse tube cooler. The cooler has no moving parts and should therefore have a very long life	Cooled sensor detectors for high-efficiency, low-noise operation of sensors to perform detection/discrimination of targets require compact space refrigerators to cool components to near-absolute-zero temperatures
Cryogenic Signal Processing	Fabricated and tested a signal processing module that operates at 10°K so as to be compatible with silicon impurity band conduction focal plane arrays Demonstrated radiation-tolerant building blocks for cryogenic signal processing functions Demonstrated very high packing density electronics for mercury-cadmium-telluride arrays that operate at 77°K	The number of wires carrying information from the focal plane array must be minimized to reduce sensor weight and power and to minimize the number of penetrations through the thermal insulator walls to maintain structural integrity. This requires signal processing at temperatures as low as 10°K

Figure 4-15
Signal Processing Accomplishments

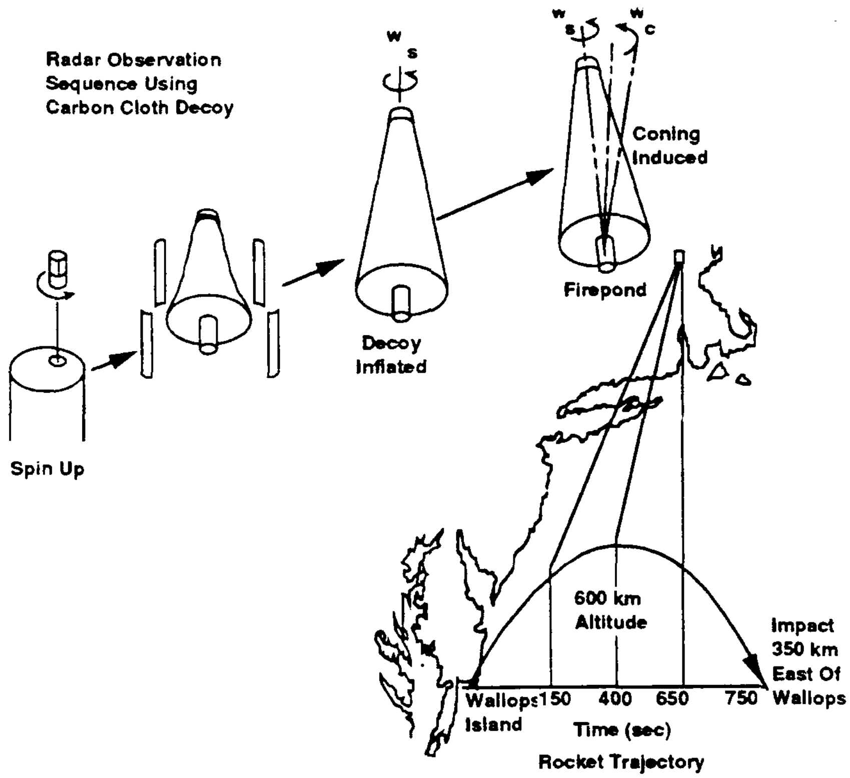
TECHNOLOGY AREA	ACCOMPLISHMENTS	IMPACT
Semiconductor Chips	Developed radiation-hardened bulk complementary metal oxide semiconductor chips tested to 10 times required total dosage.	Compact, high-capacity, fast, survivable space processors and components for sensor and interceptor signal processing and battle management functions. These processes and components result in survivable sensors and interceptors.
Static Random Access Memories	Developed a 64K-size high-speed, radiation-hardened, static random access memory using a silicon-on- sapphire process. Successfully tested to hardness required for space processors.	
Microprocessors	Started development of a high-speed (200 million operations per second node), radiation-hardened, 32-bit microprocessor for a spaceborne computer with 2 to 4 times the throughput of the previous generic very high-speed integrated circuit spaceborne computer prototype. Started development of a fault-tolerant, compact, three-dimensional computer with an ultimate processing speed of 160,000.	
Hardened Random Access Memories	Developed hybrid-hardened one-megabit static random access memory modules based on bulk, silicon-on-insulator, and silicon-on-sapphire modules, which will be tested in real space environments under the On-Board Signal and Data Processing program to be flown on the Midcourse Space Experiment satellite.	
Processing/ Algorithms	Planned for the demonstration of various on-board processing technologies/algorithms in real space environments under the On-Board Signal and Data Processing program to be flown on the Midcourse Space Experiment satellite.	

Additional accomplishments in the laser radar technology project included enhancing the data base of carbon dioxide laser target measurements by extending calibrated laboratory measurements to over 21 target signatures, validating the defense laser/target signature code, and successfully completing the second Firefly flight test. In addition to providing precision measurements of deployment dynamics and images of a decoy in space, the second Firefly test included precision ranging of a decoy in space utilizing a doubled neodymium solid-state laser similar to that required for Brilliant Eyes. Accomplishments in concomitant component development efforts included significant progress in both ladar transmitter and beam control technology. A transmitter architecture with the potential for significant weight reduction and capable of producing the required output energy for long-range imaging applications was demonstrated. In the beam control area, an innovative, lightweight, mechanical system capable of integrating 50 targets per second was demonstrated. Progress in laser radar technology has resulted in incorporating a laser radar into the BE concept.

Phenomenology

In addition, many experiments designed to understand better the phenomenology of detecting and discriminating targets in space have taken place and are planned. Some highlights appear in the following paragraphs.

Figure 4-16
Firepond CO_2 Imaging Radar Demonstration



The Electron Accelerator Experiment (EXCEDE III) sounding rocket flight was successfully conducted from White Sands Missile Range in April 1990. EXCEDE III was initiated to dose the upper atmosphere with high-energy electron beams. The electron dosing induces optical emissions and chemical processes in the ambient atmosphere. The electron injection and resulting atmospheric response simulates (in some respects) that expected in high-altitude nuclear weapon effects. These data will help improve the accuracy of predictions of nuclear weapons signatures.

During FY 1990, the Strategic Scene Generation Model project delivered the first release of the baseline version of the computer model that supplies phenomenology scenes to system elements, hardware-in-the-loop simulators, and system simulation programs. In Fiscal Years 1991 and 1992, the project will continue the scheduled incremental releases of upgraded versions of the baseline model, incorporating new and enhanced phenomenology modules.

Advanced electro-optical sensor technologies being developed include visible, ultraviolet, and infrared radiation-hardened charge-coupled device images, step-stare sensor signal processing algorithms, and processor architectures to support evolving SDI tactical and strategic surveillance concepts.

During FY 1990 the SDIO Phenomenology Data Centers continued to archive and distribute SDI experiment data. Significant accomplishments included occupancy of the Plumes Data Center; the archiving of VUE data at the Backgrounds Data Center; and the archiving and on-line availability of the Queen Match, Sounding Rocket Measurement Program, and JANUS experiment data bases at the Midcourse Data Center. Goals for FY 1991 include: Infrared Background Signature Survey and Starbird data archiving and regular operations at the Plumes Data Center; automatic data base loads and the archiving of Zodiac Beauchamp and Cobra Eye data at the Midcourse Data Center; and creation of Three Color Experiment and clouds experiment data bases and completion of the MSX data base design at the Backgrounds Data Center.

The Argus and High Altitude Observatory optical diagnostic aircraft continue to provide critical test support to a broad spectrum of SDI projects. Recent accomplishments include the collection of plume data on the Red Gemini III and Starbird missions and the collection of high-speed imagery data on the successful GBI (ERIS FTV-1) intercept event. Future missions include systematic data collection of plume phenomenology on solid- and liquid-fueled rockets and support for the Brilliant Pebbles, GBI, E^2I, Arrow, and LEAP projects.

The Infrared Background Signature Survey (IBSS) and the Cryogenic Infrared Radiance Instrumentation for Shuttle (CIRRIS) are scheduled to be launched on Shuttle Mission STS-39 in April 1991 to observe and characterize the spectral and radiometric signatures of several space objects and phenomena. IBSS experiments will take measurements of firings of the Shuttle engines to gather data on the optics signature of rocket plumes, make earthlimb and earthscan observations of radiation, observe the release of each of three liquid rocket propellant/oxidizer vapor clouds in low earth orbit, investigate the interaction of four neutral gases with the ambient weakly magnetized plasma, and attempt to characterize the containment environment in and around the Shuttle payload bay. This latter experiment will take observations for study of a "glow" around the orbiter that has been observed in the visible wavelength. IBSS will be deployed and retrieved on the Shuttle Pallet Satellite during this 7- to 8-day mission. An artist's rendition of IBSS and the Shuttle is shown in Figure 4-17. CIRRIS 1A will collect infrared background signatures of the earth's surface and atmosphere over the several-day shuttle mission. This will provide background signature data that include changes due to latitude variations and day/night conditions. These data combined with the data of the Space Infrared Imaging Telescope (SPIRIT) II experiment and MSX will be valuable in the selection of specific bands and processing techniques to limit the impact of the natural background on sensor operations.

Figure 4-17
IBSS and the Shuttle

Significant Progress and Plans

SPIRIT II is a sounding rocket-launched LWIR instrument designed to collect spectral and spatial information of a solar-heated and expanded atmosphere combined with auroral excitation. The SPIRIT II flight scheduled for early FY 1992 from Poker Flat, Alaska, is short (about 7 minutes) but should be adequate to characterize the LWIR atmosphere emissions from one of the most stressing natural backgrounds a strategic defense system might encounter. These data are of direct value to BE, GSTS, and other LWIR sensor concepts.

Unique measurements of the exhaust plumes from liquid propellant rocket motors were completed at the U.S. Air Force Arnold Engineering Development Center during FY 1990. In FY 1991, work on these models will continue, culminating with the delivery of significantly improved versions of these codes in FY 1992. The improved codes will include new ultraviolet-visible signature capabilities and the certified infrared signature model.

Target Discrimination

The Exoatmospheric Discrimination Experiment (EDX) flight project is designed to collect high-quality LWIR signature measurements of simulated midcourse target threats. The EDX sensor will be launched from Barking Sands, Hawaii, to collect LWIR data of the simulated targets as they are launched from Vandenberg Air Force Base to U.S. Army Kwajalein Atoll. These data are required to evaluate the credibility of discrimination techniques in an exoatmospheric geometry viewing intercontinental ballistic missile (ICBM)-class target sets. EDX is a significant contributor to the GSTS project. The first EDX missions are scheduled for FY 1995 and are being planned as coordinated measurements with the MSX project.

Cobra Judy is a ship-based radar platform configured to collect S- and X-band radar signature data. X-band radar data collection began in FY 1986. Cobra Eye is an airborne optical platform that began collecting LWIR data in late FY 1989 with Initial Operational Capability occurring in early FY 1990.

Cobra Judy and Cobra Eye will continue to collect data that will support strategic defense discrimination development and evaluation. In FY 1991, SDIO will assume the majority of the funding responsibility for the Cobra Eye project. Cobra Eye will support several SDI missions in FY 1991, including two ERIS test flights, one Firebird flight, one Zodiac Beauchamp flight, and one Red Tigress flight.

In FY 1990, passive and active discrimination algorithm development continued. Appropriate algorithms were evaluated using available data. Development of algorithm networks that coordinate several radar algorithms into an architecture was initiated. Algorithm architectures are required to provide a high level of discrimination capability against a varied threat. Algorithm development and evaluation are continuing activities. Promising algorithms and architectures are encoded on the real-time Lexington Discrimination Systems (LDS) test bed for critical evaluation. Several GBR algorithms were evaluated this year with the LDS system and radar data base.

In FY 1990, the Strategic Target System (STARS) booster was going into its final development phase. In the fourth quarter of FY 1991, the first operational launch will be conducted. The payloads on this mission will be part of a cooperative project with the United Kingdom.

All critical design reviews for MSX sensors and spacecraft were completed in FY 1990. Fabrication of sensors, subsystems, and spacecraft continues with spacecraft integration to be accomplished in FY 1993. MSX mission and experiment simulations will be conducted in FY 1993. MSX currently is planned to be launched on a Delta rocket from Vandenberg Air Force Base during the first quarter of FY 1994. Mission operations are expected to continue into FY 1999.

Beginning in FY 1991, the Sounding Rocket Measurements Program (SRMP) will conduct two sounding rocket target flights per year. These flights are designed to collect exoatmospheric data on various penetration aid concepts to evaluate penetration aid deployment and optical signature credibility. Two SRMP flights scheduled for May 1991 are designed to help resolve key target/instrumentation issues identified on earlier SRMP flights and Delta 181. The FY 1992 SRMP flights will use a new TALOS-ARIES booster system which provides increased measurement time (~100 seconds more), lift capability, and payload space. The FY 1992 flights will be used to assess dynamics and signature aspects of inflatable balloon decoys. Future SRMP flights will provide critical flight testing of penetration aid targets prior to use by two major SDIO space experiments (MSX and EDX).

4.2.3 Test Environment

This section provides the successes and plans of the National Test Bed, Theater Test Bed, Airborne Surveillance Testbed, and SDIO targets project.

National Test Bed

The National Test Bed (NTB) has been designed to simulate, test, and evaluate strategic defense concepts, architectures, battle management, and hardware applications. Additionally, the NTB is designed to test command and control interfaces with human-in-the-loop and hardware-in-the-loop technologies. The NTB is a network of geographically distributed test facilities, connecting nodes of the Army, Air Force, Navy, and national laboratories. The National Test Facility (NTF) serves as the operational hub of this integrated system of satellite and ground-linked test facilities. This network provides the capability to address system integration and performance evaluation capabilities. The NTB hosts the following activities: computer simulations to aid in the design and validation of ballistic missile defense architectures and the planning and operation of hardware assets; exercising and verifying the Command Center, system operations and integration functions, and doctrine associated with strategic defense and space defense operations; development of a comprehensive data base of simulations; operation of a software center incorporating software technology and development tools; operation of a software engineering environment, rehosting, and applications library; interactive gaming; conduct of studies and analysis of simulation results; experiment planning and test and evaluation; environmental analysis to support various Dem/Val studies; and the generation, distribution, and archiving of threat tapes and maintaining a centralized data base of technical information to support threat modeling.

In 1990 the NTB was successful in many activities, including the following:

- Establishing of an SDIO super-computer center in the National Test Facility
- Completing significant studies and analyses in support of SDIO research (i.e., Brilliant Pebbles, Time-phased deployment, Midcourse and Terminal Tier Review architecture support)
- Establishing the NTF as SDIO's premier gaming center to support U.S. Space Command's command operations
- Completing software confidence assessments on five medium- to high-fidelity system simulation models
- Developing and hosting the National Threat Generation Model (TG90A)
- Enhancing system simulation, revision 2.3; enhancements added Brilliant Pebbles capability and increased the level of detail of the simulation's tracking and correlation computations
- Designing, developing, and testing the framework of the Level 1 SDS simulation

- Completing system element model integration into the Level 1 SDS simulation; testing of the first build of the Level 1 SDS simulation
- Establishing modeling capability to identify and quantify system supportability requirements for candidate system architectures
- Establishing strategic defense system cost-accounting models that are traceable to components of candidate architectures.

Theater Test Bed

The Theater Test Bed effort will develop computer-based analysis centers to evaluate the component and overall system designs postulated for theater missile defense. This effort will develop a common base for simulation software and the means to augment it with location-unique software for specific, local analysis. It will also provide the capability for man-in-the-loop/hardware-in-the-loop experiments and the networking of test bed centers. In addition, the effort will identify, design, and evaluate appropriate joint and unilateral experiments. The Theater Test Bed will provide the capability for operational users, doctrine developers, and system engineers and analysts to address the issues associated with theater missile defense.

In FY 1991, the U.S. Extended Air Defense Test Bed (EADTB) System Specification was approved, the preliminary design of the simulation framework for the United Kingdom EADTB was completed, and the top level and detailed designs for the Israeli Test Bed were approved. The Israeli Test Bed will become operational in the first quarter of FY 1992. Also, the U.S. EADTB will complete software development and initiate testing in FY 1992.

Airborne Surveillance Testbed

In September 1990, the Airborne Surveillance Testbed (AST) was deployed to Kwajalein Atoll for its first experiment against an actual ICBM target. The target was a Minuteman III missile with three Mark 12 warheads flying a trajectory from Vandenberg Air Force Base into U.S. Army Kwajalein Atoll. The AST acquired and tracked the bus and all three warheads. The track accuracies achieved and the demonstration of general sensor functions established that the discrimination scheme conceived for the E^2I interceptor will work as required. The AST project has four ballistic missile defense missions scheduled at Kwajalein for FY 1991. In February 1991, the AST performed an integrated theater defense experiment with the Patriot air defense system. During this test, the AST acquired a theater ballistic missile target, established a target track, and passed that track to the Patriot system. While no intercept was attempted, this experiment clearly established the ability to link optical and radar sensors together in real time and demonstrated the applicability of optical sensors in the theater defense role.

Targets

The SDIO's consolidated targets project coordinates the development of test targets (RVs, decoys, balloons, etc.) based on multiuser requirements. SDIO-wide test requirements are compiled and analyzed by SDIO and USASDC and a target schedule is defined which allows sufficient lead time for target design, development, and testing. The previous targets project consolidated technology and element projects to eliminate duplication of effort in the two projects and streamline the target development process.

Activities conducted and initiated during the past year include: (1) The ERIS Flight Test targets were developed for the ERIS project's first flight which was successfully conducted on 28 January 1991. (2) The Baseline Target Set Study was conducted to determine the feasibility of a set of baseline targets which would meet the vast majority of test requirements. (3) The design was completed for the Operational and Developmental Experiments Simulator (ODES), a post-boost vehicle simulator. Initial mockups were built and initial testing of ODES and R4D engines was configured for early 1991 testing. The ODES will be used to deploy targets to support the MSX testing in the FY 1994 to FY 1995 time frame. (4) A Test Target Study is being conducted to evaluate past and planned flight test data and the usefulness of such data to validate and expand signature codes.

A contract was awarded in 1990 to design and produce a theater ballistic missile target that would accurately represent the threat posed by bulk or canistered chemical munitions. This target will be used by the TMD program to evaluate theater defense weapon capabilities and to validate lethality predictions and criteria.

4.2.4 Directed Energy Technology

From the start, the SDIO recognized directed energy technologies as an important contribution to robust anti-ballistic missile defenses. While directed energy weapon (DEW) systems are follow-on elements and are being pursued at a slower pace, they continue to be of major interest. Using lasers or particle beams, a strategic defense system could engage targets across thousands of kilometers in space to deliver killing energy. Targets are reached nearly instantaneously, thereby negating maneuver-to-avoid-intercept as a tactic and overcoming the time-of-flight constraints of other interceptors. In limited attacks, where more time is available to hold the lethal beam on the target, DEWs can increase the probability of success by dwelling longer and increasing the energy delivered. Equipped with precision acquisition, tracking, and pointing subsystems, DEWs could perform all of the functions of defense: detection, tracking, identification, interception, destruction, and damage assessment. Directed energy capabilities access most of the phenomena currently envisioned for destructive, interactive, active, and passive discrimination of decoys from targets. A directed energy weapon/kinetic energy weapon synergistic mix can provide a strategic defense deployment with formidable capabilities, forcing an attacker to sophisticated counters and complex tactics. These characteristics, along with worldwide coverage and effective boost-phase intercept, can make DEWs very effective systems for global protection against limited strikes.

In the execution of the directed energy projects of the SDI, directed energy weapon elements for Particle Beams (both neutral and charged particle beams), Space Lasers, and Nuclear Directed Energy are being examined. An Acquisition, Tracking, Pointing, and Fire Control (ATP-FC) project supports all the DEW concepts. In progress to date, the DEWs have been conceptually designed to augment and extend the capability of any initial deployment of sensors and kinetic energy weapon interceptors. Technologies are being successfully demonstrated at the integrated subsystem level.

Chemical Laser

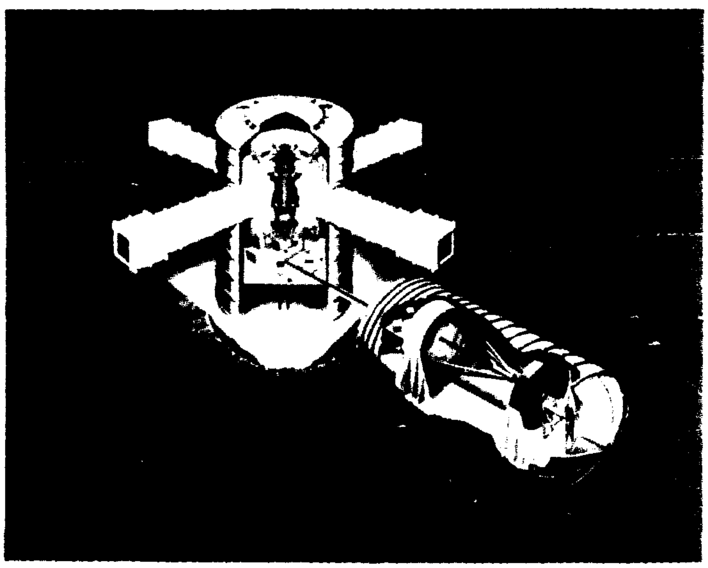
Technology accomplishments in the past year have established the space-based hydrogen fluoride (HF) chemical laser as a viable space defense concept. Space-based lasers could reach down into the atmosphere to engage ballistic missiles of all types and could also engage ballistic missiles in space.

The key technical achievement was successful testing of the Alpha Laser. On November 30, 1990, Alpha completed its sixth lasing test achieving megawatt-class operation in a space-operable configuration. This demonstrated that current technology to generate a high-quality and high-energy beam can be scaled to weapon-level requirements. Also, a wide-field-of-view sensor was integrated into the three element telescope assembly of the rapid optical retargeting brassboard. The brassboard will validate hardware and controls for smoothly and quickly moving the high-power beam from target to target without slewing the large structure of the space laser weapon. Another achievement was the development and testing of highly reflective multilayer dielectric coatings with unprecedented low absorption and scatter. These coatings will markedly improve the efficiency of beam handling and transfer in the weapon system. Finally, several techniques for lowering the threshold power for phase-conjugating continuous wave HF lasers were validated experimentally. These validations were important steps in realizing highly innovative beam control techniques that can increase performance while lowering acquisition and operation costs.

In prior years, other key subsystems of a space laser weapon have been successfully demonstrated. The Large Optics Demonstration Experiment (LODE) resolved central issues associated with wavefront sensing and control and the 4-meter Large Advanced Mirror Program (LAMP) mirror was successfully tested. These technologies will be integrated with the Alpha technology in an advanced technology demonstration called the Alpha/LAMP Integration (ALI) (see Figure 4-18) experiments. ALI, in work since early 1990, will resolve all of the technical issues involved in the high-power integration of a laser device and requisite beam control and beam expansion subsystems which can be addressed on the ground.

Demonstration and validation of space laser technology in space will occur in the STAR LITE advanced technology transition demonstration. STAR LITE will conduct experiments of key space laser functions at the performance levels achievable with Alpha, LAMP, and LODE derivative hardware and ATP hardware described elsewhere

Figure 4-18
ALI Test Facility Configuration



in this chapter. With the completion of the STAR LITE experiments, requirements for the transition of the space-based laser into system acquisition will have been essentially completed. STAR LITE is programmed for launch in the late 1990s.

Free Electron Laser

The space-based free electron laser (SBFEL) project emerged from what was previously the ground-based laser (GBL) project. Due to the severe funding constraints placed on the FEL project, the GBL concept had to be abandoned. Work on the FEL continues as a far-term space laser approach. The SBFEL concept can perform the same roles and missions as the space-based chemical laser, potentially with much less weight on orbit for a given performance level. Primary interest is as a beam generator for the very high performance levels required for a robust far-term threat.

As the project was being focused away from the GBL concept, significant achievements occurred in the area of atmospheric propagation of lasers. The Scaled Atmospheric Blooming Experiment propagated a laser beam horizontally 100 meters through the atmosphere. The test successfully characterized the interaction of the FEL beam with the atmosphere measuring the impact of thermal blooming and atmospheric turbulence on the ability to propagate the beam. A 400-meter propagation experiment is planned this year that will complete the characterization.

Development of the RF FEL continues to mature, with the successful operation of the ring resonator at the FEL facility in Seattle, Washington. Near-term plans for the FEL project focus on the design and fabrication of a proof-of-principle high-average power FEL device. This effort, known as the Average Power Laser Experiment (APLE), will demonstrate a 10.6-micron-wavelength, 100-kW FEL utilizing a same accelerator-master oscillator power amplifier design. The first light from APLE is planned for mid-FY 1993. The results of the APLE demonstration will be the basis for a decision on future development.

Particle Beam

Significant progress continues to be made on realizing a neutral particle beam (NPB) weapon. The stream of particles generated by the NPB weapon penetrates into the target to deliver lethal energies and/or induce signatures that permit discrimination of balloons and decoys from reentry vehicles.

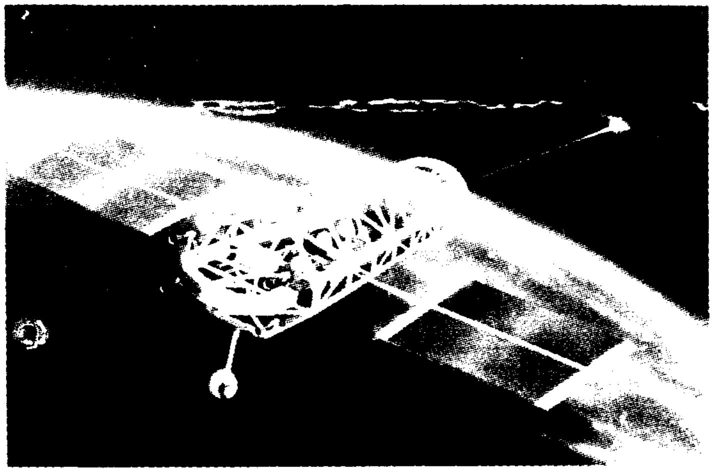
The Ground Test Accelerator (GTA) is integrating the technology from the previously successful beam production experiments at high brightness on the Accelerator Test Stand and the beam control experiments at required levels on the Argonne beamline. The combination of these technologies on GTA will provide the first fully integrated NPB beamline, in 1993, scalable to weapon level. The ion injector and the radio frequency quadrupole have been successfully integrated on GTA. The beam was successfully transmitted on the first attempt. This has provided high confidence in the codes for the design and manufacture of these technologies. The Continuous Wave Deuterium Demonstrator test accelerator project is also achieving success. Ion injector tests have been completed, successfully demonstrating a hydrogen ion source at continuous wave duty factor and high brightness.

The Army Background Experiment was launched aboard the Low-Power Atmospheric Compensation Experiment spacecraft in February 1990 to gather data on the background neutron distribution in space. Preliminary analysis indicates that the data being gathered are of excellent quality.

Critical component technologies are being developed to support the major ground- and space-integrated experiments. Foils of unprecedented diameter, strength, and thinness were developed last year for the beam neutralizer. To increase system brightness a two-beam funneling test in mid-1991 will build on last year's successful one-beam experiment. World-record peak radio-frequency fields and accelerating gradients were achieved in superconducting accelerator cavities.

Pegasus (see Figure 4-19), a follow-on experiment to the Beam Experiment Aboard Rocket flight, which successfully propagated the first particle beam in space on July 13, 1989, is in the design phase. Pegasus will provide weapon traceable technology for key NPB issues that cannot be tested on the ground. The design of the Pegasus spacecraft will continue through 1991, with hardware fabrication and integration to begin in 1992. At the end of 1990, a concept definition study was initiated on a pop-up version of the NPB to interactively discriminate RVs from decoys and balloons before they enter the atmosphere. The pop-up NPB would be significantly less expensive than the space-based version and could provide an effective adjunct to a continental U.S. defense in a GPALS architecture.

Figure 4-19
Artist's Concept of Pegasus



23 returns

The charged particle beam project has achieved several recent major advances in demonstrating feasibility. Successful propagation of an electron beam in a laser-formed channel has been demonstrated. Determination of high-explosive detonation thresholds for electron beams was also established in 1990. Research is continuing on controlling and propagating electron beams.

Acquisition, Tracking, Pointing, and Fire Control

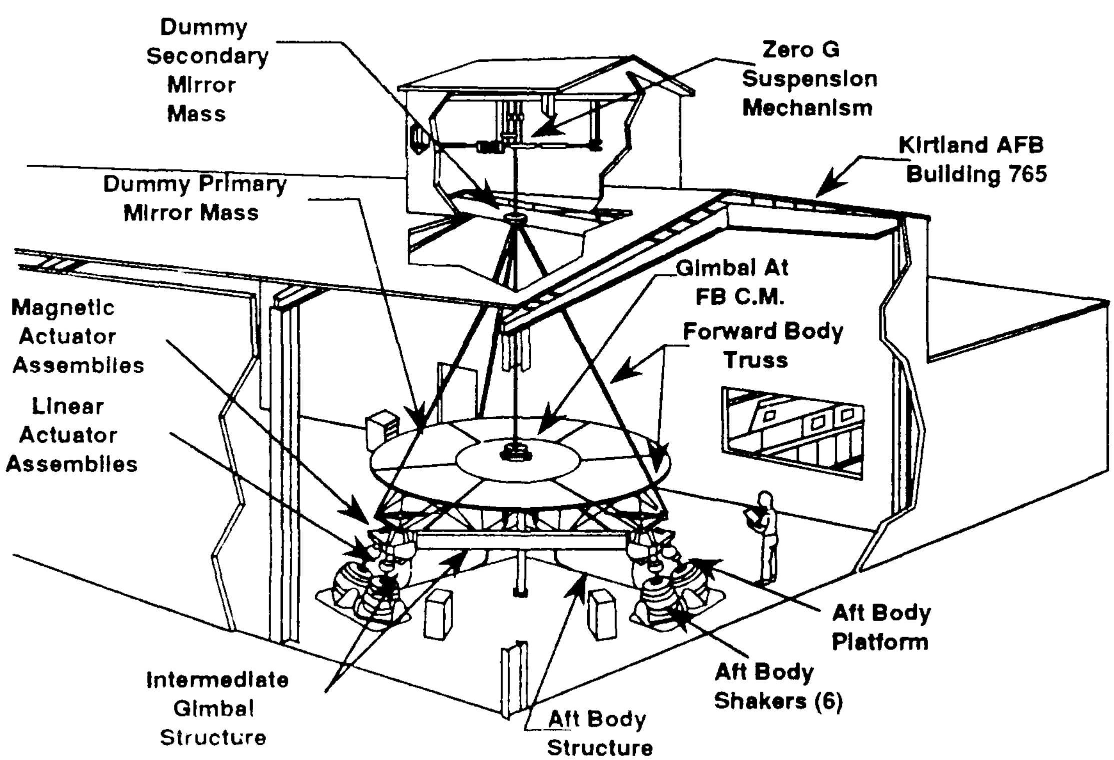
The ATP-FC project includes both space experiments and technology base projects. As noted in the 1990 report, the Relay Mirror Experiment (RME) satellite, with the Wideband Angular Vibration Experiment auxiliary payload, was placed in orbit by a Delta booster on February 14, 1990. Also orbited by this launch was the Low-powered Atmospheric Compensation Experiment (LACE) with an auxiliary payload, the Ultraviolet Plume Instrument. The two spacecraft and all of the payloads have performed successfully. The RME project is designed to demonstrate critical pointing and tracking technologies for both space-based and ground-based elements of DEW concepts. The RME spacecraft is in a 450-kilometer near-circular orbit. In consistently successful relay experiments, sensors on the spacecraft simultaneously track two independent ground beacons, and the orientation of a 60-centimeter-diameter flat mirror is controlled to reflect a laser beam transmitted from one beacon site to a remotely located target board at the other beacon site thus demonstrating high pointing accuracy, laser beam stability, and long-duration beam relays. This is a significant contribution to gaining confidence from the design of target acquisition subsystems for all types of strategic defense weapons.

Another major ATP-FC space experiment project, Starlab, successfully completed subsystems test before the project was terminated due to FY 1991 funding limitations. A new experiment project, Altair, is being formulated in an effort to achieve the most important objectives of the Starlab project at lower cost. Altair will be a free-flyer spacecraft experiment which will use some residual Starlab experiment assets. The tentative schedule is an initial launch capability in early FY 1995.

In December 1990, the first Starbird target booster was successfuliy launched. Starbird was developed to provide economical, dedicated booster targets for the Starlab project and other SDI efforts. The data collected from this experiment will refine the Altair experiment requirements and will provide the basis for Altair-dedicated booster targets.

ATP-FC technology base progress included completion of the Space Active Vibration Isolation (SAVI) project. This laboratory experiment demonstrated the feasibility of simultaneously isolating a large structure representative of a laser beam expander telescope from base motion disturbances, while controlling (within limits of $\pm 2°$) the pointing direction. Figure 4-20 illustrates the test assembly at the U.S. Air Force Phillips Laboratory, Kirtland AFB, New Mexico. The SAVI experiment facility

Figure 4-20
SAVI Pointing and Isolation Experiment



is now being modified to support a more advanced experiment configuration, the Space Pointing and Integrated Controls Experiment (SPICE). SPICE will combine the SAVI isolation and pointing capability with tracking sensors and multilevel control systems to demonstrate integrated tracking and pointing control dynamics in a simulated zero-gravity environment.

A significant technical need for directed energy ATP-FC systems is a laser illuminator with long life, high efficiency, low weight, and moderately high power. A project was initiated in FY 1990 to develop an illuminator brassboard demonstrator using diode-pumped solid-state laser technology. This technology will be used to meet the Altair experiment requirements, and higher-power versions will be developed to meet future requirements.

The Common Module Tracker (CMT) project will develop a complete ATP-FC subsystem as a follow-on to Altair, and will support integrated experiments in space or in a laboratory environment to address the full set of ATP-FC technology issues. CMT will provide ATP-FC functions for DEW technology demonstrations such as STAR LITE.

Nuclear Directed Energy Weapons

Nuclear directed energy weapon (NDEW) research is being pursued to provide a base of knowledge concerning such weaponry that would give the U.S. insight into potential Soviet capabilities and to provide the basis for a U.S. NDEW capability should it be needed in the far term against responsive ballistic missile threats. The NDEW research path is based on theoretical and computational development in concert with underground nuclear tests and related laboratory experiments. The Department of Defense and Department of Energy cooperative effort will continue to conduct mission analyses as well as explore platform engineering issues.

4.2.5 System Engineering and Integration

The system engineering and integration (SE&I) effort for FY 1990 focused on simplifying the strategic defense system architecture utilizing state-of-the-art SDIO technology developments. The resultant architectural modifications recommended by several community-wide studies were to evolve into a robust, highly testable system, while concurrently achieving significant overall cost reductions. The design concepts formulated by the candidate element organizations were modeled in significant detail and their overall contribution toward system effectiveness was measured along with associative costs. Selection of the final architecture was made in concert with the element designers to ensure that the technology risk was well balanced with resultant cost-at-the-margin considerations.

Following the top-level studies which formed the framework for the architecture selection process, the system definition process was initiated to further refine the specific requirements which are the result of balancing performance/cost trades among the system's elements. The system was then further tested against a diverse set of candidate threat scenarios to validate its capability to satisfy the complete set of mission objectives defined by the user community Documentation of the detailed system and element requirements was completed and reviewed with the various element organizations to ensure consistency with candidate design capabilities. Several high-fidelity simulators and test beds were initiated to provide further confidence during the Demonstration Validation phase of the program that the system risk areas can reasonably be addressed with a high level of confidence prior to transitioning into the Full-Scale Development Phase. An extensive System Analysis Review (encompassing nearly 60 hours of presentation, with a multiple-volume set of data packages) was held midyear to communicate the results of the SE&I efforts to the overall SDIO community.

The focus for the SE&I activities in FY 1991 will be to ensure that the system is fully responsive toward meeting the defined objectives for a GPALS. This effort will entail further development of mission needs and some additional definition of candidate test cases. The strategic missions for the GPALS system will essentially be unaltered from those protection missions previously studied for the Phase I system; the main drivers which are derivatives of the previously defined missions will be to ensure very low leakage by a reduced threat set (both in numbers and in discrimination requirements). Additionally, because the GPALS mission will encompass the mission subset of theater defense against ballistic missiles, a significant task to be addressed this year will be integration of globally capable strategic space sensor and weapon assets with deployable area protection surface-based weapons and sensors.

The adjustment of system requirements to allow a near-term GPALS deployment (which can efficiently evolve, if directed, into a Phase I system providing deterrence/protection against massive attacks) will cause some revision to the current element requirements as a result of rebalancing via trades. This, along with the appropriate modifications to the analytic tools, simulations, and test beds, will be accomplished and captured in revised system/element requirements documentation. A comprehensive System Analysis Review will be held in FY 1991 to validate the system's ability to meet GPALS mission objectives with a high degree of effectiveness. Dem/Val program plans will be adjusted to ensure technology and test resources are focused on those areas that demand the highest priority for risk mitigation prior to FSD.

4.2.6 Command and Control Technology

Command and control technology activities for FY 1991 are shown in Figure 4-21.

Figure 4-21
FY 1991 Command and Control Activities

TECHNOLOGY AREA	ACTIVITIES	IMPACT
Mobile Command Centers	Completion of the design of the Core Support Module.	Rapid update of Command and Control displays
	Prototyping of GATE, a decision display software	
Networking Technology	Continuation of algorithm (software) development	Network control
Ground Entry Points	Development of communication technology	Needed for fixed and mobile ground entry points
Common Test Environment	Development of common test environment	Efficiency in simulation development

4.2.7 Producibility and Manufacturing

The challenge of developing a series of strategic defense elements that can affordably and reliably incorporate a succession of advanced technologies requires SDIO to make producibility a significant consideration during demonstration and validation. This is accomplished by pursuing a concurrent engineering strategy which makes use of multidisciplinary teams—whose membership includes manufacturing planners. Because there is little or no manufacturing experience associated with many of SDIO's proposed technologies, this design trade-off process must be iterative. Producibility issues and risks must be identified early and considered in design and systems trade-off decisions, and risk mitigation strategies must be developed. The producibility and manufacturing (P&M) project in SDIO consists of pursuing this design and planning strategy while making early investments in key areas.

During February 1990, a producibility programming and issues resolution strategy was developed codifying P&M issues and risks of both Phase I elements and technology projects. Although based on Phase I designs, many of the issue descriptions and top-level integration plans are still applicable to GPALS.

The development of new system elements and missions—such as Brilliant Pebbles—provided an opportunity to incorporate P&M in contractor design trade-offs from the start. Brilliant Pebbles, especially, recognized that demonstrating that a number of advanced technologies were producible and affordable was critical to success. Producibility and the demonstration of manufacturing and testing capabilities became key aspects of the project.

Establishment of a comprehensive risk identification and management philosophy by a Program Office is vital to executing concurrent engineering—which is key to the SDIO P&M project. SDIO's system engineering and integration contractor developed a producibility/technology risk assessment methodology for the MATTR study and has been applying it to the system elements of the GPALS architecture.

The FY 1990 project continued to make key investments in critical generic P&M areas via SDIO's Manufacturing Operations Development and Integration Laboratories (MODILs). The Survivable Optics MODIL, integrated by Oak Ridge National Laboratory, opened an aspheric fabrication cell to complement their established precision machining and metrology cells. Efforts began in FY 1990 on the ion-finishing cell which would be part of the Productivity Validation Test Bed. The test bed is available for cooperative experiments with industry. The Survivable Optics MODIL also completed the first assessment mirror buy in this project. Contracting with the U.S. optics industry on a fixed-price, firm delivery basis (instead of the traditional R&D "best effort" contract) was used to baseline industry capabilities and identify manufacturing and metrology problems. Oak Ridge and the Survivable Optics MODIL also pioneered the use of cooperative research and development agreements, a way that industry can protect its proprietary data yet gain access to national laboratory capabilities.

Besides the Survivable Optics MODIL, SDIO sponsored initial projects toward establishing an Advanced Sensor and an Advanced Signal Processing MODILs through Sandia National Laboratory in FY 1990. The Advanced Sensor MODIL looked into strained-layer superlattices as an alternate material to mercury cadmium telluride for LWIR focal plane arrays. They also fabricated initial FPAs (2 x 2) and successfully performed some initial-radiation environment testing. The Advanced Sensor MODIL employed the facilities and expertise of Sandia in supporting SDIO signal processing projects and project contractors. SDIO is also planning MODILs for space-qualified fabrication and testing and for efficient production of mission-qualified software.

4.2.8 Lethality and Target Hardening

Lethality and Target Hardening research and development provides validated lethality criteria for the successful development of effective GPALS weapons concepts and assures defensive warhead effectiveness against nuclear, chemical, biological, and conventional ballistic missile threats.

Theater Missile Defense lethality research continued to receive strong emphasis. In 1990, TMD lethality experiments were conducted to study hydraulic ram effects. The results led to models for chemical agent aerodynamic breakup and dispersal for the TMD bulk chemical threat. The lethality tests have shown that the size, number, angle, and relative velocity of defensive warhead fragments make a significant difference in the destructive force imparted to a threat chemical warhead. The total energy imparted to the sample targets in Figure 4-22 is the same, but the energy density is different, implying a minimum fragment size to ensure destruction of threat bulk chemical warheads (only the three targets on the right are killed).

Also during 1990, the "Theater Missile Defense Lethality Criteria (Preliminary)" document was published to support anti-tactical missile weapon upgrades and development. These criteria quantify bulk chemical-threat keep-out envelopes. Keep-out envelopes have been demonstrated to be critically important in the defense of Tel Aviv and Riyadh against conventional warheads. Keep-out envelopes are even more important for nuclear, chemical, and biological warheads.

In 1990, the project also executed an Aerothermal Reentry Experiment 2E flight test to validate criteria for assured aerothermal/structural destruction of damaged RVs above a prescribed keep-out altitude (see Figure 4-23). The damaged RV is the short streak in the sky; the long streaks are undamaged RVs.

Research continued during 1990 on assessing how to kill all RVs when engaging a post-boost vehicle (PBV). To date, no lethal mechanism has been shown to destroy all the RVs on a PBV, but we are developing lethality technology options to optimize our defensive effectiveness.

In Fiscal Years 1991 through 1992, the Lethality and Target Hardening project will assess the results of Patriot-Scud engagements for lessons learned. These lessons

Figure 4-22
Lethality Against Bulk Chemical Threats

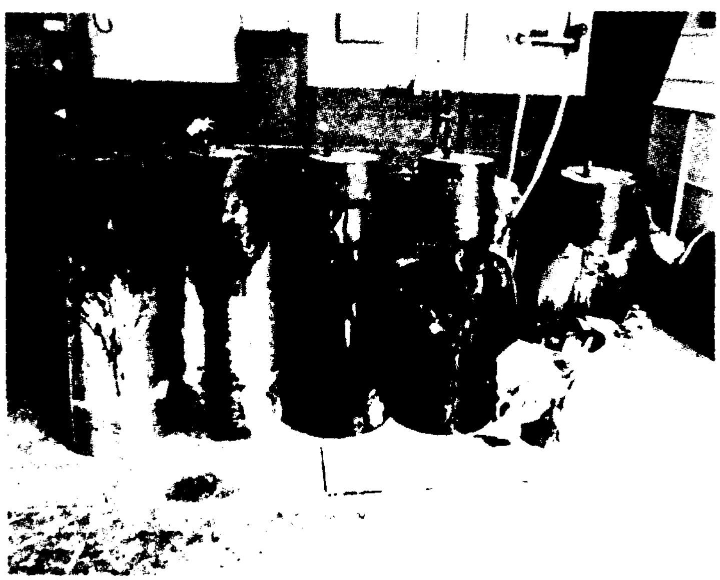
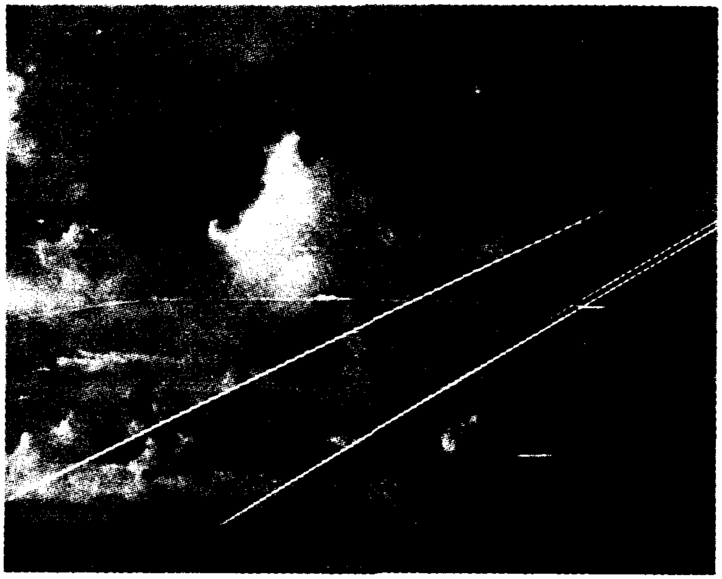


Figure 4-23
Aerothermal Reentry Experiment

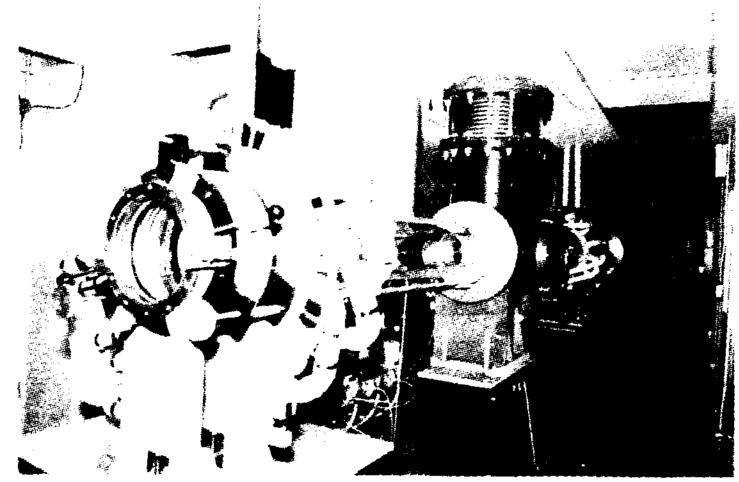


will be applied to TMD lethality research. We will conduct a flight test against a ballistic missile with a chemical warhead to quantify agent breakup and validate keepout envelopes. We will continue the Aerothermal Reentry Experiment series of flight tests to validate aerothermal/structural lethality and will conduct a mock PBV propellant initiation test to assess its potential lethality contributions to RV kill. Requisite procedures for assessing the environmental impact of these and other tests will be observed.

4.2.9 Survivability

The Survivability Technology Project has achieved significant results this year in many technology areas vital to the GPALS architecture. For example, assessments for the theater missile defense system have started development projects in concealment and radar face armor technologies and testing of support equipment for susceptibility to chemical/biological agents. In the sensors area, the survivability project, through experiments like the July 1990 Mineral Quarry underground test, has selectively analyzed and tested the nuclear, laser, and radio-frequency hardness of critical sensor components including focal plane arrays, baffles, mirrors, lenses, windows, optical filters, and the critical tolerance structures which hold these components in precise alignment. In the area of thermal control, demonstrations of materials now available to withstand laser attack occurred at the Laser Hardened Materials Evaluation Laboratory (LHEML) at Wright Laboratory. LHEML II has been constructed to support laser survivability tests of large system components. Its carbon dioxide laser operates at the 10.6-micrometer wavelength and provides 100 kilowatts power on target. It also uses a large vacuum chamber to perform tests in simulated space environments. The LHEML II CO_2 continuous wave laser device is shown in Figure 4-24. Figure 4-25 provides a summary of the survivability accomplishments and their significance.

Figure 4-24
Laser-Hardened Materials Evaluation Laboratory CO_2 Laser



4.2.10 Power and Power Conditioning

Preliminary designs and testing of power subsystems were completed for two competing survivable solar power subsystem demonstrators, called SUPER. Specific technical accomplishments included verification of survivability and performance requirements Analyses showed the SUPER subsystem to be cost and mass competitive with off-the-shelf technologies for a vast range of missions, including Brilliant Eyes. Due to recent SDI architecture emphasis on smaller low-power satellites such as Brilliant Eyes and Brilliant Pebbles, the SUPER subsystem is being restructured. Designs for the low-power SUPER concept will be completed in FY 1992. The P-91B flight test in FY 1995 will flight qualify the SUPER innovations which provide high survivability at low mass.

Preliminary design was completed for a hardened solar planar array design that is more appropriate for the lower hardness requirements at geosynchronous orbits. Initial technology development of large area solar cell, array substrate, and mast was also finished. The hardened solar planar array design has been transitioned to the Air Force.

A solar panel of gallium arsenide solar cells is currently on orbit aboard the Combined Radiation Release Experiment Satellite (CRRES). The results of this experiment will validate gallium arsenide solar cell performance when subjected to the high-energy radiation of the Van Allen belts and other experiment conditions aboard CRRES. These results will be applied to future solar planar array approaches for Brilliant Pebbles and Brilliant Eyes.

During FY 1990, the design and assembly of a 16-cell sodium sulfur battery were completed. Experimental low earth orbit cells have been life-tested through approximately 4,000 charge/discharge cycles. The sodium sulfur battery used in solar power systems reduces battery mass by a factor of two for solar power systems including SUPER. Upon completing material changes and design improvements, long-life testing of 42 sodium sulfur battery cells will begin in the fourth quarter of FY 1991. Planning is under way to include a space flight validation experiment of a sodium sulfur battery on the P-91B satellite.

Figure 4-25
Survivability Accomplishments

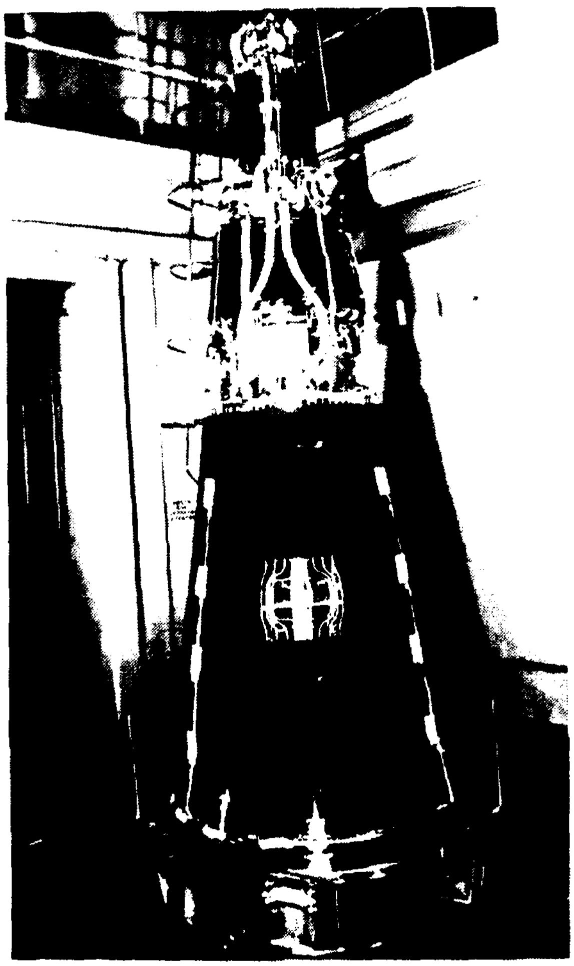
SUBSYSTEM	ACCOMPLISHMENTS	IMPACT
Sensors	Demonstrated GBI filtering algorithms Initiated wavelength-agile protection Conducted Mineral Quarry underground nuclear test Lightweight mirror Baffles Critical tolerance structure Characterized infrared detector response to radio frequency threats	Enables tighter intercept spacing Protects sensors against many laser wavelengths Reduces cost, improves performance Establishes performance of competing materials Not likely to limit performance in the nuclear environment Demonstrates importance of RF threat—will lead to hardened designs
Communication	Developed hardened 60 GHz system components	Allows testing of a hardened communications system
Guidance/Control	Tested inertial measurement unit components	Allows hardened IMU design
Power	Conducted laser and Mineral Quarry tests of solar power components	Determines cost-effective solar power design
Thermal Control	Performed LHEML II tests of thermal control coatings, adhesives	Adhesives and thermal control materials now available to withstand laser attack
Structure	Developed carbon-carbon components	Only structural material that withstands high laser threat loads
TMD	Initiated radome armor development Supported equipment chemical agent tests	Protection for acquisition tracking radar Identify chemical hardening requirements
Active Techniques	Conducted STARMATE post-test analysis	Identify candidate active survivability enhancements for space elements.

A joint SDI-Air Force-National Aeronautics and Space Administration (NASA) project has fabricated two designs of a cryogenic oxygen heat pipe experiment to fly in a Space Shuttle "Hitchhiker" canister. This type of heat pipe is critical to selected SDIO focal plane array sensor systems.

In the SP-100 nuclear power project, thermoelectric elements were fabricated. These elements demonstrated successful electrical current generation at the reactor design temperature. The reactor and outer reflector core have been redesigned to provide more robust control and reduce mass. Substantial progress has been made in the design of the nuclear-hardened instrumentation and control multiplexers. The SP-100 project will complete design and begin fabrication of the coolant loop, including thermoelectric magnetic pumps and heat exchangers, by the first quarter of FY 1992. Design of the thermoelectric converter/pump assembly is scheduled to be complete by the fourth quarter of FY 1992. Restart of site preparation is scheduled to begin by the first quarter of FY 1995. SP-100 is being developed to meet baseload power requirements beyond those that can be practically met with solar power systems.

Life-cycle testing of thermionic fuel elements (TFE) continued in FY 1990. Sufficient test data have been accumulated to indicate a potential for a 7-year operational life for a multiunit TFE. In-core life testing of thermionic fuel element cells, sheath insulators, and cesium reservoirs will continue to develop reliability data for 7- to 10-year applications of units. A new thermionic reactor system technology is being developed as an alternate reactor project. It is expected that arrangements to purchase an unfueled TOPAZ II class reactor and test facilities for non-nuclear testing at the University of New Mexico will be completed in FY 1991 (see Figure 4-26). Non-nuclear testing of TOPAZ II reactor will begin in FY 1992 and end in FY 1994.

Figure 4-26
Thermionic Space Nuclear Power



Significant progress continued to be made during FY 1990 in the non-nuclear multimegawatt technologies. The design for a lightweight, hydrogen-cooled, insulated, and lubricated generator that will produce 40 megawatts has been completed. Testing of the one-megawatt exciter for the generator was completed, demonstrating the feasibility of this technology. Construction of the 40-megawatt generator is scheduled to be completed by early FY 1993. In another technology area, fabrication of a high-power-density (50-kilowatt) prototype lead-acid battery is complete. A high-power-density fuel cell stack will be tested in FY 1991. This fuel cell stack technology could increase the Space Shuttle fuel cell stack power density by a factor of 10.

Radio frequency (RF, or microwave) solid-state technologies are crucial to the NPB and FEL accelerators. Several concepts have been developed for the thermal management of RF devices, including operation at cryogenic temperatures to improve the efficiency of the device. Solid-state RF devices have demonstrated high-power density at over 70% efficiency with no device modifications at liquid nitrogen temperatures (approximately minus 200°C).

The Power project continues to maintain technology exchange discussions with technical and defense program representatives of the United Kingdom. Recent visits with other European Space Agency representatives and contractors have identified many technology development opportunities for cooperative SDI-European efforts, including solar arrays and thermionics.

The Directed Energy Power Demonstrator (DEPD), designed to integrate power technology components in an end-to-end power system appropriate for directed energy weapons and to demonstrate the feasibility and technology readiness in a cost-effective manner, will be initiated in FY 1991. DEPD is scheduled to be completed by the second quarter of FY 1995.

4.2.11 Materials and Structures

Materials and structures investments in critical materials technologies such as structural lightweight composites, space environmental effects, tribology, optical, and superconducting material and structures have provided spacecraft components with superior properties enabling significant improvements in the performance of space defense systems. Insertion of advanced materials will be facilitated by the Space Active Materials Modular Experiments (SAMMES) providing an industry standard module for materials testing in the space environment. Integration of advanced technologies into an adaptive structures effort (see Figure 4-27) for on-orbit health monitoring, control, and threat attack assessment has been initiated.

Some of the significant FY 1990 accomplishments of the Materials and Structures project in support of GPALS and follow-on systems are shown in Figure 4-28.

Planned accomplishments for FY 1991 through FY 1993 are as follows: (1) continue advanced-manufacturing and component-joining methods of metal-and-glass matrix, thermoplastic-resin, and carbon-carbon composite structures, (2) continue natural environment space- and ground-simulation testing of critical platform materials, (3) design and fabricate SAMMES modular hardware and conduct space environment effects materials experiments in support of low-earth-orbit system elements, (4) design, fabricate, and conduct performance tests of lightweight dry lubricant, precision bearing assemblies for BE sensor platform gimbal structure, (5) conduct altitude firing of an N-dimension carbon-carbon GBI class nozzle and fabricate and test moveable carbon-carbon nozzle and motor for interceptor boosters, (6) fabricate, optically and mechanically characterize, and survivability test advanced optical baffles for sensor systems, (7) develop a project in adaptive structure technology for active vibration suppression, on-orbit system identification, system aging and health monitoring, and threat attack warning and assessment, (8) fabricate and demonstrate system performance on orbit of a hybrid semiconductor and high-temperature (70°K)

Figure 4-27
Adaptive Structures Technology Integration

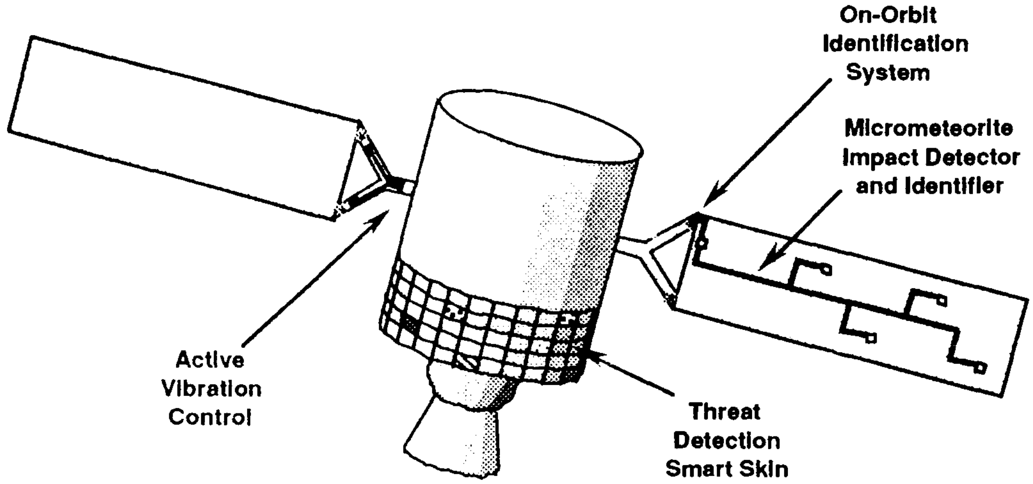


Figure 4-28
Materials and Structures Accomplishments

TECHNOLOGY AREA	ACCOMPLISHMENTS	IMPACT
Materials	Demonstrated on-orbit materials properties stability of survivable thermal control coatings and atomic oxygen protective coatings	Ensures extended lifetime of space defense assets
	Conducting sea level firing of GBI class lightweight, low cost booster nozzle	Demonstrates carbon-carbon technology maturity to provide advanced nozzle option for ground-based interceptors
	Demonstrated superconducting analog-to-digital convertor for IR focal plane array processing	Improved target acquisition, tracking, and discrimination
	Demonstrated HEDI flight capable thruster port frame material and 4-D carbon-carbon nosetip on a high speed sled	Accelerates insertion of advanced structural and thermal control materials for high performance interceptors
Structures	Delivered advanced composite interceptor hover test housing to prime contractor for evaluation	Successful insertion of advanced thermoplastic composite materials technology
	Demonstrated adaptive structure truss actively damped strut using embedded sensor/actuators for system elements	Results provide baseline for space demonstration enhancing performance of system elements
	Completed dynamic ground test of lightweight, stiffened prototype ground based interceptor (GBI)	Successful demonstration enhances hit-to-kill probability

superconductor 60-gigahertz communication receiver on-orbit, and (9) demonstrate end-to-end performance of the 10°K superconducting LWIR detector, analog-to-digital converter, and signal processor for a space surveillance system.

4.2.12 Space Transportation

Progress continues to be made in maturing propulsion, avionics, structures, and operation-related technologies in the joint DOD-NASA Advanced Launch Development Program (ALDP). Over the last year, the Advanced Launch System (ALS) engine, type, size, and cycle were selected. The baseline ALS engine will be a 600-kilopound-thrust class, liquid oxygen hydrogen (LOX/H_2), gas generator cycle engine. Design is under way. Prototype-engine development is expected to begin in FY 1992. This LOX/H_2 engine will be the basis upon which the nation can build a modular family of space launch vehicles to satisfy both DOD and NASA requirements well into the next century.

In FY 1991, the Vice President, through the National Space Council, tasked DOD and NASA to develop a joint plan to address the development of a next-generation evolutionary, unmanned launch vehicle. The existing ALDP will form the basis for the joint plan expected to be completed in the early spring of 1991.

4.2.13 Innovative Sciences

This section describes two types of projects: Innovative Science and Technology (IST) and Small Business Innovative Research (SBIR). Figure 4-29 depicts the accomplishments in innovative science and research for 1990.

Innovative Science and Technology

The IST project is that part of the technology base effort that encourages prompt exploration of new initiatives. As such, its goal is to exploit innovative technologies seeking "breakthroughs or quantum leaps" that would improve the capability of a ballistic missile defense to perform its specific assigned functions.

The project provides funds for advanced research in fundamental science and engineering, focusing particularly on exploitable technical areas applicable to ballistic missile defense. The IST office sponsors fundamental research in six areas: (1) advanced high-speed computing, (2) materials and structures for space applications, (3)sensing and discrimination, (4) advanced space power, (5) advanced propellants and propulsion, and (6) directed/kinetic energy concepts. This sponsorship, which is limited by available funding to a relatively small portion of potential participants, is exercised and carried out by 40 science and technology agents. These agents, in turn, enlist the services of innovators in many different scientific areas. Basic research results are structured to expand the forefront of science and technology, with ultimate transfer of such results to tasks in other parts of the SDI Program. IST research is conducted throughout the scientific community in universities (including those with a significant ethnic or minority student population), government and national laboratories, small businesses, and large industries.

Small Business Innovation Research

Pursuant to Public Law 97-219, the SBIR project provides seed capital for technology innovation that will help the federal government and foster commercialization of federal research and development (R&D) at small U.S. businesses.

SBIR rewards innovations by small U.S. firms where seed capital is needed to mature the technologies enough to attract users and venture capitalists. SDI spreads 1.25 percent of its extramural R&D among hundreds of firms developing technology innovations that help SDI and also hold promise of commercialization. Competition is

Figure 4-29
SDI Innovative Science and Research Accomplishments

RESEARCH AREA	ACCOMPLISHMENTS	POTENTIAL APPLICATION OR IMPACT
Fast Electronics	Demonstrated worlds quickest transistor, a 22-picosecond gate delay	Tenfold faster than today's: faster transistors mean faster computers
Diamond Films	Developed free-standing diamond mask for x-ray lithograph	Both commercial and military electronics
Electro Magnetic Launcher	Propelled 95 grams at 5.6 kilometers/second	Washington, DC to New York City in 1 minute
Microwave Power Projection	Demonstrated largest ever microwave energy and power (20 gigawatt) from a single source	Reached power levels predicted for 1995; microwaves could burn electronics of RVs
Missile Detection	Confirmed the ultra-violet glow from ICBM bow-shock is 50 times the calculated value previously calculated	Found a beacon with which to find the hard body
Multiplying Microwave Power	Proved, with a 6-gigawatt power source, that phase-locking allows separate microwave power sources be added	Microwaves could burn RV electronics
Infrared Detectors	Developed 6 to 8 percent efficiency silicon/germanium detectors	More efficiency means better sensors to locate the missiles
Electric Propulsion	Nearly doubled specific impulse with hydrogen arcjet	Moving orbiting satellites to view sensitive areas
Accelerometer	Demonstrated a tiny accelerometer that works even after high radiation dose (SBIR)	Interceptor survivability improved
Composite Materials	Developed a higher damage resistant composite	Tenfold increase: system elements with longer lives and greater survivability
Solar Blind Detection	Demonstrated diamond film as solar blind detector-first lightweight solid state solar blind detector	Solar blind detectors can see into the atmosphere even when sunlight bounces off the clouds and air
Miniaturized Electronics	Demonstrated triple speed in half the space for an analog-to-digital converter	Smaller processors
Long-Wavelength Detection	Achieved high pixel-to-pixel uniformity in silicon	Improved detection and tracking of cold bodies
Superconducting Gyroscope	Made tiniest superconducting gyroscope (SBIR)	Smaller and lighter interceptors
Laser Interference Filter	Demonstrated a light filter a million times more sensitive	Satellite-to-satellite contact by laser

Figure 4-29
SDI Innovative Science and Research Accomplishments (Cont'd)

RESEARCH AREA	ACCOMPLISHMENTS	POTENTIAL APPLICATION OR IMPACT
High-Power Simulation	Simulated 100,000 amperes and 100,000 volts in space near-vacuum conditions	High power for space-based weapons
Laser Beam Steering	Bent a laser beam 28° with one-fifth the power	Laser radars must use minimum power to bend beams to detect and track missiles
Light Traps	Developed a new material that records data with green laser and reads it with red laser (SBIR)	Optical storage of data is much more compact than straight magnetic storage of data for computing and signal processing
Heat-Resistant Electronics	Developed first bipolar silicon carbide transistor (SBIR).	Silicon carbide can withstand heat; less cooling required for electronics
Shrinking Detectors	Demonstrated a dynamic comparator that cuts circuits size by 90 percent for analog-to-digital converters (SBIR)	Smaller system elements
Light Heat Pipes	Developed the thinnest walled alkali metal heat pipe	Thinner walls mean lighter weight system elements, thus less launch cost per target kill
Ranging Finding	Quintupled target detection range with new moving target indicator (SBIR).	Improved target detection provides more time to react and intercept
Intermetallic Materials	Developed economic method for making intermetallics	Tenfold faster; cheaper intermetallics means cheaper system
Signal Processing	Found numerics for efficient wavelet image representation	Efficient representation results in smaller computers
New Design Guide	Rewrote the book of design rules for high power in space	High power for space-based weapons
Atmosphere Measurement	Delivered instrument package for French atmospheric probe satellite	Laser beam propagation through the atmosphere

keen; only one-fifth of the candidates get the $50,000 Phase I awards, and only 40 percent of those receive the $500,000 2-year-duration Phase 2 awards. SDIO probably selects the highest percentage of Phase I awards among all federal agencies. The current allocation will continue in accordance with PL 97-219, although new legislation is under consideration to increase it.

SDIO completed 29 Phase 2 projects in FY 1990. Further development of those project concepts by SDIO, DOD, and other users may follow as Phase 3. Each Phase 2 contract was managed by a government expert who knows where the firm's technology fits into SDI and the areas where it would fit into other DOD programs. SDIO is developing projects to help connect the Phase 2 successes with other government and commercial opportunities.

4.2.14 Technology Application

In response to Congressional and Presidential initiatives on competitiveness and technology transfer, the SDIO established the Office of Technology Applications to develop and implement a technology applications project designed to make SDI technology available to federal agencies, state and local governments, universities, and

U.S. business and research interests. SDIO acts as a facilitator by referring those who have a technology requirement to the inventors and developers of SDI-funded technology.

Technology Transfer Mechanisms

The SDIO Office of Technology Applications has developed a technology transfer data base referral system, the Technology Application Information System (TAIS). The SDIO TAIS contains nearly 1,500 unclassified, nonproprietary abstracts describing SDI technologies in such areas as superconductivity, sensors, lasers, supercomputers, materials, and industrial processes. Entrepreneurs and researchers can access the TAIS by computer modem to identify potential investment opportunities, supplement research and development activities, or move an emerging technology from the laboratory to the marketplace.

The SDIO Office of Technology Applications also participates in activities which bring together SDI-related technology experts with commercialization specialists from universities, laboratories, research institutions, businesses and professional associations. These meetings are designed to encourage and accelerate the transfer of SDI-developed technologies to the commercial marketplace.

Several technology transfer demonstration projects are conducted by the Office of Technology Applications. These demonstrations range from meeting the needs of the medical research and treatment community with SDI-developed technologies to encouraging cooperation between SDI developers and state and educational institutions which are involved in technology transfer.

In addition to the TAIS, the SDIO Office of Technology Applications conducts a technology transfer outreach project which includes the following components:

- Briefings and speeches to professional societies and trade associations
- Prominent leadership of the activities and initiatives of key technology transfer institutions, particularly the National Technology Transfer Center and the Federal Laboratory Consortium.

SDI Spinoffs

SDI-sponsored research is serving as a catalyst for spinoffs in many scientific and technical fields. Spinoffs, for example, have been spawned in medicine, computer technology, electronics, aerospace innovations, optics, automotive engine components, as well as industrial and manufacturing processes. Figure 4-30 provides examples of some of the spinoffs.

Figure 4-30
SDI Technology Spinoffs

SPINOFF AREA	EXAMPLES
Medicine	Use of lasers, originally developed with SDI funds, to remove burn and scar tissue from the skin; fragment kidney stones; treat heart disease, cancer, glaucoma, and psoriasis; and remove tattoos without scarring the skin Use of SDI-developed carbon material for use in orthotic braces. This has led to fabrication of leg braces that are twice as strong and weigh two-thirds less than steel braces Medical supply companies evaluation of a photodynamic treatment process that cleanses donor blood bank supplies of herpes, measles, hepatitis-B, and HIV
Computer Technology	Computer-aided design tools Components for optical computers Development of new computer security measures
Electronics	Electronics integrated into flow meters and magnetometers Laser technology used to design range finders and to micromachine integrated circuits Electronics that help analyze sensor images Advanced materials that improve sensor performance Semiconductor electronics
Aerospace Technology	New technologies incorporated into airport bomb detectors Instrumentation that tests missiles and rocket engines A polymer-materials process that makes lightweight, durable materials for space structures Inspection of rocket motors and aircraft engines for corrosion, internal damage, and structural defects
Optics	A high-resolution, wide-angle lens with applications for television and satellite navigational systems Manufacturing process to make precision lenses and mirrors A synthetic diamond materials process used in optics
Automotive Engine Components	Materials in automotive engine components An efficient electrical generator that works without moving parts
Manufacturing Process	An industrial manufacturing process that casts parts and equipment for use in electronics, cars, satellites, and spacecraft A polymer materials process designed to make electronic circuit boards

Chapter 5

SDI and the Allies

Chapter 5
SDI and the Allies

This chapter responds to the Congressional requirement to include in the 1991 Report to the Congress on the Strategic Defense Initiative the status of consultations with other member nations of the North Atlantic Treaty Organization (NATO), Japan, and other appropriate allies concerning research being conducted in the SDI Program.

The security of our friends and allies has always been an objective of the SDI Program, and we will pursue even more active participation on their part in the Global Protection Against Limited Strikes (GPALS) defensive system.

5.1 GPALS and the Allies

President Bush, in his 1991 State of the Union address, directed that the SDI Program be refocused to provide protection from limited ballistic missile strikes for the United States, for U.S. forces overseas, and for our friends and allies. Several elements in particular of the GPALS defensive system could contribute to the protection of U.S. allies and friends:

- GPALS sensors, which could provide threat information to U.S. forces and, potentially, to those of our allies and friends as well
- Surface-based theater systems to defend against theater/tactical ballistic missiles
- Space-based interceptors (Brilliant Pebbles), with their continuous, global interdiction capability against missiles with ranges greater than 600 kilometers.

With the refocusing of the SDI Program toward GPALS, the United States has significantly increased the priority assigned to theater missile defenses—improved theater missile defenses would be the first elements of GPALS to be deployed. Moreover, the U.S. Congress has appropriated funds to accelerate Theater Missile Defense (TMD).

With respect to theater defenses specifically, the United States could deploy such transportable defenses to a region during times of heightened tensions, or they could be permanently deployed by a government on its own territory. It is likely that U.S. forces forward deployed in peacetime will have theater missile defenses as part of their equipment.

The United States believes a number of friends and allies will be interested in the TMD aspects of GPALS, particularly because third world ballistic missile proliferation is a growing concern to many of them. If friends and allies decide to deploy their own theater missile defenses, i.e., in parallel with those deployed by the United States, we would envision them as being autonomous systems potentially capable of being interoperable with elements of United States defenses, such as receiving space-based sensor data to increase their efficiency.

The deployment of GPALS would contribute to the security of U.S. friends and allies. To that end, there are several general areas for cooperation with allies and friends on GPALS:

- Participation in SDIO's basic research and development programs that have application to GPALS. This could mean participation in technology research and development, or in GPALS-related experiments.
- Government-to-government cooperation specifically in TMD-related aspects of GPALS, which may be of particular interest to allies.
- Independent acquisition of a theater missile defense system, either purchased from another country such as the United States, or indigenously developed, which could be interoperable with other elements of a GPALS system.

Such cooperation would not be a new activity. Allied participation in SDI research predates the refocus of the program toward GPALS. In fact, the United States has already developed a considerable level of allied participation in SDI-related research since early in the program (see Sections 5.3 and 5.4).

5.2 Consultations With Allies on the SDI

Consultations with allies on the SDI broadened and deepened throughout 1990, and early 1991. As in past years, such discussions are a regular feature of numerous bilateral and multilateral meetings with allied officials at all levels, both in Washington, D.C., and abroad.

After President Bush announced the refocusing of the SDI Program, the United States presented allied and friendly governments greater detail on GPALS than the 1991 State of the Union address provided. In addition, the United States briefed the NATO High Level Group on the GPALS concept in January 1991.

President Bush, Secretary of State Baker, and Secretary of Defense Cheney have discussed the Program in many of their bilateral meetings on security matters with their allied counterparts. Secretaries Cheney and Baker also consulted with NATO defense and foreign ministers on the SDI and SDI-related arms control issues at the ministerial meetings of the NATO Nuclear Planning Group (NPG) and the North Atlantic Council. Ambassador Cooper, Director of the SDIO, discussed in October 1990 the changing global threat and the need for ballistic missile defenses with senior allied leaders in London and Paris.

Also, in response to former Prime Minister Thatcher's request to receive, during a private visit to Colorado, an update on SDI's technology achievements and to meet some government and industry personnel who are contributing to those achievements, SDIO hosted a visit of the former Prime Minister to the National Test Facility, Falcon Air Force Base, Colorado Springs, on August 3, 1990. In addition to receiving an overview briefing on the National Test Facility and its National Test Bed network, former Prime Minister Thatcher toured technology displays and was briefed on SDI's technology achievements by the attending scientists and engineers. In an address at the conclusion of the visit, the former Prime Minister stated, "I firmly believe that it was the determination to embark upon that SDI programme and to continue with it that eventually convinced the Soviet Union that they could never, never, never achieve their aim by military might because they would never succeed." and "...we must always keep our defences sure and we must always keep our technology well ahead."

In addition, U.S. officials consulted extensively with allied leaders, both bilaterally and at NATO, on the results of high-level meetings with the Soviet Union at which SDI was discussed. For example, the United States consulted its allies immediately following each round of the Defense and Space Talks in Geneva. Furthermore, senior government and industry personnel from several allied countries have visited the United States for detailed technical discussions and updates on the SDI Program. In addition, the SDI Program is sponsoring annual advanced planning briefings to acquaint government and industry representatives from selected allied nations, as well as U.S. industry, with SDI projects, initiatives, missions, and future acquisition plans. The SDIO also sponsors an annual classified multinational conference on theater ballistic missile defense technology.

5.3 Allied Participation in SDI Research

Allied participation in SDI research is of great benefit to the United States as well as to the participating nations. Allied participation contributes to the timely attainment of SDI objectives with work of the highest quality performed at the lowest possible cost.

The United States has signed Memoranda of Understanding (MOUs) on participation in SDI research with the governments of the United Kingdom (December 1985), Germany (March 1986), Israel (May 1986), Italy (September 1986), and Japan (July 1987). The MOUs are not related to specific projects; they are designed to facilitate allied participation in SDI research insofar as permitted under U.S. laws, regulations, and international obligations (including the Anti-Ballistic Missile Treaty). While such an MOU is helpful, it is not mandatory for participation. Companies in countries that have not signed an MOU have successfully competed for contracts, and countries that have not signed an overarching SDI MOU have signed government-to-government agreements for cooperative research on specific SDI-related projects.

All SDI contracts are awarded strictly on the basis of technical merit and cost in accordance with the procurement practices mandated by the Congress. Several such provisions apply to the awarding of SDI contracts to foreign firms. The Bayh Amendment to the FY 1973 Department of Defense Appropriations Act provides that no Department of Defense research and development (R&D) contracts may be awarded to foreign firms if a U.S. entity is equally competent to carry out the work and is willing to do so at lower cost. The Defense Appropriations Acts for Fiscal Years 1986 and 1987 prohibited any set-asides of funds for SDI research contracts awarded to foreign firms and stated that U.S. firms should receive SDI contracts unless such awards would be likely to degrade research results.

In 1987, the Congress enacted additional legislation (Section 222, National Defense Authorization Act for Fiscal Years 1988 and 1989) regarding allied participation in the SDI Program. The new legislation prohibits the award of new SDI contracts to allied entities unless certain conditions are satisfied. Such provisions shall not apply to the award of subcontracts. In FY 1990 four contracts were awarded to foreign entities under Public Law 100-180, Section 222, Subsection (b). Of these contracts, SDIO awarded one to the United Kingdom (U.K.) Ministry of Defence (MOD) to develop and demonstrate an innovative machine tool based on the Tetraform principles. The Department of the Air Force awarded the other three contracts; of these contracts, two were awarded under a Broad Agency Announcement. The first award was to a British firm to design and model a system of fault-tolerant wafer-scale integration association string processor modules. The second award was to the National Center of Tribology, U.K. Atomic Energy Authority, to develop ultra-low friction, solid-lubricant films. The final contract was awarded to a U.S. corporation, wholly owned by a German firm, to fabricate a large glass ceramic mirror blank.

Long-standing laws and policies governing rights to research results developed under U.S. contracts ensure that the U.S. technology base receives the benefits of all SDI research, whether performed by a domestic or foreign contractor. In accordance with these laws and policies, the U.S. government will receive rights to use the technology developed under SDI contracts. Contractor rights to use the results of their SDI research depend on security considerations and the specific conditions of each contract. These ground rules for cooperation are fully reflected in each of the MOUs and Memoranda of Agreement (MOAs) the United States has signed on participation in SDI research.

A summary of major SDI contracts and subcontracts awarded to allied firms and research establishments between October 1985 and October 1990 is as follows:

- Belgium: $0.367 million. Theater defense architecture and laser algorithms
- Canada: $7.38 million. Power system materials, particle accelerators, platforms, and theater defense architecture
- Denmark: $0.028 million. Metrology of magnetic optics
- France: $13.38 million. Sensors, theater defense architecture, free-electron laser technology, and klystrons
- Germany: $76.75 million. Pointing and tracking, optics, lethality and target hardening, electron laser technology, and theater defense architecture
- Israel: $252.17 million. Electrical and chemical propulsion, magnetohydrodynamics, short-wave chemical lasers, theater defense architecture, Arrow experiment, and the Israeli Test Bed
- Italy: $15.79 million. Cryogenic induction, superconducting magnetic energy storage, millimeter-wave radar seeker, theater defense architecture, and smart electro-optical sensor techniques
- Japan: $3.83 million. Superconducting magnetic energy storage, superconducting materials, Western Pacific theater architecture study
- Netherlands: $14.34 million. Theater defense architecture and electromagnetic launcher technology
- United Kingdom: $95.18 million. Optical and electron computing, thyratrons, ion sources for particle beams, electromagnetic rail gun technology, optical logic arrays, countermeasures and penetration aids, test bed, and theater defense architecture analyses.

5.4 Cooperative SDI Programs With the Allies

Since the allies began to participate, SDIO envisioned cooperative programs as one modality for research efforts. Beginning with the FY 1987 National Defense Authorization Act, the Congress has continued to encourage such cooperation by providing specific direction and funding. Congressional language for FY 1991 states that SDIO's Theater and Anti-Tactical Ballistic Missile (ATBM) Defenses program element shall include programs, projects, and activities that have as one of its primary objectives cooperation with friendly and allied nations to develop theater defenses against tactical ballistic missiles. The following illustrates cooperative research arrangements with allies and their industries.

The 5-year cooperative research agreement on electromagnetic launcher technologies signed in July 1987 with the Netherlands Organization for Applied Scientific Research is proceeding extremely well. The electromagnetic launcher (EML) provided by SDIO as part of the project was initially tested in 1988. Since then, the Dutch have redesigned the EML to improve its performance, designed new types of solid armatures to improve launch efficiencies, and identified promising new concepts for pulse-power investigations. Beginning in the first quarter of FY 1991, the Dutch are also engaging in plasma armature research using an SDIO plasma utility gun system.

In June 1988, SDIO and the Israeli Ministry of Defense concluded an MOA for a cooperative SDI research project on the Arrow ATBM experiment. This experiment is designed to demonstrate the capability to intercept a surrogate tactical ballistic missile; it will be conducted at an Israeli test range. The first flight test of the missile occurred on August 9, 1990, and the second on March 25, 1991. A follow-on MOA for Arrow Continuation Experiments is currently being negotiated.

In March 1989, SDIO and the Israeli MOD concluded an MOA for a cooperative project to develop the Israeli Theater Ballistic Missile Defense Test Bed, an advanced computer simulation/emulation facility to be built in Israel to evaluate Middle East missile defense concepts and designs. Software design and coding for this computer simulation facility have been completed and software integration and testing are underway.

In November 1988, SDIO signed a contract with a Japanese firm to analyze and assess the unique requirements associated with the defense of U.S. and allied assets in the Western Pacific against attack by medium- and short-range ballistic missiles. The second phase of this effort was completed in March 1991 and a TMD architecture has been developed. Phase three will further define and evaluate architectures in light of contingency operations and further development of battle management, command, control, and communications (BM/C^3).

In May 1989, SDIO signed a cost-sharing contract to develop a low-cost hypervelocity gun with an Israeli government research facility. The project will develop a gun capable of accelerating projectiles to velocities in excess of 2.5 kilometers per second using electrothermal, or other advanced concepts, perform barrel and armature material research, and resolve other technical issues regarding hypervelocity gun technology. In 1991, efforts began to develop a 60-millimeter bore gun based on the successes with the 25-millimeter gun.

In January 1989, SDIO and the U.K. MOD signed a cooperative agreement to develop a prototype artificial intelligence framework. The framework is based on the principle of comparing *a priori* information about offensive missile objects to real-time sensor data. The prototype is based on a blackboard architecture where signal processing, clustering, and raid assessment rules are partitioned. Tasking and data sharing are managed adaptively by the framework control module to maximize the timeliness and accuracy of the discrimination process. Two of the three programs are near completion.

In April 1989, SDIO and the U.K. MOD signed a cooperative agreement in April 1989 to develop a Knowledge-Based System (KBS) Data Fusion Demonstrator. The effort will develop battle management algorithms based on KBSs for fusing information gathered by disparate types of sensors, an area identified by the European BM/C^3 Architecture Concept Definition Study as warranting further emphasis. The project involves developing a data fusion demonstrator and a research effort in KBSs. A study to define the research efforts has been completed.

In September 1988, SDIO, under a cost-sharing Letter of Offer and Acceptance with the U.K. MOD, undertook a joint cooperative project, known as the Extended Air Defense Test Bed. This test bed is designed to support extended air defense planning, concept analysis, doctrine development, and battle plan development. The project is now in the design and implementation phase. The simulation framework has been developed and is currently being tested. Requirements for a terminal tier experiment were defined as of March 1991.

Work is continuing with the United Kingdom to collectively develop neutral particle beam (NPB) technology. High-brightness, ion-source technology for SDIO is being developed on the Ion Source Test Stand at Culham Laboratory through the U.S. Air Force Office of Scientific Research. Culham Laboratory has also developed the ion source, instrumentation and control, and beam stop for the Continuous Wave Deuterium Demonstrator (CWDD), which will provide the low-energy ground integration and test for the NPB. The CWDD, during FY 1991, will be integrated and tested at Argonne National Laboratory in Chicago. Power technology for the CWDD is being developed by a British firm. Two British firms and Culham Laboratory have also assisted in designing the SDI Neutral Particle Beam Power System Demonstrator. Additionally, Culham Laboratory and one British firm have used significant internal funding to initiate the design of a space flight engineering NPB ion source for the Neutral Particle Beam Space Experiment (NPBSE). Because of the advanced quality of their effort, both Culham Laboratory and the British firm have been selected by the U.S. prime contractor for NPBSE to provide the ion source.

In January 1990, SDIO signed an MOA with the French Ministry of Defense regarding free electron laser (FEL) research. Under this 5-year agreement, information will be exchanged and cooperative research projects will be developed with the goal of reducing both the cost and schedule of the participants' research projects. Over the past year, visits and discussions have begun which are resulting in valuable information exchanges and initial concepts for cooperation in FEL research.

The above descriptions indicate that SDIO is conducting a robust program of cooperation with our allies. The SDIO also is engaged in exploratory discussions with allies to determine other areas of mutual research interest to be pursued in similar types of cooperative arrangements.

5.5 Summary of Allied Participation and Cooperation

Allied scientific excellence and technical capabilities have been and continue to be demonstrated through contractual efforts and cooperative research projects. They have made many technical contributions to both strategic ballistic missile and theater missile defenses. Currently, trends in allied involvement in the SDI Program are theater-missile-defense-related activities, test bed and technology experiments, and other cooperative activities of mutual interest. Continued allied participation and cooperation in the SDI Program promote greater scientific understanding and technological mastery of the ballistic missile defense problem. Through these multinational efforts, SDIO's theater and strategic missile defense technologies continue to advance. Additionally, such participation and cooperation will provide a sound basis for U.S. and allied leaders to make informed decisions about their common security.

Chapter 6

SDI Technology and Other Defensive Missions

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This chapter responds to portions of Section 224 of parts (b)(9) and (b)(10) of Public Law 101-189. This law requests details on SDI technologies that could be developed or deployed within the next 5 to 10 years to defend against significant military threats and which may help accomplish critical military missions.

The results of Desert Storm will be analyzed for some time to come, but, it provides a strong argument for the benefits of properly applied technologies. Clearly, smart sensors; smart weapons; integrated command and control; and a voracious appetite for data, communications, and processing capability were evident. These concepts are embodied in 1970s and early 1980s hardware weighing tens and hundreds of pounds. Through miniaturization, hardening, and integration, SDI provides solutions in ounces at a fraction of the cost. Further, new technologies such as electromagnetic guns and lasers offer solutions previously unavailable. The remaining sections show some of the applications in other defensive missions.

Several of the potential missions have been addressed earlier in connection with discussions of global protection against limited strikes (GPALS) and, i.e., defense against tactical ballistic missiles and defense against limited ballistic missile attacks. Therefore, this chapter will address other defensive missions—specifically, air defense, maritime operations, conventional forces, space defense, and tactical warning and attack assessment. No additional initial operating capability dates, funding estimates, or survivability and cost-effectiveness information for these other missions are provided because such information would be speculative at this time. The SDI projects referred to in this chapter are addressed in Chapter 4 and the Appendix to this report. Displayed in Figure 6-1 at the end of this Chapter are areas in which other defensive missions could benefit from SDI technologies. Figure 6-1 also shows the benefitting SDI technologies and provides the locations in Chapter 4 and the Appendix in which a description of the technology projects can be found.

6.1 Air Defense

The air defense mission encompasses surveillance, warning, interception, and identification or negation of unknown aircraft that penetrate the air defense identification zone. Systems that contribute to that mission in the North American continent include the Joint Surveillance System network of Air Force and Federal Aviation Administration radars, the Distant Early Warning Line/North Warning system of radars across Alaska and Canada, Over-the-Horizon Backscatter radar, Airborne Warning and Control System (AWACS) aircraft, and those fighter-interceptors on continuous alert. The technical promise of SDI could significantly improve air defense mission efficiency and effectiveness, especially against future threats.

Tactical air defense in a theater of operations is closely integrated with Theater Missile Defense (TMD), as discussed in Chapter 4, and includes sensors such as the AWACS and other (non-TMD) mobile ground-based radars. These provide early warning and engagement control of Air Force air defense and Army antiaircraft surface-to-air missile systems such as the Patriot (in its anti-aircraft role), Hawk, Stinger, and Chaparral, as well as Vulcan gun systems. This leads to a highly decentralized command and control environment that is today constrained by limitations in current Battle Management/ Command, Control, and Communications (BM/C^3) systems.

North American air defense assets operate as a system, with one type of surveillance asset compensating for the deficiencies of others. Interceptor aircraft are necessary because fixed surveillance sensors cannot identify all tracks. In some cases, AWACS aircraft and interceptors actually perform surveillance when transient gaps occur in radar coverage. If fixed or aircraft-based sensors had greater capability, interceptors could perform more critical missions. Improvements in sensor range, data processing, and operating efficiency would greatly facilitate the air defense mission.

Because aircraft can be diverted to many possible targets, it is difficult to discern the character of an air-breathing attack. However, broad patterns of mass raids can be revealed if information from multiple sensors can be assimilated simultaneously. Advances in survivable communications and distributed computation could significantly improve raid recognition, attack assessment, and efficient assignment of interceptors.

Theater air defense operations depend on limited sensor and BM/C^3 architectures, which are in turn affected by electronic countermeasures and raid size. The addition of adjunct sensors using a variety of physical principles would ensure sustained operation and preclude being hampered by a simplified development of countermeasures. Robust BM/C^3 and data processing systems are needed to ensure that adequate theater air defense operations are maintained

The air defense surveillance mission could obtain substantial benefit from a variety of SDI efforts. SDI electrical power projects could provide long-term energy sources for unattended ground-based radar systems. Battle management and communications systems within the SDI Program could facilitate sensor data fusion and attack assessment. Improvements in aircraft-based compact data processing and sensor operations could greatly enhance airborne surveillance of air-breathing threats. Survivable, high-data-rate communication systems could help maintain connectivity among the air defense regions and improve the allocation of interceptors and sensors within and among regions.

At the global level, SDI computational technologies and simulation display advances could help integrate air-breathing and missile threat information necessary to respond to combined attacks. SDI kinetic energy interceptor technologies may allow more intercepts with fewer aircraft. Sensor, kinetic energy interceptor, and battle management technologies pursued by the SDI Program could all be applicable to the strategic air defense missions.

Theater air defense operations could also benefit from the development of SDI technologies. For example, the extension of air defense systems to a more robust role could be derived from hypervelocity gun, laser, and kinetic-kill vehicle experiments. Early-warning attack assessment functions could benefit from sensor developments. Missile lethality enhancements could be based on improved lethality and vulnerability analyses. Command, control, and data processing could be improved as a result of the software development and signal data processing work being accomplished for the SDI Program. Reductions in size and weight of the missile components and better rocket motors and gun launch components will result in both increased range and higher probability of kill.

The utility of space lasers for worldwide air defense has been studied since the 1970s. Lethal beams can be projected to the cloudtops, destroying strategic bombers in seconds. Theater aircraft are similarly vulnerable. SDI progress in hydrogen fluoride chemical laser technology, and in the pointing and control of the high power beam makes a militarily useful system possible. An advanced development demonstrator could be configured to provide validated technology for both the missile and air defense applications.

6.2 Maritime Operations

The global maritime operations of U.S. naval units and fleets in peacetime and wartime are critically dependent on surveillance, communications, and the ability to intercept hostile forces beyond the range at which they can actively threaten fleet units. The U.S. Navy is confronted by a Soviet maritime threat of growing sophistication, a multidimensional force that possesses demonstrated capability for surveillance, track, and attack from space, air, surface, and subsurface platforms. Existing Navy defenses involve multiple layers and redundant systems, similar to those proposed for a layered strategic defense against ballistic missiles.

Massive raids of Soviet land-based bombers such as the Backfire (with each bomber carrying numbers of sophisticated anti-ship missiles [ASMs]) present a threat to the surface fleet. Technology spinoffs from the Endo-Exoatmospheric Interceptor project could contribute to the development of a long-range, ship-based missile for intercepting bombers.

The Soviet land-based bomber threat has greatly increased the fleet defensive perimeter. The United States, which desires to detect bombers at long ranges, requires secure and survivable communications networks and advanced processing capability to exercise command and control over widely distributed ships, aircraft, sensors, and weapons. Spinoffs from advances in communications, multiprocessors, intelligence interfacing, and software, all now under development in the SDI Program to meet the BM/C^3 needs of a global defense system, should greatly benefit fleet operations in both the near and far term. For example, the battle management software developed to track and intercept thousands of ballistic missiles and reentry vehicles (RVs) should be readily adaptable to the Navy's less stressing requirements to perform similar operations involving fewer seaborne and airborne friendly and hostile objects. Further, SDI software development tools employing artificial intelligence and knowledge-based technology should markedly reduce the cost and time required to develop and manufacture secure and fault-free software for tactical use.

In the longer term, it is expected that the Soviet bomber ASM launch range and jamming capability will increase and that bomber detectability will decrease. The SDI advanced infrared sensor technology, if applied in naval aircraft and air defense missiles, could help fleet defenses keep pace with advances in the bomber threat. Space-based radar, employing major advances in high-frequency and sophisticated signal processing techniques for extending sensor performance, will offer a valuable mix for confronting the Soviets with a multispectral surveillance, tracking, and targeting capability.

Spinoffs from hypervelocity gun and laser technology could result in highly effective ship-based weapons for close-in defense. For example, a rapid-fire electromagnetic gun (rail gun) that propels a low-cost guided projectile would be very attractive for defending against Soviet ASMs launched from bombers, ships, or submarines. Additionally, electromagnetic coil launchers, with the potential to launch much heavier aircraft from an aircraft carrier than is currently being done, offer a replacement for the steam catapults.

Applications of SDI laser weapon technology could provide the sure quick-kill defense capability needed to counter even the most advanced Soviet ASMs. Advances made in developing high-power microwave technologies for strategic defense may be applied to seaborne tactical weapons in defense against missiles and targeting satellites and, when delivered by missiles and aircraft in the form of a warhead, may be applied to suppression of enemy ship- and land-based defensive radars and C^3 systems.

6.3 Conventional Forces

For conventional ground force operations in a general war, it can be assumed that enemy forces will have deployed a vast array of weapons to provide massive firepower. This array includes tanks, mobile artillery, armored personnel carriers, and attack helicopters. These weapons are designed to provide the mobility and firepower necessary to defeat allied forces. As a counter to this capability, friendly conventional forces require continued infusion of new technologies to provide improved capabilities in the areas of firepower, fire control, command and control, communications, and improved power supplies to enhance the mobile operations of advanced weapons.

The SDI Program is developing a range of advanced technologies that could be used to develop advanced weapons, support systems, and control systems for conventional forces. For example, lightweight, rapid-fire hypervelocity gun technologies could provide significant improvements in anti-armor, antiaircraft, and fleet defense operations. These kinds of systems could be capable of long-range, rapid, lethal response to conventional attack, especially when coupled with low-cost guided hypervelocity projectiles.

In addition, the development of high-power-density power suppiies could provide a significant benefit to the modern conventional force, especially command and control and support elements. The technical improvements being made in communications, battle management, and resource allocation also are generating greater demands on the design of effective power supply systems that can provide sufficient power with low noise and/or thermal signatures. Lightweight, quiet power systems would contribute to reducing the signature of critical units, thus enhancing survivability while meeting power needs.

The ability to engage more than one target at a time is being developed through advances in computer-aided and controlled multitarget fire control systems. This ability would enhance the battle management functions of all forces and enhance their efficiency in the use of resources.

Recent experiments have demonstrated technologies related to hypervelocity weapons development and have demonstrated rapid-fire operations, launch efficiencies, projectile mass firings, electronic switch operations, and significant muzzle energies.

The SDI Program is pursuing technology for advanced fire control systems to track multiple targets and guide hypervelocity projectiles to targets. Included are lightweight command guided projectiles. Such projectiles could provide an air defense or anti-armor capability.

In another critical area, the SDI Program is developing technologies to automate the collection, fusion, and processing of massive amounts of intelligence data on a near-real-time basis. The application of expert systems will further facilitate processing the data to allow force structures to be categorized and tracked. These developments can ensure the timeliness and availability of reliable intelligence to keep pace with increased application of heliborne and mobile forces on a battlefield.

6.4 Space Defense

The defense of U.S. and allied military space assets is increasingly important as the United States becomes more dependent on the force enhancement capabilities they provide. The Soviets maintain their present co-orbital anti-satellite (ASAT) interceptor and electronic warfare capability, continue to develop large-scale directed energy facilities with satellite-attacking capability, and maintain a potential direct-ascent ASAT capability with their deployed anti-ballistic missile interceptor (the nuclear-tipped

Galosh). The problem of space defense covers the following three areas: space surveillance and tracking, space defense weapons, and space system survivability.

This section summarizes SDI contributions to provide sufficient warning and tracking information to support satellite survivability as well as a means to defend against, evade, or counter any attack on U.S. military satellites. SDI technologies are synergistic with existing near-term or planned systems, and are meant for countering and defending against the growing threat to our military space assets. Particularly relevant are SDI technologies being developed for GPALS (e.g., the Brilliant Eyes satellites, Brilliant Pebbles, and exoatmospheric ground-based interceptors) and ground-based lasers, as well as for responsive or random maneuver, and nuclear, fragment, and laser hardening of space platforms.

The SDI Program offers a wide range of sensor, radar, and laser technologies to address these problems. Multispectral focal plane arrays and on-board processing are being developed to work together to provide global coverage and multiple track file maintenance. The technology also may be used on rocket-launched suborbital "probes" for near-term use. Potential space- and ground-based radar technology for space object identification is exemplified by the phased-array Ground-Based Radar Experiment. Short-wavelength lasers have direct potential for tracking and providing rapid images of satellites. In the long term, interceptors or other means of active self-defense are likely to be required (ground-launched interceptors could be used against the co-orbital ASAT).

A third category of space defense technologies involves assuring space system survivability through passive and active countermeasures. The United States has worked on hardening of satellite sensors, structures, and communications systems. Because we must anticipate operations in a future wartime environment with advanced technology defense suppression threats, the SDI Program has invested in survivability technology aimed at high protection levels using both passive and active countermeasures.

6.5 Tactical Warning and Attack Assessment

Tactical warning and attack assessment (TW/AA) includes providing crucial information that decision makers require to allow them to respond adequately to a ballistic missile attack. TW/AA for strategic defenses will be accomplished using the complete suite of SDI sensors tied into the Command Center/System Operation and Integration Functions. These sensors would complement existing and planned systems. This surveillance and tracking capability also will enhance our current offensive-based deterrence posture. Integration of SDI sensors into the TW/AA network will require close coordination with the network operators and users to maintain system integrity and the confidence of those who depend on unambiguous warning and assessments. TW/AA functions are important in all aspects of defensive operations. The sensors being developed in support of SDI goals could provide similar support to conventional defense elements, aid in the proper assessment of information, and help develop appropriate warning.

For a multilayered system, tactical warning and initial attack assessment would occur in the boost layer. However, succeeding layers—post-boost, midcourse, and terminal—would provide additional sensor information on ballistic missiles or their deployed RVs.

During the boost stage, the Brilliant Pebbles satellites will contribute to the initial TW/AA stage. The BPs will detect the launch of ballistic missiles and provide rapid alert. The post-boost layer occurs as the post-boost vehicle (PBV) leaves the atmosphere and begins deploying its RVs and decoys. During this stage, as the RVs fly their ballistic trajectories, more accurate information about the enemy's targets and intent could be provided to prepare subsequent tiers for their defensive roles. This information also would aid in the timely management of offensive strategic forces.

Tracking using the Brilliant Eyes satellites would begin during the post-boost stage. This element would track the cold bodies of the RVs and other objects using advanced passive sensors. Using stereo processing in conjunction with other satellites, this element would be able to track the cold objects. Information for attack assessment would then be more accurate and would begin to include the number of RVs as well as their target locations.

In the midcourse layer, objects deployed from the PBV travel ballistically through space. Brilliant Eyes satellites, which would begin tracking in the post-boost layer, would continue to track reentry clusters. During the midcourse layer, the Ground-Based Surveillance and Tracking System would track the threat cloud. Accurate and timely tracking information would support battle planning and refinement of impact point predictions.

As objects reenter the atmosphere in the terminal layer, ground-based terminal radars could provide final attack assessment. This final assessment of the potential RV impact could aid force management.

To enable each tier's suite of sensors to provide continuous early-warning and attack assessment, survivable C^3 systems must be built. Systems contemplated by SDI complement C^3 systems already in place and being upgraded by the Air Force. SDI would build on these existing systems to provide continuous C^3 functioning via highly survivable communications links. Command and control nodes would proliferate on various weapons and sensor platforms, thereby reducing the vulnerability of the complete system. The SDI Program will provide the technology to implement most of these improvements into existing C^3 systems even if the decision is made not to deploy strategic defenses.

Figure 6-1

Potential SDI Technology Benefits to Other Defensive Missions

AREA OF BENEFIT TO OTHER DEFENSIVE MISSIONS	SDI TECHNOLOGIES	CHAPTER 4 PARAGRAPHS	APPENDIX PROJECT NUMBERS
Air Defense			
Long-term energy service	Electrical Power	4.2.10	1503
Sensor data fusion and attack assessment	Battle management and communications systems	4.1.4 and 4.2.5	1405, 2300, 3102, and 3306
Survivable high data rate communications			3102
Integration of threat information	Computational technologies and simulation deploy	4.1.4	2300, 3302, and 3306
More intercepts with fewer aircraft	Kinetic energy interceptor	4.2.1	1201 and 1202
More robust	Hypervelocity gun	4.2.1	1203
	Laser	4.2.4	1301 and 1302
	Kinetic-kill vehicle	4.2.1	1201 and 1202
Missile lethality	Lethality and vulnerability analysis	4.2.9	1502
Command, control, and data processing	Software development and signal data processing	4.1.2 and 4.2.6	1405, 2300, 3102, and 3306
Destroy strategic bombers and theater aircraft	Space-based chemical lasers	4.2.4	1302
Maritime Operations			
Long-range intercept	Theater endoatmospheric, and exoatmospheric interceptors	4.1.2, 4.1.4, and 4.2.1	1201, 1202, 1206, 2202, and 2203
Secure, survivable communications network and advanced processing	Communications, multiprocessors, intelligence, interfacing, and software	4.1.4, 4.2.5, and 4.2.6	1403, 1405, 2300, 2304, 3102, and 3109
Advanced infrared sensor technology in naval aircraft and air defense missiles	Advanced infrared sensor technology	4.1.4, 4.2.1, and 4.2.2	1101, 1201, 2102, 2103, and 3307
Close-in defense	Hypervelocity gun and laser	4.2.1 and 4.2.4	1203, 1301, and 1302
Conventional Forces			
Anti-armor and antiaircraft	Hypervelocity gun	4.2.1	1203
High-power density power supplies	Power and power conditioning	4.2.10	1503
Computer-aided and -controlled multitarget fire control	Battle management	4.1.4 and 4.2.5	2300, 3102, and 3306
Space Defense			
Support satellite survivability	Space surveillance and engagement and satellite survivability	4.1.3, 4.1.4, 4.2.1, 4.2.2, 4.2.4, and 4.2.8	1301, 1302, 1303, 1501, 2102, 2103, 2205, and 3307
Multispectral focal plane arrays and on-board processing	Space sensors	4.1.3, 4.1.4, and 4.2.2	1101, 2102, 2103, and 3307
Ground-based radar	Ground-based radar	4.1.4	1102 and 2104

Figure 6-1
Potential SDI Technology Benefits to Other Defensive Missions (Cont'd)

AREA OF BENEFIT TO OTHER DEFENSIVE MISSIONS	SDI TECHNOLOGIES	CHAPTER 4 PARAGRAPHS	APPENDIX PROJECT NUMBERS
Tactical Warning and Attack Assessment			
Boost phase	Space surveillance	4.1.3	1101, 2205
Post-boost phase	Space surveillance	4.1.3 and 4.1.4	1101, 2102, and 2205
Midcourse phase	Space surveillance	4.1.4	1101, 1102, 1103, 2102, and 2103
Terminal phase	Space surveillance	4.1.2 and 4.1.4	1102 and 2104
Survivable command, control, and communications		4.1.4, 4.2.5, 4.2.6 and 4.2.8	1405, 2300, 3102, 3110, 3302, and 3306

Chapter 7

Threat and Potential Countermeasures

Chapter 7
Threat and Potential Countermeasures

This chapter discusses adversary challenges to SDI including the known and potential third world and Soviet threat systems and countermeasures.

7.1 Introduction

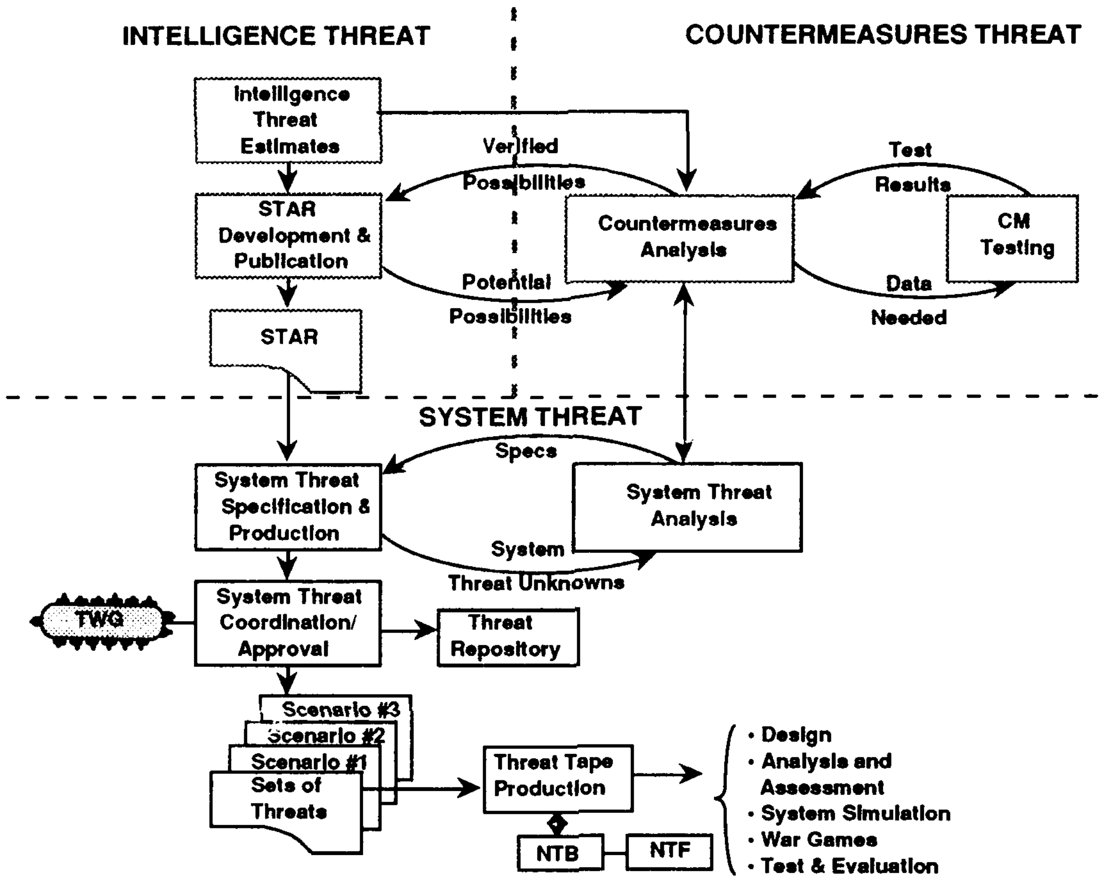
The threat environment for missile defense has expanded significantly. The President's decision to refocus the Program to protect the United States, its allies and friends, its forces overseas, and other interests against limited ballistic missile attack has recognized an evolving class of threats and encouraged a review of current assessments of the Soviet threat and countermeasures. In today's world, the proliferation of missile capability through arms commerce and technology transfer has created an environment that demands missile defenses. Recent events in the Middle East are evidence not only that such threats are real and can be employed but also that, when employed, even low-technology threats can have devastating consequences. Fortunately, those same events demonstrated dramatically that defenses can respond effectively to those threats. Thus, as missile technology proliferates in the third world, both the technology and the conditions under which ballistic missiles would be used will expand. As a result, the United States must respond to the capabilities and potential technologies available on the world stage.

While this significantly expands the scope of the threat problem into new dimensions, care must be taken not to neglect the continued capabilities and developments in the Soviet Union. The Soviet strategic force modernization program continues and their missile systems are being further improved in ways that portend a more capable and flexible future Soviet threat. Not only are new ballistic missiles coming on line, but development of future systems continues. Research and development on countermeasures to U.S. defenses, often discussed in the Soviet Union, is surely part of this development.

To effectively project and define the ballistic missile environment against which U.S. defenses must be effective requires a threat definition and specification effort that is based on the best intelligence community analysis; is realistic, consistent, and traceable to quantifiable analysis; and is applicable to the epoch when the defense will be deployed. The complexity and importance of these factors demand a broad, yet carefully managed, threat development approach.

Given the range and uncertainty of potential third world and Soviet threats that must be countered by a future U.S. defensive system, the Strategic Defense Initiative Organization (SDIO) maintains close ties with the U.S. intelligence community to define more accurately adversary capabilities and potential countermeasures. As shown in Figure 7-1, the threat definition process implemented within SDIO is an interactive process comprised of three parts: Intelligence Threat, System Threat, and Countermeasures Threat. The development of the Intelligence Threat results in the production of the System Threat Assessment Report (STAR) that is validated by the Defense Intelligence Agency and forms the basis for the threat specification and characterization efforts of the System Threat project. The threat specifications produced by the System Threat project are detailed, unambiguous descriptions of the projected

Figure 7-1
Threat Development Process



threat, written in engineering language, and presented in scenario formats, which can be used by system and/or element developers and designers to perform design/performance evaluations. The threat specifications are documented in Threat Description Documents and automated on threat tapes produced by the National Test Facility (NTF) for the National Test Bed (NTB) and other users. The Countermeasures Threat project provides a process by which potential adversary countermeasures to the proposed ballistic missile defense architecture elements can be identified, evaluated, and tested if required. As part of the Countermeasures Threat project, SDIO maintains a Red-Blue Team effort wherein innovative thinkers adopt an adversary mind-set (Red Team) and develop excursions to the baseline intelligence estimates. SDIO's close relationship with the intelligence community and its Red-Blue Team efforts enable it to maintain a balanced program with prudent hedges against realistic adversary capabilities.

7.2 Threat Environment

The threat to U.S. security is no longer limited to the Soviet Union. In addition to the ballistic missile countries with long-standing strategic nuclear and ballistic missile capabilities (i.e., Soviet Union, Great Britain, China, and France), there is a growing threat from various third world nations. Some of these have already acquired ballistic missile capabilities. Many, while not yet nuclear in nature, nevertheless pose serious threats to U.S. interests.

Currently, many third world countries have purchased or developed missiles with ranges equal to or greater than 300 kilometers, and some of these countries have missiles in development or operational with ranges greater than 500 kilometers. Although the United States, Canada, Great Britain, France, Germany, Italy, and Japan agreed in 1987 not to export missiles or technology for missiles in this capability range, the Soviet Union, and North Korea have been selling Scud-Bs or modified Scud-Bs to a variety of states otherwise incapable of acquiring such capabilities. China has sold CSS-2s and is taking orders for its M-9 and M-11 missiles, while Brazil is taking orders for its MB/EE series of missiles now in development. The Argentinean Condor II program seems to have fallen apart, but it indicates the interest in ballistic missile acquisition. Some countries have developed chemical warheads for use on these purchased or indigenously produced missiles.

At the same time as the third world threat is growing, it remains clear that the Soviets continue to demand an ever increasing capability in their ballistic missile forces. Their attitude on SDI will continue to be shaped by their perception of the effect that it would have on their overall strategic nuclear strategy—a strategy established independent of any consideration of SDI. To date, their perception has been that any U.S. anti-ballistic missile (ABM) defenses would severely undercut Soviet longstanding preemptive offensive force capability. Of all nations that pose ballistic missile threats to U.S. interests, the Soviet Union is clearly in the best position to develop counters to SDI. Their efforts to counter SDI will be driven largely by their assessment of the extent of the program (current and projected) and of how effective it would be against their systems. In determining specific countermeasures, they will likely rely on their historical practice of combining technology and tactics to undercut SDI effectiveness in the most straightforward manner.

By the end of this decade the composition of Soviet strategic forces will change significantly. The proportion of mobile intercontinental ballistic missile (ICBM) launchers will increase to about two-thirds of the total ICBM force. Heavy ICBMs will continue to carry about half of the total Soviet inventory of warheads, despite reductions in the number of launchers. The broad area available for deployment of both the SS-24 and SS-25 mobile systems and the use of concealment measures would complicate locating these systems in wartime. The capabilities of the new versions of the SS-18 will be substantially improved. The improvements will permit a smaller number of its multiple independently-targeted reentry vehicles (MIRVs) to effectively attack the same number of U.S. targets, including hard targets such as the U.S. Minuteman and Peacekeeper silos. The Soviets are destroying older ICBMs as new ones are deployed; thus by the end of the decade their force will consist of the SS-18, SS-24 Mods 1 and 2, and SS-25. Similar modernization is occurring with the submarine-launched ballistic missile (SLBM) forces. The size of the ballistic missile submarine (SSBN) force will decline by about one-third; however, it will be composed of more modern platforms with more lethal weapon systems. In sum, the Soviet force modernization program will produce a formidable force that is highly capable and more survivable and flexible than its predecessors.

7.3 Third World and Soviet Threat Capabilities

7.3.1 Representative Third World Ballistic Missile Threats

Third world ballistic missile system capabilities are spreading and growing. By the end of the decade a wide variety of missile production and commerce will be available to the world at large. The United States will have to develop means of responding to this situation. Ballistic missile defenses can make an important contribution.

Iraq: As is now well known, Iraq's strategic weapons program was aided by the Soviet-supplied Scud-Bs, which have a 300-kilometer range. Modifications and improvements of the Scud-B led to the Al-Hussayn and the Al-Abbas. The Al-Hussayn has a range of 600 kilometers and was used extensively in the war with Iran. The Al-Abbas was used against Israel and Saudi Arabia in the recent Persian Gulf War. Two Al-Abid SSM missiles were in testing prior to the Gulf War with a reported range of 2,000 kilometers. Iraq announced in December 1989 that it had successfully test-launched the first stage of a three-stage, 48-ton satellite-launch rocket, the Al Abid. Prior to the Persian Gulf War, Iraq was working very hard to acquire or develop nuclear weapon technology. As part of United Nations' Security Resolution 687, which established the terms ending the Gulf War, Iraq is required to accept the destruction, removal, or rendering harmless of its weapons of mass destruction including ballistic missile systems with a range greater than 150 kilometers.

Iraq's ballistic missile program is rightfully being seen as a harbinger of things to come. If Iraq can buy crude technology, upgrade it, and produce longer-range or more lethal systems, others can as well. In addition, Iraq is not the only third world country to pursue a developmental nuclear weapons program.

India: India already leads Southwest Asia in the indigenous production of arms. India has test-fired a two-stage Agni missile with a range reported between 1,500 and 2,000 kilometers.

Brazil: Brazil plans to expand its long-standing sounding rocket business into the production of military missiles. Brazil's missiles, the MB/EE-600, SS-300, and SS-1000, are reported to have ranges of 600, 300, and 1,000 kilometers, respectively.

Pakistan: Pakistan has recently received the Chinese M-11 system.

Others: Saudi Arabia has acquired CSS-2s from China. Scud-Bs from the Soviet Union and North Korea have proliferated for the past 20 years. Modifications to many of these missiles have increased their ranges from the original 300 kilometers.

Terrorists: As weapon systems proliferate, the opportunities for state-sponsored terrorist activities also increase. It was not anticipated that the Scud-B would proliferate and then be modified for nearly twice the range capability. It also was not anticipated that these modified versions would generate a new third world missile business with China and North Korea as early leaders for development and sales.

With this many players in the land-based and land-mobile systems, a transfer to ship-based systems is a reasonable extrapolation. Although the utility of this type of capability might be obvious for regional conflicts as well, the extreme application might use one or more shipboard missile launchers concealed in a single tanker cell, within a single container on a container vessel, or in the fish storage hold of a large fishing vessel. Such a vessel could target nearly any coastal city in the world while appearing to be on normal business.

7.3.2 Soviet Threat

Ballistic Missiles: The Soviet offensive nuclear force is composed of a wide variety of missile systems that are being continuously upgraded and modernized. Of these, the ICBMs have always been the most capable and presented the greatest threat; however, some SLBMs are approaching ICBM capabilities and will be a serious hard target, attack threat in the future.

The SS-18 Mod 4 and Mod 5 missiles have good accuracy and are capable of effectively attacking hardened silos. The Mod 5, which is replacing the Mod 4, has greater accuracy and increased yield.

ASATs: The Soviets continue to maintain their co-orbital anti-satellite (ASAT) system, the world's only operational ASAT system; it is a distinct threat to low-altitude satellites. Other Soviet systems that have ASAT capabilities or potential include the Galosh and one other type of ABM interceptor deployed around Moscow and in test silos at Sary Shagan and possibly lasers at Sary Shagan. The Soviets also have the technology to conduct electronic warfare against space systems.

KEW: Research and development of technologies applicable to more advanced ASAT systems continue at a steady pace. Areas of investigation that appear to hold promise include high-energy laser, particle beam, radio frequency, and kinetic technologies.

7.4 Countermeasures

In 1990, the Countermeasures project focused its effort on the potential technical abilities of the Soviet Union to respond to the proposed U.S. strategic defense systems and architectures. The project focused on this area for two reasons: (1) the Soviet ballistic missile force is clearly the threat against which SDI was expected to operate and was so identified by the Joint Chiefs of Staff; and (2) the Soviet Union is the only country with the expertise capable of producing on a large scale sophisticated technical counters to a deployed strategic missile defense. One of the Countermeasures tenets has been that if the SDI Program could successfully respond to the most technically stressing counters projected for the Soviets, simpler counters generated by less technically capable countries could be overcome easily.

Potential Soviet countermeasures examined in prior years include modifications to the offensive threat, such as decoys and replicas, that attempt to confuse and overwhelm the defense, and defense suppression/anti-satellite techniques, such as orbital and direct-ascent interceptors, which attempt to destroy defense elements. Advanced technologies, such as those employed in ground- and space-based directed energy weapons and kinetic energy weapons, are also potentially available to the Soviets to enhance threats to ballistic missile defenses. Existing Soviet ASAT capabilities, such as the co-orbital system and the Galosh and one other type of anti-ballistic missiles used as direct-ascent ASATs, are judged to be relatively ineffective countermeasures in their present numbers and design.

As the SDI Program has moved toward a global protection against limited strikes (GPALS) system with focus on accidental and unauthorized Soviet strikes and a greater concern about third world missile systems, the Countermeasures project has begun to refocus on the simpler counters that may be used against a more limited deployed missile defense. In the coming year, as the GPALS architectures are analyzed by the Red Teams, the technical abilities of third world states will be projected along with the implications of technology transfers. Countermeasures resulting from these analyses will be incorporated into the Red-Blue interactions to determine their potential effectiveness against the SDI architecture and possible SDI responses to them. The objective of this effort continues to be the examination of the range of possible counters to ensure that the defense system and its elements are robust enough to deny an adversary's attempts to degrade or defeat it.

7.4.1 Countermeasures Costs

The potential costs to the Soviets and third world nations to develop countermeasures or other responses to a strategic defense system continue to be the subject of ongoing analytical efforts. Economic conditions and pricing factors in the

Soviet Union are currently undergoing dramatic upheavals. The reliability of costing data as well as the affordability of any large-scale response is highly questionable and no doubt subject to significant change. Costing and affordability analyses for third world nations will be addressed as potential countermeasures developed by those states are identified.

Of course, the greatest cost to the offense is the reduction in its effectiveness, the denial of offense objectives, and the great uncertainty created in the mind of the offense planner. The recent mid-East conflict demonstrated that the cost of not having the Patriot System available would have been measured in lives, property, and, probably, political alliances.

7.4.2 Countermeasures Evaluations

The SDI Countermeasures project is designed to provide technical evaluations of potential adversary countermeasures to ensure that responses are considered by SDI system designers and technology developers. The analyses focused primarily on boost, post-boost, and midcourse countermeasure issues during 1990. As previously, the analyses examined the technical credibility, effectiveness, cost, and possible deployment schedules for various countermeasure concepts. These included candidate offensive enhancements and defense suppression threats. The major technical analysis conducted in 1990 was of the Phase I Architecture with Brilliant Pebbles. In addition, analyses were conducted to provide political-military perspectives on technical countermeasures and to provide separate assessments of Soviet behavior.

Countermeasures considered recently included maneuvering boosters, post-boost vehicle coast with decoys, anti-simulated reentry vehicles and decoys, depressed trajectory defense suppression attack, and multiple countermeasure suites.

In addition to technical analysis, a Strategic Red Team (SRT) of political-military analysts supported technical analyses and performed independent analyses of Soviet responses to the SDI Program. The SRT recognized the crisis state of the Soviet economy and noted that diplomacy and arms control would continue to be the preferred means to attempt to counter SDI. Failing this, the Soviets might consider acceding to some level of very limited mutual missile defense that was not a prelude to a full-scale strategic defense system. Beyond diplomacy, the Soviets would attempt to utilize a combination of tactics and straightforward countermeasures in the near-term to reduce SDI effectiveness and U.S. confidence. Longer-term projects would include those more technical approaches mentioned above.

In a separate report on Soviet views of strategic defense, the SRT analyzed an ongoing discussion in the Soviet press regarding the future of ballistic missile defenses. Most of this discussion has been among academics who were speaking more in theoretical terms. Little or none was from any official sources. None of the discussed alternatives to longstanding official policy appeared to have gained sufficient support to have caused an identifiable shift in Soviet policy. Based on the majority of articles and some statements by Soviet officials, it seems that if the Soviets move to expand ballistic missile defense, their preference will be to revise the ABM Treaty to allow additional defense sites and ground-based interceptors. The extent to which additional defensive capabilities might be negotiable could not be determined from available evidence.

7.5 Threat and Countermeasures Verification

The threat and countermeasures verification effort seeks to determine through physical tests the effectiveness of potentially stressing threats and countermeasures. The major thrust of the threat and countermeasures verification effort include laboratory and flight tests of the countermeasure concepts identified by Red-Blue analyses. Many have never been tested by the United States. In addition, the physical principles that underlie the feasibility of a Red countermeasure may be at issue in the scientific community. Test items include RV replicas, lightweight replicas (LREPs), and devices to accurately control their motions during deployment and plume transit, methods of RV and replica signature control, and techniques for generating exoatmospheric masking clouds. One experiment, in various phases during FY 1990, is of particular interest. The experiment, Project Firebird, is intended to refine the study of optical signature and decoy motion control, among other goals.

7.6 Summary

The proliferating ballistic missile threat to the United States, U.S. forces, allies, and other U.S. interests dictates that missile defense systems must be designed to reduce, and eventually negate, the offensive threat posed by land- and sea-based ballistic missiles. In addition to the missiles themselves, we can expect potential adversaries to develop technical and operational countermeasures to reduce the performance and operational effectiveness of our ballistic missile defenses. Such countermeasures could include improvements to offensive ballistic missile systems, defense suppression threats for direct attacks against the defense itself, and techniques and devices designed to degrade the performance of a defense system's functions (decoys, masking, etc.).

In developing a GPALS-type defense, the broadest spectrum of threat classes and countermeasure types must be considered. Within SDIO, the Intelligence Threat, System Threat, and Countermeasures Integration projects combine to identify, examine, specify, and characterize the known and potential threats and countermeasures arrayed against the GPALS system. This combination of projects is a critical link in providing detailed, unambiguous descriptions of the projected threat. Once described, it is written in engineering language and presented in scenario formats that can be used by the system designers and developers to perform design/performance evaluations. Using this multi-tiered approach, the SDIO Threat and Countermeasures projects are designed to explore and keep pace with innovation and development of any and all countermeasures to SDI.

Finally, the proliferation in ballistic missiles, sources of ballistic missile threats, and variety in potential countermeasures not only pose great challenges, but dictate that there are a great number of unknowns associated with defining the total threat to GPALS.

Chapter 8

SDI Compliance With the ABM Treaty

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SDI Compliance With the ABM Treaty

This chapter addresses paragraph 6 of Section 224, National Defense Authorization Act for Fiscal Years 1990 and 1991 (Public Law 101-189), which requests "A statement of the compliance of the planned SDI development and testing programs with existing arms control agreements, including the 1972 Anti-Ballistic Missile Treaty."

8.1 Introduction

The 1972 Anti-Ballistic Missile (ABM) Treaty addresses the development, testing, and deployment of ABM systems and components. It should be noted that nowhere does the ABM Treaty use the word "research." Neither the United States nor the Soviet delegation to the Strategic Arms Limitation Talks (SALT I) negotiations chose to place limitations on research, and the ABM Treaty makes no attempt to do so. The United States made it clear during the ABM Treaty negotiations that development commences with the initiation of field testing of a prototype ABM system or component. The United States had traditionally distinguished "research" from "development" as outlined by then U.S. delegate Dr. Harold Brown in a 1971 statement to the Soviet SALT I delegation. Research includes, but is not limited to, conceptual design and laboratory testing. Development follows research and precedes full-scale testing of systems and components designed for actual deployment. Development of a weapon system is usually associated with the construction and field testing of one or more prototypes of the system or its major components. However, the construction of a prototype cannot necessarily be verified by national technical means of verification. Therefore, in large part because of these verification difficulties, the ABM Treaty prohibition on the development of sea-, air-, space-, or mobile land-based ABM systems, or components for such systems, applies when a prototype of such a system or its components enters the field-testing stage.

The ABM Treaty regulates the development, testing, and deployment of ABM systems whose components were defined in the 1972 Treaty as consisting of ABM interceptor missiles, ABM launchers, and ABM radars. ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars are addressed only in Agreed Statement D. In order to fulfill the basic Treaty obligation not to deploy ABM systems or components except as provided in Article III, this agreed statement provides that in the event that ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars are created in the future, specific limitations on such systems and their components would be subject to discussion in accordance with Article 13 and agreement in accordance with Article 14 of the Treaty. The Agreed Statement does not proscribe the development and testing of such systems, regardless of basing mode. The SDI Program will continue to be conducted in a manner that fully complies with all U.S. obligations under the ABM Treaty.

Research and certain development and testing of defensive systems are not only permitted by the ABM Treaty, but were anticipated at the time the Treaty was negotiated and signed. Both the United States and the Union of Soviet Socialist Republics supported this position in testimony to their respective legislative bodies. When the Treaty was before the Senate for advice and consent to ratification, then Secretary of Defense Secretary Melvin Laird advocated, in his testimony, that the United States "vigorously pursue a comprehensive ABM technology program." In a statement before the Presidium of the Supreme Soviet, Marshall Grechko said the ABM Treaty "places no limitations whatsoever on the conducting of research and experimental work directed toward solving the problem of defending the country from nuclear missile strikes."

8.2 Existing Compliance Process for SDI

The Department of Defense (DOD) has in place an effective compliance process (established with the SALT I agreements in 1972) under which key offices in DOD are responsible for overseeing SDI compliance with all United States arms control commitments. Under this process the SDI Organization (SDIO) and DOD components ensure that the implementing program offices adhere to DOD compliance directives and seek guidance from offices charged with oversight responsibility.

Specific responsibilities are assigned by DOD Directive 5100.70, 9 January 1973, "*Implementation of SAL* (Strategic Arms Limitation) *Agreements*." The Under Secretary of Defense (Acquisition), USD(A), ensures that all DOD programs are in compliance with United States arms control obligations. The Service secretaries, the Chairman of the Joint Chiefs of Staff, and agency directors ensure the internal compliance of their respective organizations. The DOD General Counsel provides advice and assistance with respect to the implementation of the compliance process and interpretation of arms control agreements.

DOD Instruction S-5100.72 establishes general instructions, guidelines, and procedures for ensuring the continued compliance of all DOD programs with existing arms control agreements. Under these procedures, questions of interpretation of specific agreements are to be referred to the USD(A) for resolution on a case-by-case basis. No project or program which reasonably raises a compliance issue can enter into the testing, prototype construction, or deployment phase without prior clearance from the USD(A). If such a compliance issue is in doubt, *USD(A) approval shall be sought.* In consultation with the office of the DOD General Counsel, Office of the Assistant Secretary of Defense for International Security Policy, and the Joint Staff, USD(A) applies the provisions of the agreements, as appropriate. DOD components, including SDIO, certify internal compliance periodically and establish internal procedures and offices to monitor and ensure internal compliance.

In 1985, the United States began discussions with allied governments regarding technical cooperation on SDI research. To date, the United States has concluded bilateral SDI research Memoranda of Understanding with the United Kingdom, Germany, Israel, Italy, and Japan. All such agreements will be implemented consistent with United States international obligations, including the ABM Treaty. The United States has established guidelines to ensure that all exchanges of data and research activities are conducted in full compliance with the ABM Treaty obligations not to transfer to other states ABM systems or components limited by the Treaty, nor to provide technical descriptions or blueprints specially worked out for the construction of such systems or components.

8.3 SDI Experiments

All SDI field tests must be approved for ABM Treaty compliance through the DOD compliance review process. The following major projects and experiments, all of which involve field testing, have been approved and are to be conducted during the remainder of FY 1991 and FY 1992: Low-power Atmospheric Compensation Experiment (LACE), Relay Mirror Experiment (RME), and Wideband Angular Vibration Experiment (WAVE) (on orbit, launched February 1990); the Kinetic Energy Kill Vehicle Integrated Technology Experiment (KITE) flights in the High

Endoatmospheric Defense Interceptor (HEDI) project (when tests incorporate Endo-Exoatmospheric Interceptor (E^2I) capabilities, such tests will require further review); the Airborne Surveillance Testbed (AST), a revision of the Airborne Optical Adjunct project (including AST viewing Patriot intercepts); the Ground-Based Interceptor (GBI) (formerly the Exoatmospheric Reentry Vehicle Interceptor Subsystem [ERIS]) flight experiments; the Arrow anti-tactical missile flight experiments; the Lightweight Exoatmospheric Projectile (LEAP) flight experiments; the Low Altitude Satellite Experiment (LoSAT-X); Brilliant Pebbles flight testing, which has been approved through flight number 10; and the Extended Range Interceptor (ERINT) project flight experiments.

The following major projects and experiments have been approved for later years, subject, in some cases, to review of more completely defined experiments: the Midcourse Space Experiment (MSX); the Ground-Based Radar Experiments (GBR-X); Neutral Particle Beam Space Experiment (NPBSE); Star Lite Space-Based Laser Experiment (formerly Zenith Star); STARLAB (since canceled; Altair, a less capable STARLAB, is to be reviewed when project is adequately defined); Ground-based Surveillance and Tracking System (GSTS); and Exoatmospheric Discrimination Experiment.

In addition, the following data collection activities, which have not been considered as major, continue to be approved: the Optical Airborne Measurement Program (OAMP); Scaled Atmospheric Blooming Experiment (SABLE); the Sounding Rocket Measurement Program (SRMP); Red Gemini IV through IX; the Infrared Background Signature Survey (IBSS) experiment and the Cryogenic Infrared Radiance Instrumentation for Shuttle (CIRRIS) 1A experiment; SPIRIT II; Space Power Experiments Aboard Rockets (SPEAR) III; Zodiac Beauchamp; the Firebird experiments; Tracking Field Experiments (TFE); Astral Dancer experiments; the Ultraviolet Science Package (UVSP); Red Tigress; and Project Zest.

The following projects have approved activities that are not considered to be in field testing: Average Power Laser Experiment; Alpha/LAMP Integration; Hypervelocity Gun (HVG); and the Space-Based Interceptor (SBI). Also, the National Test Bed has been determined to be compliant with the ABM Treaty.

The following target development projects have been approved: STARBIRD—future launch date(s) not yet finalized; Strategic Target System (STARS); Operational and Developmental Experiments Simulator (ODES); and Project Redwood. All SDI launches are reviewed for compliance with the research and development launch provisions of the 1987 Intermediate-Range Nuclear Forces Treaty. Such launches will be notified to the Soviet Nuclear Risk Reduction Center as required.

The following programs, most of which have not yet been sufficiently defined for compliance review, are not yet approved: Brilliant Pebbles pre-full scale development test flights; Patriot Pre-Planned Product Improvements (P^3I); the follow-on phase of the U.S.-Israel Arrow interceptor development known as the Arrow Continuation Experiments (ACES) (bilateral negotiations are under way); LEAP (flight tests 3, 4, 5, and 6); Advanced Contingency Theater Sensor (ACTS); Theater High Altitude Area Defense (THAAD); the Ground-Based family of radars (TMD-GBR and GBRT); and Corps SAM (no acquisition milestones currently established).

Currently, no experiment has been approved which would not fall within the categories used in Appendix D to the 1987 Report to the Congress on the Strategic Defense Initiative. Changes to previously approved experiments require compliance review.

Chapter 9

Program Funding

Chapter 9

Program Funding

Tables 9-1 through 9-5 and Tables 9-7 through 9-11 present SDI Program funding in two ways: (1) the amount expended through 1990 (in millions of dollars) and the estimated amount of funds in 1991 under the old PE structure, and (2) the funding under the new Congressionally mandated PEs from 1991 through 1993 (in millions of dollars). A crosswalk from the old PE structure to the new structure is shown in Table 9-6. Tables 9-12 through 9-14 present the funding under the TMDI PEs from 1991 through 1993. The estimated funding required to reach the next milestone for each major SDI project is provided in Table 9-15.

Table 9-1
Program Element 0603220C
PE Title: Surveillance, Acquisition, Tracking, and Kill Assessment (SATKA)
(In Millions of Dollars)

Project Number and Title		Funds Expended Through FY 1990	FY 1991 Appropriation
1101	Passive Sensors	381.3	35.1
1102	Microwave Radar Technology	97.9	5.2
1103	Laser Radar Technology	401.3	30.0
1104	Signal Processing	451.6	45.0
1105	Discrimination	781.9	121.8
1106	Sensor Studies and Experiments	616.6	158.8
1107	Interactive Discrimination	24.8	0.0
1601	Innovative Science and Technology	229.5	34.0
1602	Small Business Innovative Research	28.6	0.0
2101	Boost Surveillance and Tracking System	937.1	0.0
2102	Space-Based Sensor	312.4	48.0
2103	Ground-Based Surveillance and Tracking System	65.1	46.8
2104	Ground-Based Radar	256.0	39.0
3302	System Test Environment	60.4	0.0
3304	Test and Evaluation Resources	89.3	64.9
3307	Midcourse Experiment	579.4	44.3
4000	Operational Support Costs	245.9	46.0
4305	Miniaturized Accelerators for PET	3.0	0.0
	PE Total	5562.1	718.9

Table 9-2
Program Element 0603221C
PE Title: Directed Energy Weapons (DEW)
(In Millions of Dollars)

Project Number and Title		Funds Expended Through FY 1990	FY 1991 Appropriation
1106	Sensor Studies and Experiments	127.5	0.0
1204	Interceptor Studies and Analysis	65.6	0.0
1301	Free Electron Laser Technology	963.4	29.1
1302	Chemical Laser Technology	678.7	91.0
1303	Neutral Particle Beam Technology	547.4	105.4
1304	Nuclear Directed Energy Technology	116.5	9.8
1305	Acquisition, Tracking, Pointing, and Fire Control	1315.1	80.4
1306	Directed Energy Weapons	8.9	0.0
1307	DEW CDTE	277.4	0.0
1505	Launch Planning, Development, and Demonstration	3.6	0.0
1601	Innovative Science and Technology	79.8	0.0
1602	Small Business Innovative Research	31.1	0.0
2204	DEW Concept Definition	135.7	3.6
4000	Operational Support Costs	130.0	30.0
4102	Sandia Construction	41.4	1.6
	PE Total	4522.1	350.9

Table 9-3
Program Element 0603222C
PE Title: Kinetic Energy Weapons (KEW)
(In Millions of Dollars)

Project Number and Title		Funds Expended Through FY 1990	FY 1991 Appropriation
1104	Signal Processing	6.6	0.0
1105	Discrimination	102.6	0.0
1106	Sensor Studies and Experiments	1.1	0.0
1201	Interceptor Component Technologies	392.4	99.9
1202	Interceptor Integration Technology	337.7	129.0
1203	Hypervelocity Technology	133.5	15.1
1204	Interceptor Studies and Analysis	531.8	53.5
1205	Foreign Technology Support	26.9	12.0
1206	Theater Interceptors	249.3	30.7
1601	Innovative Science and Technology	82.7	17.0
1602	Small Business Innovative Research	35.2	0.0
2201	Space-Based Interceptor	564.4	35.0
2202	Ground-Based Exoatmospheric Interceptor Development	582.2	84.5
2203	HEDI (Endo/Exoatmospheric Interceptor (E^2I))	454.6	103.0
2205	Brilliant Pebbles (BP)	137.5	392.0
3107	Environment, Siting, and Facilities	6.5	0.0
3302	System Test Environment	3.3	0.0
3304	Test and Evaluation Resources	113.3	0.0
4000	Operational Support Costs	134.3	24.0
	PE Total	3896.2	995.7

Table 9-4
Program Element 0603223C
PE Title: Systems Analysis/Battle Management (SA/BM)
(In Millions of Dollars)

Project Number and Title		Funds Expended Through FY 1990	FY 1991 Appropriation
1206	Theater Interceptors	0.3	0.0
1301	Free Electron Laser Technology	28.0	0.0
1306	Directed Energy Weapons	0.1	0.0
1403	Computer Engineering	0.7	0.7
1405	Communications Engineering	6.2	6.3
1505	Launch Planning, Development, and Demonstration	0.8	0.5
1601	Innovative Science and Technology	61.4	4.3
1602	Small Business Innovative Research	8.2	0.0
2300	Command Center	622.8	38.5*
2304	System Software Engineering	0.0	4.4
3102	System Engineering	125.3	65.0
3104	Integrated Logistics Support	38.6	4.4
3105	Producibility and Manufacturing	20.2	8.5
3107	Environment, Siting, and Facilities	38.5	13.5**
3108	Operational Environments	0.8	1.0
3109	System Security Engineering	0.0	6.9
3110	Survivability Engineering	0.0	1.5
3111	Surveillance Engineering	0.0	7.3
3201	Architecture and Analysis	183.2	7.0
3202	Operations Interface	21.4	7.3
3203	Intelligence Threat Development	22.8	0.0
3205	Theater Missile Defense (TMD) Special Studies	106.9	29.8
3206	System Threat	0.0	7.0
3207	System Architecture	0.0	19.9
3282	Operational Planning	0.6	0.0
3292	Offense-Defense Analysis	0.6	0.0
3302	System Test Environment	374.1	103.8
3303	Independent Test and Evaluation Oversight and Assessment	11.3	4.2
3304	Test and Evaluation Resources	6.3	0.0
3305	Theater Test Bed	62.6	37.9
3306	Advanced Research Center	26.9	12.0
3308	System Simulator, Level II	0.0	4.5
4000	Operational Support Costs	402.9	116.9
4302	Technology Transfer	3.6	2.4
4305	Miniaturized Accelerators for PET	45.5	0.4
	PE Total	2220.6	515.9

* Includes MILCON Funds of 3.870M FY 91
**Includes MILCON Funds of 7.500M FY 91

Table 9-5
Program Element 0603224C
PE Title: Survivability, Lethality, and Key Support Technologies (SLKT)
(In Millions of Dollars)

Project Number and Title		Funds Fxpended Through FY 1990	FY 1991 Appropriation
1106	Sensor Studies and Experiments	14.1	0.0
1501	Survivability Technology Project	428.4	56.5
1502	Lethality and Target Hardening	399.2	27.2
1503	Power and Power Conditioning	412.1	48.6
1504	Materials and Structures	107.3	26.5
1505	Launch Planning, Development, and Demonstration	264.1	15.0
1601	Innovative Science and Technology	68.1	11.0
1602	Small Business Innovative Research	11.3	0.0
1603	New Concepts Development	0.0	25.0
1701	Launch Services	0.0	23.6
1702	Special Test Activities	0.0	22.7
3203	Intelligence Threat Development	29.0	10.0
3204	Countermeasures Integration	89.4	19.2
4000	Operational Support Costs	53.2	7.0
	PE TOTAL	1876.2	292.3

Table 9-6
Crosswalk of Old PE Structure to New PE Structure
(In Millions of Dollars)

PEs Prior to FY 1991		FY 1991 Budget Request	FY 1991 Appro-priation***	Allocation of Appropriated Funds to New PEs: Phase I	LPS	Theater/ ATBM	Follow-on	Research & Support
Surveillance, Acquisition, Tracking and Kill Assessment (SATKA)								
1101	Passive Sensors	65.2	35.1	35.1				
1102	Microwave Radar Technology	10.0	5.2	5.2				
1103	Laser Radar Technology	67.5	30.0	9.0			21.0	
1104	Signal Processing	77.4	45.0	45.0				
1105	Discrimination	170.0	121.8	26.9	94.9			
1106	Sensor Studies and Experiments	240.5	158.8	92.6	62.4	3.8		
1601	Innovative Science and Technology	50.3	34.0					34.0
2101	Boost Surveillance and Tracking System*	137.0	0.0					
2102	Space-Based Sensor	95.0	48.0	48.0				
2103	Ground-Based Surveillance and Tracking System	100.0	46.8		46.8			
2104	Ground-Based Radar	150.0	39.0	24.0		15.0		
3304	T&E Resources	58.0	64.9					64.9
3307	Midcourse Experiment	40.3	44.3		40.0	4.3		
4000	Operational Support	45.4	46.0					46.0
	Total SATKA	1306.6						
Directed Energy Weapons (DEW)								
1301	Free Electron Laser Technology	130.0	29.1				29.1	
1302	Chemical Laser Technology	211.0	91.0				91.0	
1303	Neutral Particle Beam Technology	165.0	105.4				105.4	
1304	Nuclear Directed Energy Technology	15.0	9.8				9.8	
1305	Acquisition, Tracking, Pointing, and Fire Control	225.0	80.4				80.4	
1601	Innovative Science and Technology	14.4	0.0					
2204	DEW Concept Definition	12.0	3.6				3.6	
4000	Operational Support Costs	28.2	30.0					30.0
4102	Sandia Construction	2.3	1.6				1.6	
	Total DEW	802.9						

* Transferred to the U.S. Air Force
*** Sum of entries does not equal Total due to rounding

Table 9-6
Crosswalk of Old PE Structure to New PE Structure (Cont'd)
(In Millions of Dollars)

PEs Prior to FY 1991		FY 1991 Budget Request	FY 1991 Appro-priation***	Allocation of Appropriated Funds to New PEs: Phase I	LPS	Theater/ ATBM	Follow-on	Research & Support
Kinetic Energy Weapons (KEW)								
1201	Interceptor Component Technologies	106.0	99.9				99.9	
1202	Interceptor Integration Technology	115.0	129.0	11.0			118.0	
1203	Hypervelocity Technology	25.1	15.1				15.1	
1204	Interceptor Studies and Analysis	20.4	53.5				43.0	10.5
1205	Foreign Technology Support	11.8	12.0			12.0		
1206	Theater Interceptors	75.2	30.7			30.7		
1601	Innovative Science and Technology	21.9	17.0					17.0
2201	Space-Based Interceptor	53.0	35.0		35.0			
2202	Ground-Based Exoatmospheric Interceptor Development	142.0	84.5		84.5			
2203	HEDI Endo/Exoatmospheric Interceptor (E^2I)	95.0	103.0	83.0		20.0		
2205	Brilliant Pebbles (BP)	329.0	392.0	392.0				
4000	Operational Support Costs	23.2	24.0					24.0
	Total KEW	1017.6						
Systems Analysis/Battle Management (SA/BM)								
1403	Computer Engineering	0.9	0.7					0.7
1405	Communications Engineering	7.8	6.3				4.1	2.2
1505	Launch Planning, Development, and Demonstration	2.0	0.5	0.5				
1601	Innovative Science and Technology	12.4	4.3					4.3
2300	Command Center	140.2	38.5*	28.2	9.8*	0.5		
2304	System Software Engineering	0.0	4.4	2.4	2.0			
3100	System Engineering	75.0	0.0					
3102	System Engineering	0.0	65.0	36.5	8.0	10.0		10.5
3104	Integrated Logistics Support	8.1	4.4					4.4
3105	Producibility and Manufacturing	10.3	8.5					8.5
3107	Environment, Siting, and Facilities	4.5	13.5**					13.5**
3108	Operational Environments	1.2	1.0					1.0
3109	System Security Engineering	0.0	6.9	4.9	2.0			
3110	Survivability Engineering	0.0	1.5					1.5
3111	Surveillance Engineering	0.0	7.3	3.0	4.3			

*Includes MILCON Funds of 3.870M FY 91
**Includes MILCON Funds of 7.500M FY 91
***Sum of entries does not equal Total due to rounding

Table 9-6
Crosswalk of Old PE Structure to
New PE Structure (Cont'd)
(In Millions of Dollars)

PEs Prior to FY 1991		FY 1991 Budget Request	FY 1991 Appro-priation***	Allocation of Appropriated Funds to New PEs: Phase I	LPS	Theater/ ATBM	Follow-on	Research & Support
Systems Analysis/Battle Management (SA/BM) (Cont'd)								
3201	Architecture and Analysis	15.2	7.0					7.0
3202	Operations Interface	7.1	7.3					7.3
3205	Theater Missile Defense (TMD) Special Studies	15.7	29.8			29.8		
3206	System Threat	0.0	7.0					7.0
3207	System Architecture	0.0	19.9	8.1	2.0	9.8		
3302	System Test Environment	140.0	103.8					103.8
3303	Independent Test and Evaluation Oversight and Assessment	5.5	4.2					4.2
3305	Theater Test Bed	40.9	37.9			37.9		
3306	Advanced Research Center	13.8	12.0					12.0
3308	System Simulator, Level II	20.0	4.5	1.0	3.5			
4000	Operational Support Costs	130.0	116.9					116.9
4302	Technology Transfer	2.4	2.4					2.4
4305	Miniaturized Accelerators for PET	21.0	0.4				0.4	
	Total SA/BM	674.0						
Survivability, Lethality and Key Support Technologies (SLKT)								
1501	Survivability Technology Project	136.0	56.5	1.7	0.5	1.3		53.0
1502	Lethality and Target Hardening	40.0	27.2			4.9		22.3
1503	Power and Power Conditioning	90.0	48.6				13.7	34.9
1504	Materials and Structures	42.0	26.5				5.2	21.3
1505	Launch Planning, Development, and Demonstration	25.0	15.0				15.0	
1601	Innovative Science and Technology	17.7	11.0					11.0
1603	New Concepts Development	0.0	25.0				25.0	
1701	Launch Services	0.0	23.6	8.3			15.3	
1702	Special Test Activities	0.0	22.7					22.7
3203	Intelligence Threat Development	13.5	10.0					10.0
3204	Countermeasures Integration	22.4	19.2					19.2
4000	Operational Support Costs	7.0	7.0					7.0
	Total SLKT	393.6						
	TOTAL SDIO	**4195.0**	**2873.8*,*** **	**866.4**	**395.7***	**180.0**	**696.6**	**735.0****

*Includes MILCON Funds of 3.870M FY 91
**Includes MILCON Funds of 7.500M FY 91
*** Sum of entries does not equal Total due to rounding

Table 9-7
Program Element 0603214C
PE Title: Phase I Defenses
(In Millions of Dollars)

Project Number and Title		FY 1991	FY 1992	FY 1993
1101	Passive Sensors	35.1	50.0	54.9
1102	Microwave Radar Technology	5.2	18.0	18.0
1103	Laser Radar Technology	9.0	15.5	15.6
1104	Signal Processing	45.0	67.0	70.0
1105	Discrimination	26.9	29.9	31.1
1106	Sensor Studies and Experiments	92.6	111.5	104.9
1202	Interceptor Integration Technology	11.0	15.5	15.5
1501	Survivability Technology Project	1.7	16.1	17.1
1505	Launch Planning, Development, and Demonstration	0.5	5.3	6.4
1701	Launch Services	8.3	10.4	10.8
2101	Boost Surveillance and Tracking System*	0.0	0.0	0.0
2102	Space-Based Sensor	48.0	243.9	247.1
2104	Ground-Based Radar	24.0	15.0	45.0
2203	HEDI (Endo/Exoatmospheric Interceptor (E²I))	83.0	244.0	241.7
2205	Brilliant Pebbles (BP)	392.0	659.1	582.4
2300	Command Center	28.2	44.1	52.3
2304	System Software Engineering	2.4	4.4	4.7
3102	System Engineering	36.5	44.7	54.9
3109	System Security Engineering	4.9	8.5	9.2
3111	Surveillance Engineering	3.0	4.0	5.0
3207	System Architecture	8.1	0.0	0.0
3308	System Simulator, Level II	1.0	5.3	6.8
	PE Total	866.4	1612.2	1593.4

*Transferred to the U.S. Air Force

Table 9-8
Program Element 0603215C
PE Title: Limited Protection Systems (LPS)
(In Millions of Dollars)

Project Number and Title		FY 1991	FY 1992	FY 1993
1105	Discrimination	94.9	124.7	141.1
1106	Sensor Studies and Experiments	62.4	72.7	73.9
1501	Survivability Technology Project	0.5	2.5	3.0
2102	Ground-Based Surveillance and Tracking System	46.8	180.7	188.2
2201	Space-Based Interceptor	35.0	17.0	0.0
2202	Ground-Based Exoatmospheric Interceptor Development	84.5	207.6	268.6
2300	Command Center	9.8*	42.2	42.7
2304	System Software Engineering	2.0	3.6	3.9
3102	System Engineering	8.0	10.0	10.3
3109	System Security Engineering	2.0	3.5	3.8
3111	Surveillance Engineering	4.3	6.0	7.0
3207	System Architecture	2.0	0.0	0.0
3307	Midcourse Experiment	40.0	0.0	0.0
3308	System Simulator, Level II	3.5	3.9	5.0
	PE Total	395.7	674.4	747.5

*Includes MILCON Funds of 3.870M FY 91

Table 9-9
Program Element 0603216C
PE Title: Theater and ATBM Defenses
(In Millions of Dollars)

Project Number and Title		FY 1991	FY 1992	FY 1993
1106	Sensor Studies and Experiments	3.8	5.4	5.9
1205	Foreign Technology Support	12.0	51.2	61.3
1206	Theater Interceptors	30.7	10.0	10.0
1306	Directed Energy Weapons	0.0	5.0	10.0
1501	Survivability Technology Project	1.3	5.5	7.0
1502	Lethality and Target Hardening	4.9	10.0	10.0
2104	Ground-Based Radar	15.0	58.4	75.9
2203	HEDI (Endo/Exoatmospheric Interceptor (E^2I))	20.0	15.0	0.0
2300	Command Center	0.5	10.2	11.6
3102	System Engineering	10.0	16.4	16.8
3205	Theater Missile Defense (TMD) Special Studies	29.8	53.0	114.5
3207	System Architecture	9.8	0.0	0.0
3305	Theater Test Bed	37.9	39.3	17.6
3307	Midcourse Experiment	4.3	0.0	0.0
	PE Total	180.0	279.4	340.6

Table 9-10
Program Element 0603217C
PE Title: Follow-on Systems
(In Millions of Dollars)

Project Number and Title		FY 1991	FY 1992	FY 1993
1101	Passive Sensors	0.0	4.0	5.0
1103	Laser Radar Technology	21.0	45.5	41.4
1104	Signal Processing	0.0	5.0	7.0
1107	Interactive Discrimination	0.0	10.0	12.0
1201	Interceptor Component Technologies	99.9	149.0	155.4
1202	Interceptor Integration Technology	118.0	139.5	146.6
1203	Hypervelocity Technology	15.1	20.0	32.0
1204	Interceptor Studies and Analysis	43.0	18.0	19.0
1301	Free Electron Laser Technology	29.1	27.0	30.0
1302	Chemical Laser Technology	91.0	131.5	146.5
1303	Neutral Particle Beam Technology	105.4	131.5	146.5
1304	Nuclear Directed Energy Technology	9.8	15.0	16.6
1305	Acquisition, Tracking, Pointing, and Fire Control	80.4	105.0	116.0
1405	Communications Engineering	4.1	8.3	16.0
1501	Survivability Technology Project	0.0	0.0	1.0
1502	Lethality and Target Hardening	0.0	5.0	15.0
1503	Power and Power Conditioning	13.7	23.9	24.9
1504	Materials and Structures	5.2	11.1	11.5
1505	Launch Planning, Development, and Demonstration	15.0	27.0	17.3
1603	New Concepts Development	25.0	30.7	34.6
1701	Launch Services	15.3	6.2	6.4
2204	DEW Concept Definition	3.6	10.4	15.1
4102	Sandia Construction	1.6	0.0	0.0
4305	Miniaturized Accelerators for PET	0.4	1.5	0.5
	PE Total	696.6	925.1	1016.3

Table 9-11
Program Element 0603218C
PE Title: Research and Support Activities
(In Millions of Dollars)

Project Number and Title		FY 1991	FY 1992	FY 1993
1204	Interceptor Studies and Analysis	10.5	24.0	26.0
1403	Computer Engineering	0.7	0.7	0.8
1405	Communications Engineering	2.2	2.3	9.0
1501	Survivability Technology Project	53.0	99.2	100.1
1502	Lethality and Target Hardening	22.3	47.9	46.1
1503	Power and Power Conditioning	34.9	78.8	81.9
1504	Materials and Structures	21.3	47.1	49.1
1601	Innovative Science and Technology	66.3	90.7	86.3
1702	Special Test Activities	22.7	48.0	41.2
3102	System Engineering	10.5	12.0	13.0
3104	Integrated Logistics Support	4.4	6.7	6.9
3105	Producibility and Manufacturing	8.5	14.8	20.6
3107	Environment, Siting, and Facilities	13.5**	14.3**	6.5
3108	Operational Environments	1.0	1.0	1.0
3110	Survivability Engineering	1.5	4.0	8.1
3201	Architectures and Analysis	7.0	7.3	7.5
3202	Operations Interface	7.3	7.2	7.5
3203	Intelligence Threat Development	10.0	10.4	10.7
3204	Countermeasures Integration	19.2	22.9	23.5
3206	System Threat	7.0	7.3	7.5
3302	System Test Environment	103.8	124.6	146.8
3303	Independent Test and Evaluation Oversight and Assessment	4.2	6.0	6.5
3304	Test and Evaluation Resources	64.9	105.1	99.3
3306	Advanced Research Center	12.0	28.7	25.1
4000	Operational Support Costs	223.9	275.8	401.2
4302	Technology Transfer	2.4	2.5	3.0
	PE Total	735.0	1089.3	1235.2

**Includes MILCON Funds of 7.500M FY 91, 8.100M FY 92

Table 9-12
Program Element 0603744C
PE Title: Tactical Missile Defense Initiative Demonstration and Validation
(In Millions of Dollars)

Project Number and Title		FY 1991	FY 1992	FY 1993
2207	Patriot	45.4	75.5	0.0
2208	Extended Range Interceptor (ERINT)	103.0	171.0	20.0
2209	Arrow Continuation Experiments (ACES)	42.0	60.0	60.0
2210	Theater High Altitude Area Defense Interceptor (THAAD)	0.0	150.0	122.0
3208	Interservice Integration	27.8	51.5	55.3
	PE Total	218.2	508.0	257.3

Table 9-13
Program Element 0604225C
PE Title: Tactical Missile Defense Initiative Full-Scale Development
(In Millions of Dollars)

Project Number and Title		FY 1991	FY 1992	FY 1993
2106	Advanced Contingency Theater Sensor	0.0	0.0	34.7
2207	Patriot	0.0	70.0	75.0
2208	Extended Range Interceptor (ERINT)	0.0	0.0	75.0
2210	Theater High Altitude Area Defense Interceptor (THAAD)	0.0	0.0	108.0
	PE Total	0.0	70.0	292.7

Table 9-14
Program Element 0208060C
PE Title: Tactical Missile Defense Procurement
(In Millions of Dollars)

Project Number and Title		FY 1991	FY 1992	FY 1993
2207	Patriot	0.0	25.0	100.7
2208	Extended Range Interceptor (ERINT)	0.0	0.0	43.0
2210	Theater High Altitude Area Defense Interceptor (THAAD)	0.0	0.0	30.0
	PE Total	0.0	25.0	173.7

Table 9-15
Estimated Funding Required to Meet Next Milestone
(In Millions of Then-Year Dollars)

Program /Project	Required After FY 1993	Description of Milestone
Ground-Based Interceptor	624	Complete demonstration/validation
Terminal Ground-Based Radar	276	Complete demonstration/validation
Ground-Based Surveillance and Tracking System	369	Complete demonstration/validation
Brilliant Eyes	449	Complete demonstration/validation
Brilliant Pebbles	798	Complete demonstration/validation
Command Center	331	Complete demonstration/validation
Endo-Exoatmospheric Interceptor	401	Complete demonstration/validation
Chemical Laser	847	Capstone Technology Integration Experiment
Free Electron Laser	124	Operation of full duty cycle Average Power Laser Experiment (APLE) with energy recovery
Neutral Particle Beam	847	Capstone Technology Integration Experiment
Acquisition, Tracking, and Pointing (ATP)	140	Altair stand-alone ATP space experiment

Appendix

Congressional Descriptive Summary Extracts

SDI Program Elements Projects

PROJECT NUMBER: **1101**
PROJECT TITLE: **Passive Sensors**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603217C Follow-On Systems

PROJECT DESCRIPTION

Phase I Defenses

This project develops and demonstrates the infrared sensor component technology required for the performance, reliability, survivability, producibility, and affordability of the Global Protection Against Limited Strikes (GPALS) surveillance systems funded under the Phase I PE. The specific infrared technology areas include: improving the producibility of high quality radiation hardened beryllium mirrors, optical contamination, infrared detectors, readout devices, on-array signal processing techniques, optical test facilities for characterizing and calibrating sensors, nuclear test capability, active cryocooler development and life testing, pilot line production, "learning curve" mfg. techniques out of lab and into industry, demonstrations of focal plane components, cost-performance-yield models for accurate system cost estimates, and integrated advanced sensor demonstrations.

Follow-On Systems

FY1992-1993 Follow-On program element funding will fund advancements to those projects listed above that have applicability to Follow-On System element needs, i.e. for deployment after the beginning of the twenty-first century.

PROJECT NUMBER: **1102**
PROJECT TITLE: **Microwave Radar Technology**
PROGRAM ELEMENT: 0603214C Phase I Defenses

PROJECT DESCRIPTION

Phase I Defenses

Innovative Radar Technology: This task is developing high risk radar technologies which have direct benefit for ground-based radar operation in electronic countermeasures and nuclear environments. Innovative concepts which exploit neural network aperture controllers, resonant target phenomenology features, and advanced beam forming will be developed.

PROJECT NUMBER: **1103**
PROJECT TITLE: **Laser Radar Technology**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603217C Follow-On Systems

PROJECT DESCRIPTION

Phase I Defenses

Ladar Engineering: This project develops laser radar systems, components and architectures capable of providing an early deployment option against limited attacks and for providing low to moderate defensive capabilities against a large-scale ballistic missile attack against the United States. System and component development will emphasize fieldability issues such as weight/volume reduction, efficiency improvement, producibility, survivability and cost for GPALS elements funded under Phase I. Laboratory and field measurements supporting system design and validating system concepts and effectiveness will be performed. Technologies supporting precision bus tracking, threat tube definition, and impact point prediction will be emphasized. Specifically, short wavelength laser radar transmitters, such as solid state and excimer; receivers; and rapid retargeting beam steering and receiving systems will be developed.

Follow-On Systems

Ladar Technology: This project develops and demonstrates the laser radar technologies capable of supporting SDS, components and architectures for applications for deployment in the next century. Laser radar technology includes development of components, systems, data bases of target measurements and supporting analysis. Laser transmitters, receivers, mechanisms for steering and directing beams, and signal processing are included in component development. Data base development includes both laboratory and field measurements, and developing simulations for calculating laser radar cross sections and evaluating system performance.

For many missions, laser radars are preferred over microwave radars due to smaller size and tighter beam divergence. Laser radars also provide the spatial and velocity resolution for midcourse discrimination of RVs from other objects. This technology will also be used in boost phase for active tracking of threat boosters and precision pointing of boost-phase weapons, and in midcourse for designation. Specific technologies include lasers with high temporal and frequency stability and wide bandwidth, wide bandwidth detectors, optical beam steering and receiving systems for rapid retargeting, and signal processing and analytical tools required for implementation. The Army Missile Optical Range is utilized to make calibrated laboratory target measurements and the Firepond laser radar is used to make field measurements of deployment events for targets launched from Wallops Island, VA.

PROJECT NUMBER: **1104**
PROJECT TITLE: **Signal Processing**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603217C Follow-On Systems

PROJECT DESCRIPTION

Phase I Defenses

This project develops and demonstrates the techniques and components associated with on-board high speed sensor signal and data processing for multiple interceptor and surveillance sensor systems and provides a radiation hardened digital and analog circuit component technology base supporting GPALS concepts funded under this Phase I PE. To accomplish mission objectives, key elements must perform large numbers of computations to perform surveillance, acquisition, tracking, and kill assessment of missiles and reentry vehicles. These elements must survive and continue to perform in high levels of natural and nuclear radiation. Selected elements must continue to operate through very high flash levels of nuclear burst. High speed and low power Very Large Scale Integrated (VLSI) electronic circuits and memories with performance comparable to DOD Very High Speed Integrated Circuit (VHSIC) technology must be developed to achieve very high levels of performance and radiation hardening. Further development of this technology is absolutely critical to lowering the risk and system costs involved with a deployment/full scale development decision.

Follow-On Systems

FY1992-1993 Follow-On Systems program element funding will fund advancements to those GPALS projects listed above that could lead to deployment after the turn of the century.

PROJECT NUMBER: **1105**
PROJECT TITLE: **Discrimination**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603215C Limited Protection Systems

PROJECT DESCRIPTION

Phase I Defenses

This total project description is classified.

Limited Pro tion Systems

This total project description is classified.

PROJECT NUMBER: **1106**
PROJECT TITLE: **Sensor Studies and Experiments**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603215C Limited Protection Systems
0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

This project includes a variety of experiments, studies, and support elements designed to examine the interrelationships between sensors, discriminants and other information fusion considerations. Data collected within this project is critical to the design of all surveillance and weapon sensors and sensor processing algorithms in the Strategic Defense System. Most of the following research supports the development of GPALS elements funded under Phase I (PE No. 0603214C). The Midcourse Space Experiment (MSX) also supports GPALS elements funded under Limited Protection Systems (PE No. 0603215C) and Advanced Electro-optics under Theater Missile Defense (PE No. 0603216C).

Phase I Defenses

The Infrared Background Signature Survey (IBSS) is a near-term experiment which gathers infrared (IR), visible, and ultraviolet (UV) radiation data of critical value to a number of SDIO systems such as Brilliant Pebbles (BP), and advanced directed energy concepts. Multi-spectral measurements will be made of orbiter plumes, gas releases, orbiter environment (for contamination-caused sensor degradation), earth background radiance, chemical release (a known mission observable), and calibration sources for on-orbit sensor performance verification. Measurements are planned both with the Shuttle Pallet Satellite (SPAS) platform in the Shuttle bay and with the SPAS deployed from the Shuttle that has maneuvered from the immediate vicinity. The IBSS instrumentation package is being developed jointly by the U.S. and the Federal Republic of Germany and uses satellite hardware which has been flown on previous Shuttle missions. A follow-on SPAS mission is being planned for FY1993.

The MSX is a multi-year spacecraft mission designed to address the outstanding issues of space based sensor design and operations, midcourse sensor functions; and to collect target, plume and background signatures. That portion funded under the Phase I PE concentrates on the Brilliant Eyes post-boost and midcourse acquisition, tracking and discrimination functions.

Limited Protection Systems

That portion of MSX funded under the LPS PE addresses outstanding issues for ground based probe sensors and midcourse interceptors. It addresses sensor design and operations and optical contamination issues; and collects midcourse (cold-body) and background signatures in support of GSTS and GBI acquisition, tracking, and thermal discrimination functions.

PROJECT NUMBER: **1106**
PROJECT TITLE: **Sensor Studies and Experiments (Continued)**

Theater and ATBM Defenses

Advanced electro-optical sensor technologies being developed include visible, ultraviolet, and infrared radiation hardened charge-coupled device (CCD) imagers, step-stare sensor signal processing algorithms, and processor architectures to support evolving SDI midcourse surveillance concepts. Methodologies and techniques for performing track correlation and multisensor discrimination are also included. Progress will be verified by designing, building, and field testing sensors and by performing end-to-end simulations. Sensors will be demonstrated on the MSX experiment.

PROJECT NUMBER: **1107**
PROJECT TITLE: **Interactive Discrimination**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

This project develops and demonstrates the interactive discrimination technologies that could contribute to highly effective strategic defenses for deployment after the beginning of the twenty-first century. A portion of this project addresses discrimination from the system view, taking into account the on-going sensor development and data collection available elsewhere within SDIO. The focus is to develop, evaluate/validate a discrimination architecture that provides SDS with the overall optimum accomplishment of detection, bulk filtering, and assessment. This program not only develops the discrimination, tracking, correlation, discrimination, sensor management and kill, but also the appropriate tools and test beds necessary for its evaluation/validation.

PROJECT NUMBER: **1201**
PROJECT TITLE: **Interceptor Component Technologies**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

This project will develop advanced component technologies for lightweight, low cost interceptors for ballistic missile defense. The technologies provide a basis for highly effective ground- and space-based SDI interceptor systems, components, and architectures that are deployable in the beginning of the 21st century. The component technologies are organized into several areas:

Seeker technology investigations will comprise amacronic sensors MWIR, LWIR, UV/Visible, millimeter wave and dual mode sensors, as well as an assortment of atmospheric seeker head prototypes and a demonstration of hardened HgCdTe production. Interceptor avionics technology will develop hardened parallel VHSIC II

PROJECT NUMBER: **1201**
PROJECT TITLE: **Interceptor Component Technologies (Continued)**

processors, on-FPA techniques for intelligent sensors based on biological analogies, and advanced algorithms for multi-seeker integration, image processing, and autopilots. Inertial unit development will include fiber optics gyros, an optical wide angle stellar sensor, and a micro-mechanical inertial guidance system. Solid state ladars, agile beam steering, and algorithms will be developed for fire control discrimination and bus watching. Axial and divert propulsion will develop high efficiency solid, gelled, and liquid propellant systems as well as thrust vector and aerodynamic control systems. Kill enhancement efforts will include investigations of hypervelocity liquid droplets and submunitions. Vehicle designs, advanced concepts, and test interfaces will also be developed. A primary new initiative is to design, develop, and demonstrate vehicle technologies compatible with affordable lightweight interceptors to perform high and low - endoatmospheric Defense and TMD.

PROJECT NUMBER: **1202**
PROJECT TITLE: **Interceptor Integration Technology**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603217C Follow-On Systems

PROJECT DESCRIPTION

Phase I Defenses

Funding under the Phase I PE provides for modifications to government test facilities to provide independent government evaluation of GPALS systems and components.

Follow-On Systems

Follow on funding provides for the development, independent government testing, and experimental integration of state-of-the-art component technology to provide risk reduction for systems that could be deployed after the beginning of the twenty-first century.

Develop miniaturized, advanced interceptor components to integrate into Lightweight Exoatmospheric Projectiles (LEAP) with a hit to kill kinetic energy mission, required for improved system cost effectiveness. Develop and test a sensor package which will fly along on and observe interceptor demonstration flights. Develop independent government validation technology to verify contractor material performance, archive test data, and exercise baseline interceptor models in support of a Full Scale Engineering Development (FSED) decision. This project has the capability of determining proper technology integration techniques, conducting digital simulation of interceptor kill vehicles in real time, validating seekers and inertial measurement units in hardware-in-the-loop facilities, performing free flight hover tests, and, as required, performing technology validation flights in suborbital, reduced mission scenarios.

PROJECT NUMBER: **1203**
PROJECT TITLE: **Hypervelocity Technology**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

This project will develop, integrate, and demonstrate the technologies required for ground- and space-based ballistic missile defense using miniature projectiles launched from Hypervelocity Guns (HVGs). This effort will be split into two parts: a Terminal Defense System (TDS) and a Space-Based Hypervelocity Launcher System.

A Hypervelocity Launcher (HVL) TDS will be developed to serve as a ground-based terminal defense system in the 5 to 50 KM intercept range. The HVL TDS promises potentially lower cost per kill than a rocket system. It will have faster flyout times and higher firing rates which will provide an increased defensive effectiveness against a more dense and responsive threat. Its high inventory of inexpensive projectiles will result in reduced discrimination requirements. Requirements for terminal defense role are: muzzle velocity 4 km/sec; projectile mass 5 kg; firing rate per gun 1-3 Hz; bore size 105-120 mm; barrel length 10-18m; acceleration 60-100 Kgees; muzzle energy 40 Mj.

Technology for space-based HVL will be developed to defend against strategic targets in the boost, post-boost, and midcourse phases. Faster flyout times, higher firing rates, lower costs per kill, and high inventories of inexpensive projectiles will render advantages similar to that of the HVL TDS. Variable muzzle velocities will allow the system to negate responsive boost phase threats at high velocities and efficiently counteract midcourse targets at low velocities, as well as facilitate sector launch fire control schemes. Preliminary system studies show that inclusion of a properly performing HVL with GPALS systems could increase system effectiveness. Requirements for space based defense role are: muzzle velocity greater than 7 km/sec; projectile mass less than 2 kg; firing rate 1-3 Hz; muzzle energy 100 Mj.

Cooperative HVL experimental and applied research efforts will be conducted with approved foreign organizations in accordance with SDIO memorandum of understandings.

PROJECT NUMBER: **1204**
PROJECT TITLE: **Interceptor Studies and Analysis**
PROGRAM ELEMENT: 0603217C Follow-On Systems
0603218C Research and Support Activities

PROJECT DESCRIPTION

Follow-On Systems

Studies and Analysis: This project satisfies the mission requirement for interceptor studies and analyses through systems engineering and technical assistance, special projects for advanced technologies, program planning and analysis, and aerodynamic studies and analysis. Additionally, trade studies are conducted to determine the best possible technologies in which to invest, in order to give the highest payoff to Strategic Defense System (SDS) element interceptors that could be deployed after the beginning of the twenty-first century.

Research and Support Activities

Vehicle Interactions: The second part of this project provides basic research critical to the successful design and performance of optical sensors to be employed in the space environment. The project includes the Vehicle Interactions Program (VIP) related to mid-course discrimination and a Special Access Program that is to be transferred to the Air Force beginning in FY1992. The generic results of this project can be expected to have significant effect on all SDIO Program Elements.

PROJECT NUMBER: **1205**
PROJECT TITLE: **Foreign Technology Support**
PROGRAM ELEMENT: 0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

Theater and ATBM Defenses

The purpose of this project is to demonstrate, in cooperation with U.S. Allies, technologies with potential for application to Theater Missile Defense (TMD).

Included in this project is the TMD Experiments Program which will evaluate various contractor-proposed TMD system components, subsystems, system elements and concepts to determine their utility with regard to supporting missile defense technology needs. TMD Experiments will provide data to aid in the development of a tactical missile defense capability for other theaters of interest such as Europe, the Middle East, and the Western Pacific Region.

This project also will support the development of a technology base for a rapidly-deployable, survivable sensor system to support defense against a tactical missile threat in contingency theaters of operation. Development of a required sensor suit, called the Advance Contingency Theater Sensor (ACTS), and a technology demonstration of one or more of the individual sensors comprising the ACTS system will be accomplished.

PROJECT NUMBER: **1206**
PROJECT TITLE: **Theater Interceptors**
PROGRAM ELEMENT: 0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

Theater and ATBM Defenses

The purpose of this project is to perform research on Theater Missile Defense (TMD) Interceptors, interceptor components and subcomponents, and associated technologies in concert with TMD architecture study results, other SDIO technology efforts (e.g., ground sensors for queuing interceptors) and overall Strategic Defense Initiative global objectives. The project is structured with a near-term goal of supporting development of a TMD system to counter the current theater threats and a long-term goal of technology advancement to support future theater defense as well as overall SDIO system development.

The project objectives are being accomplished through a number of technology demonstration programs and studies including Theater High Altitude Area Defense (THAAD), Arrow, Electrothermal Gun (ETG), and Wide-Area Missile (WAM). The THAAD program will design and demonstrate an area defense hypervelocity, ground-launched interceptor capable of engaging reentry vehicles in the upper atmosphere and over large ground regions. THAAD will be designed as an overlay to planned asset defense systems such as Patriot or ERINT to defend against the post-INF, year 1995 and beyond threat. It will be compatible with existing air defense hardware (i.e., launchers, BM/C^3, sensors, etc.) and will be capable of supporting contingency force operations. The missile will use SDI derivative and other technologies to the fullest extent possible. A follow-on P3I program will improve THAAD capabilities for the year 2000 and beyond threat.

The Arrow program is a cooperative U.S./Israeli research and development program which responds to the significant tactical ballistic missile threats which are proliferating throughout the Middle East. This program demonstrates an Israeli concept for long-range interceptor engagements and large area defense of population centers and other assets. Specifically, the Arrow program demonstrates the ability of an Israeli developed missile to intercept a surrogate tactical ballistic missile. Key technologies involved in this program include seeker development, warhead development, and aerodynamic guidance and control. Certain experimental data from the Arrow program will provide significant benefits to several U.S. interceptor programs. Independent analysis and review of the Arrow program is also performed as part of this project.

The ETG technology project is exploring the feasibility of combining electrical and chemical energy sources to produce hypervelocities. Two projectile acceleration schemes, hybrid gun and traveling charge (TC), are being developed simultaneously. The hybrid acceleration scheme uses electrothermal injectors to provide an electrically-enhanced conventional chemical charge to propel a projectile. The TC scheme provides initial acceleration to a projectile via the hybrid scheme, and then further accelerates the projectile by igniting a second charge, integrated with the projectile, with electrothermal injectors located midway down the gun barrel. A series of experiments will be conducted to demonstrate each process. Additional efforts include strategic and theater missile defense threat and mission analysis studies, the results of which will be used to

PROJECT NUMBER: **1206**
PROJECT TITLE: **Theater Interceptors (Continued)**

guide development and demonstration planning, fire control conceptual design, and critical issue resolution appropriate for hit-to-kill, gun-launched hypervelocity projectiles.

The WAM program consists of a FY1991 concept feasibility study for a sea-based interceptor to be part of an area and theater defense system meeting current Joint Chiefs of Staff (JCS), SDIO, and USN mission requirements. The concept analysis will investigate the feasibility of a modular, "mix-and-match" approach with existing Navy systems (such as the vertical launch system and the AEGIS), with any compatibility/integration problems discovered during this evaluation to be noted in the study final report.

PROJECT NUMBER: **1301**
PROJECT TITLE: **Free Electron Laser Technology**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

Free Electron Laser (FEL) technology is currently focused on the development of the space-based FEL (SBFEL) concept. The FEL program has undergone massive restructuring and reprogramming due to severe budget reductions. The ultimate goal of the program is to demonstrate the capability of a high power FEL to perform boost phase and post-boost phase intercept of ballistic missiles from earth orbiting platforms. Midcourse interactive discrimination can also be performed by destroying simple decoys and thermally tagging or imparting velocity change to sophisticated decoys. Additional SBFEL missions include self defense and defense of other platforms in the SDS constellation, and the suppression of strategic aircraft.

The primary thrust of the current program is the design and fabrication of a proof-of-principle FEL device to validate FEL technology and demonstrate operation of a moderate power FEL. This effort, called the Average Power Laser Experiment (APLE), is a jointly funded, cooperative venture between the US Army and SDIO. The device being fabricated under APLE is a 10.6 micron, 100kW average power FEL utilizing a Same Accelerator Master Oscillator-Power Amplifier (SAMOPA) design. A continuation of the High Brightness Accelerator Facility (HIBAF) experiment at Los Alamos will continue in parallel with APLE. The HIBAF project involves operation of a peak SAMOPA FEL.

SBFEL technology development will occur in parallel with the APLE device fabrication, concentrating on advancing and tailoring the existing FEL technology to that required for operation in a space environment. This technology includes superconducting and cryogenic accelerator development. The technology development strategy includes leveraging a large amount of the necessary technology from the other directed energy weapon concepts to develop the SBFEL concept.

PROJECT NUMBER: **1302**
PROJECT TITLE: **Chemical Laser Technology**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

Space-based chemical lasers (SBL) will enhance a SDS consisting of kinetic energy weapons by adding zero time-to-intercept hard kill of boosters down to the cloud tops, increasing the capability for hard kill in the bus phase, adding additional robust passive and active midcourse surveillance against simple decoys, and providing interactive discrimination against more sophisticated decoys. Also, the capability for intercept to the cloud-tops will prevent long-range strategic bombers from underflying the SDS. Critical technical issues for the SBL element can be grouped into five areas: laser devices; beam control; optics; acquisition, tracking, pointing and fire control (ATP/FC); and high power integration. The beam generating device is a hydrogen fluoride chemical laser which produces the high-power laser beam through the processes of spontaneous and stimulated emission. The beam control subsystem corrects for aberrations introduced by the device and the high-power optical elements, establishes the boresight of the beam and focuses it on target, and moves the beam from target to target. The ATP/FC subsystem acquires the target, selects and maintains the aimpoint during irradiation, and assesses damage to the target. Key SBL technology developments include the Alpha laser, the Large Advanced Mirror Program (LAMP) mirror, and the Large Optics Demonstration Experiment (LODE) beam control system architecture. The technical feasibility of ATP technology will be demonstrated through a series of ground- and space-based experiments that are presently being designed. Alpha, LAMP, and LODE technologies will be integrated in a series of ground experiments, called Alpha Lamp Integration (ALI), which will investigate and validate the performance of the high-power beam control and pointing subsystem. Demonstration and validation of SBL technology in space will occur in the Starlight program. Starlight, in conjunction with ALI, will resolve the remaining key integration issues prior to entering the engineering and manufacturing development phase.

PROJECT NUMBER: **1303**
PROJECT TITLE: **Neutral Particle Beam Technology**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

The Neutral Particle Beam (NPB) project exploits the capability of a stream of atomic particles to penetrate into a target 1) to provide lethal energies and/or 2) to induce signatures that permit discrimination. Such a beam is also capable of effecting kill of launch systems in the boost, post-boost, and midcourse phases. The NPB project has a technology development segment, a ground-based technology integration segment, and a space experiments segment. Together, these segments address the key technical and system issues associated with the feasibility of deploying an NPB system capable of boost and post-boost intercept as well as midcourse discrimination. The technology development segment concentrates on developing enabling technologies for the ground

PROJECT NUMBER: **1303**
PROJECT TITLE: **Neutral Particle Beam Technology (Continued)**

and space experiments and initially deployable NPB systems. In the ground-based integration experiments, the Accelerator Test Stand (ATS) was used to integrate and test low energy components; the Ground Test Accelerator (GTA) is the primary test bed for initial NPB system development and also for advanced technologies such as high brightness ion sources, advanced neutralizer development, and Acquisition, Tracking, Pointing and Fire Control (ATP/FC); and the Continuous Wave Deuterium Demonstrator (CWDD) examines high duty factor and deuterium operation at low energies. The NPB space experiments include Beam Experiments Aboard Rocket (BEAR) flown in July 1989, which addressed basic space operability issues, and Pegasus, an orbital experiment which will address key NPB issues that cannot be tested on the ground.

PROJECT NUMBER: **1304**
PROJECT TITLE: **Nuclear Directed Energy Technology**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

Nuclear Directed Energy Weapon (NDEW) concepts offer the promise of fundamental improvements in defense technology, including high brightness, large lethal volume, multiple simultaneous target engagement, and alternative lethality mechanisms. Development of NDEWs is being pursued to provide a base of knowledge concerning such weaponry that would permit the U.S. to better judge potential Soviet capabilities, and to provide the basis for a ground based or pop-up U.S. NDEW capability should it be needed at some point for Strategic Defense System (SDS) follow-on phases. The NDEW research path is focussed on a program of theoretical and computational development in concert with underground nuclear tests and related laboratory experiments. A DOD and DOE cooperative program is conducting mission analyses as well as exploring systems engineering concerns.

PROJECT NUMBER: **1305**
PROJECT TITLE: **Acquisition, Tracking, Pointing and Fire Control Technology**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

Acquisition, tracking, pointing and fire control (ATP/FC) technology efforts will advance the technologies required to perform critical functions for all candidate DEW concepts to be used in an SDI multilayer defense architecture. These functions include acquiring, identifying, and prioritizing the targets to be engaged, precision tracking of each target, selecting and establishing the line-of-sight to the target aimpoint, holding the beam on the aimpoint, assessing the results, and reinitiating the sequence to engage a new target. ATP/FC technologies are required for both boost-phase and midcourse interactive discrimination. Efforts in the ATP/FC project are in several related areas. Space experiments in progress include the Low Power Atmospheric Compensation Experiment (LACE) and the Relay Mirror Experiment (RME). Funding constraints have forced the termination of the Starlab experiment project. The most critical objectives of the Starlab project will be addressed by a less costly experiment, Altair. This project will use some Starlab components and other available resources on a free-flying satellite platform to demonstrate precision tracking and beam pointing in space. Efforts within the ATP/FC technology base address major tracking/pointing component performance issues, and the development of technologies for advanced ATP/FC experiments, through the Common Module Tracker (CMT) program. Studies are in progress to define experiments that integrate ATP/FC with weapon beam experiments in both the laser and NPB projects.

PROJECT NUMBER: **1306**
PROJECT TITLE: **Directed Energy Weapons**
PROGRAM ELEMENT: 0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

Theater and ATBM Defenses

The purpose of this project is to demonstrate directed energy weapons with potential application to Theater Missile Defense (TMD).

Included in this project is a concept development effort which will evaluate the feasibility of developing a laser system for Theater Defense application. The effort will evaluate ground-based, space-based, and airplane-based laser system effectiveness in boost, midcourse, and terminal phase intercept of tactical ballistic missiles. Various candidate laser systems such as the chemical oxygen iodine laser and the free electron laser will be evaluated. The effort will include concept definition for each of the basing modes. Evaluation of candidate laser systems will provide funding for high-leverage development of laser subsystems. Development of either a ground-based or an airplane-based laser system would provide one critical component of a rapidly transportable Theater Missile Defense system.

PROJECT NUMBER: **1403**
PROJECT TITLE: **Computer Engineering**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

This effort provides technologies required to develop a highly reliable space borne multiprocessor computer architecture. This project consists of two technology tasks: An Advanced Information Processing System (AIPS) able to meet reliability and throughput requirements; and a Very High Speed Integrated Circuit (VHSIC) multiprocessor development effort. This project results in a technology base for a radiation hardened 32-bit multiprocessor system.

PROJECT NUMBER: **1405**
PROJECT TITLE: **Communications Engineering**
PROGRAM ELEMENT: 0603217C Follow-On Systems
0603218C Research and Support Activities

PROJECT DESCRIPTION

Follow-On Systems

Develop communications technology to support operational requirements for defensive systems that could be deployed after the beginning of the twenty-first century. Develop communications components, both radio frequency (RF) and laser communications, for space--to-space, space-to-ground, and ground-to-space links.

Research and Support Activities

Develop a technologically different approach for laser communications capability. Efforts to define requirements for space qualification of 60 GHz RF components needed for robust communications are included.

PROJECT NUMBER: **1501**
PROJECT TITLE: **Survivability Technology (ST) Project**
PROGRAM ELEMENT:

0603214C	Phase I Defenses
0603215C	Limited Protection Systems
0603216C	Theater and ATBM Defenses
0603217C	Follow-On Systems
0603218C	Research and Support Activities

PROJECT DESCRIPTION

Phase I Defenses

Phase I Survivability Technology Support Program develops and demonstrates survivability technologies specific to GPALS elements funded under the Phase I PE (e.g., Brilliant Pebbles (BP), Space-based sensors (BE), E^2I, GBRT, and Command Center Element (CCE)). Issues addressed in this program include: Survivability Analysis and Modeling; Technology Development; Technology Transfer; and Demonstration, Test, Validation, and Evaluation.

Limited Protection Systems

Limited Protection Systems Survivability Technology Support Program develops and demonstrates survivability technologies specific to possible GPALS elements funded under the Limited Protection Systems PE (e.g., GSTS, GBI-X, and CCE). Issues addressed in this program include: Survivability Analysis and Modeling; Technology Development; Technology Transfer; and Demonstration, Test, Validation, and Evaluation.

Theater and ATBM Defenses

Theater and ATBM Defenses Survivability Technology Support Program develops and demonstrates survivability technologies specific to GPALS elements funded under the TMD and TMDI PEs. Issues addressed in this program include: Survivability Analysis and Modeling; Technology Development; Technology Transfer; and Demonstration, Test, Validation, and Evaluation.

Follow-On Systems

Follow-On Systems Survivability Technology Support Program develops and demonstrates survivability technologies to enable the survivability of systems deployed after the beginning of the twenty-first century. Issues addressed in this program include: Survivability Analysis and Modeling; Technology Development; Technology Transfer, and Demonstration, Test, Validation, and Evaluation.

Research and Support Activities

Multi-Element Survivability Technology Program develops and demonstrates survivability technologies to enable GPALS and subsequent system elements to survive defense suppression attacks with sufficient capability to meet defined mission requirements. It addresses technologies which are generally applicable to more than one of the SDS Program Elements. Issues addressed in this program include: Survivability Analysis and Modeling; Technology Development; Technology Transfer; and Demonstration, Test, Validation, and Evaluation.

PROJECT NUMBER:	**1502**	
PROJECT TITLE:	**Lethality and Target Hardening**	
PROGRAM ELEMENT:	0603216C	Theater and ATBM Defenses
	0603217C	Follow-On Systems
	0603218C	Research and Support Activities

PROJECT DESCRIPTION

The Lethality of SDI and TMDI weapons is part of the measure of effectiveness of how well SDI and TMDI systems fulfill defense mission requirements. The Lethality and Target Hardening program is developing a necessary and sufficient understanding of physical principles involved in weapon/target interaction, target response and kill modes, and resulting signatures needed for interactive discrimination and kill assessment.

Theater and ATBM Defenses

The TMD lethality task has similar requirements to the other tasks but addresses TMD interceptors and theater threats. Theater threats include conventional, chemical, toxins, biological, and nuclear warheads. A common, validated lethality criteria for a high confidence kill against any/all threat warheads is required. This lethality criteria is developed in coordination with TMD interceptor development, and the lethality of the interceptors will be validated in cooperation with interceptor demonstration/validation flight tests.

Follow-On Systems

These tasks have the same requirements and objectives as the other tasks but for SDI Directed Energy Weapons (DEWs) and other follow-on defensive weapon concepts. Priority follow-on lethality efforts are validation of particle beam electronic systems kill levels for threat missiles and planning for particle beam and thermal laser interactive discrimination experiments. Lethality of follow-on concepts need further evaluation for potential TMD applications.

Research and Support Activities

Objective of the Research and Support Lethality task is to produce validated lethality criteria and to assess the developmental SDI Phase I and LPS weapons lethality against the SDI threat. This task also includes lethality technology interface to TMD and Follow-On weapon concepts, SDI Red Team activities, intelligence threat definition efforts, and space debris concerns.

PROJECT NUMBER: **1503**
PROJECT TITLE: **Power and Power Conditioning**
PROGRAM ELEMENT: 0603217C Follow-On Systems
0603218C Research and Support Activities

PROJECT DESCRIPTION

Follow-On Systems

This program was established to develop generation and conditioning technologies capable of producing required quantities of electrical power needed by advanced ground- and space-based kinetic/directed energy weapons and surveillance and BM/C^3 systems that might be deployed after the beginning of the twenty-first century. Power requirements for the various SDIO payloads are divided into two broad categories: (1) baseload power for surveillance, communication and housekeeping applications; (2) burst power for weapons and discrimination operations, and periodic testing. The nuclear power technologies developed under this PE support the follow-on systems of SDIO and are characterized by high power density requirements and the need for higher levels of passive survivability. The major projects in this PE to satisfy these follow-on requirements are the SP-100 program and the Thermionic Fuel Element (TFE) program. Due to budget cuts these nuclear power technology programs have been modified and stretched.

Research and Support Activities

This program was established to develop generation and conditioning technologies capable of producing required quantities of electrical power needed by advanced ground- and space-based kinetic/directed energy weapons and surveillance and BM/C3 systems. Power requirements for the various SDIO payloads are divided into two broad categories: (1) baseload power for surveillance, communication and housekeeping applications; (2) burst power for weapons and discrimination operations, and periodic testing. General categories in the program and major projects to satisfy program requirements include: baseload power (Survivable Solar Power Subsystem Demonstrator-SUPER; advanced solar technology; Thermionic Reactor development), multi-megawatt technology (generators, fuel cells, power conditioning), and assessments and analyses. Due to budget cuts many of the burst power and power conditioning technology development programs have been stretched or terminated.

PROJECT NUMBER: **1504**
PROJECT TITLE: **Materials and Structures**
PROGRAM ELEMENT: 0603217C Follow-On Systems
0603218C Research and Support Activities

PROJECT DESCRIPTION

The Materials and Structures (M&S) Project conducts research, development and flight and ground test demonstrations in lightweight structural materials, adaptive structures technology, propulsion/thermal/optical materials, tribomaterials, superconductor devices, and space environmental effects.

Follow-On Systems

Follow-On M&S projects focus on providing advance materials and structures technologies to meet the extreme pointing and tracking, secure communications and enhanced discrimination requirements of DEW systems as they mature in development after the turn of the century. To gain confidence in the ability of these systems to operate in the natural and threat environments, requires system selected materials evaluations and adaptive structure technologies. Superconducting devices will provide orders of magnitude increased capabilities in secure communications and target discrimination.

Research and Support Activities

The M&S component of the Research & Support Activities program element applies near-term generic M&S technologies that are available for technology insertion into GPALS and TMD systems. M&S technologies are designed to make GPALS elements lighter, stronger, more reliable and cheaper to produce, thereby contributing to the overall reduction in system design risk. The need to operate sensors and interceptors in low earth orbit necessities low-weight high stiffness materials and requires the application of low-cost space durable metal matrix and thermoplastics composites. Finally the requirement for reliability of these designs provides for the applications of tribology and adaptive structures technologies.

PROJECT NUMBER: **1505**
PROJECT TITLE: **Launch Planning, Development & Demonstration**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603217C Follow-On Systems

PROJECT DESCRIPTION

Phase I Defenses

Phase I Launch Study/Planning: The 1988 Strategic Defense System (SDS) Defense Acquisition Board Annual Review directed that the OSD perform a study to determine the most cost effective approach to meeting SDS launch requirements in concert with other national security launch requirements. The study included all aspects of SDS deployment, maintenance, and replenishment, as well as consideration of

PROJECT NUMBER: **1505**
PROJECT TITLE: **Launch Planning, Development & Demonstration (Continued)**

existing ranges and launch vehicles currently available, and explored the possibility of using alternative launch sites or boosters. An assessment of the capability of both production and launch facilities to support the required deployments was made. Emphasis was placed on achieving minimum cost for deployment of a Phase I SDS. A product of the launch study was a methodology which allows for rapid cost estimation of launch costs for various SDS launch architectures. As the GPALS architecture solidifies, the study will be updated, using the developed methodology, to determine the best launch solution.

Follow-On Systems

Advanced Launch Development Program (ALDP): Past launch failures, an outdated space transportation technology base, diminished launch capacity, and high space transportation costs have seriously undermined America's ability to access space. To economically meet the growing space launch requirements of the 1990s and beyond, a system is needed which will provide low cost, reliable, high capacity, and operationally flexible access to space. The objective of the Advanced Launch Development Program is to provide a technology basis for a launch vehicle program to begin in the late 1990s. Previous cost goals established for the Advanced Launch System (ALS) program are still valid: A ten-fold reduction in the cost to deliver cargo to low earth orbit as compared to the present cost of the Titan IV. Current concepts call for a modular family of vehicles to satisfy a range of payload requirements. The FY1992 program concentrates on development of a high thrust, low cost LOX/H_2 engine applicable across the family of vehicles. Selected propulsion and non-propulsion technology demonstrations will validate cost and performance projections.

PROJECT NUMBER: **1601**
PROJECT TITLE: **Innovative Science and Technology (IS&T)**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

Explore innovative science and technology for several technologies of interest to SDIO.

PROJECT NUMBER: **1603**
PROJECT TITLE: **New Concepts Development**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

Explore innovative concepts pursuant to PL97-219 which mandates a two-phase R&D competition for small businesses with innovative technologies. Those projects are specifically related to SDI Follow-On Systems which might be deployed after the turn of the century.

PROJECT NUMBER: **1701**
PROJECT TITLE: **Launch Services**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603217C Follow-On Systems

PROJECT DESCRIPTION

Phase I Defenses

Special Projects: Develop and deploy flight hardware to support accelerated test programs for emerging specialized application technologies associated with GPALS elements funded under the Phase I PE. Plan and execute test programs; collect and analyze data; and issue final reports as appropriate. Plan for and conduct orbital insertion missions in support of other special test activities. Low Orbit Satellite (LOSAT) involves the development and deployment of a satellite to gather phenomenology data on selected sources to use in enhancing SDIO computer simulation codes.

Follow-On Systems

Launch Services-Low Cost Flight Test Services (LCFTS): Define, develop, and conduct fast-response, ground-based pre-flight verification and ballistic or space flight testing of unique concepts and high yield approaches for SDI weapons, seekers and targeting applications that might be deployed beyond the turn of the century. Provide experienced launch and flight test teams including: launch services; payload processing; payload integration; mission operations/planning; range operations/integration; mission analysis; and test operations, integration and analysis to fuse together dissimilar concepts into integrated and efficient space experiment packages.

PROJECT NUMBER: **1702**
PROJECT TITLE: **Special Test Activities**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

Develop accelerated test programs for emerging special application technologies. Determine acquisition strategy. Acquire test systems and test equipment. Plan and execute test programs including on-orbit command, control, and validation of demonstration payloads and resulting data collection.

Programs being accomplished under this effort include LACP, ZEST, and Single Stage to Orbit (SSTO). ZEST is a phenomenology oriented test program to replicate and evaluate the effects of certain phenomena associated with various rocket and missile systems. The SSTO program will design, develop, and validate a reusable launch vehicle (either manned or unmanned) capable of airline-like operations to augment existing space launch capability. LACP is a development effort to investigate techniques for space-based discrimination of reentry vehicles and decoys. This program has the potential to lead to the development of a space-based weapon system for use during the midcourse phase of ballistic flight.

PROJECT NUMBER: **2102**
PROJECT TITLE: **Space Based Sensor**
PROGRAM ELEMENT: 0603214C Phase I Defenses

PROJECT DESCRIPTION

Phase I Defenses

This total project description is classified.

PROJECT NUMBER: **2103**
PROJECT TITLE: **Ground-Based Surveillance and Tracking System**
PROGRAM ELEMENT: 0603215C Limited Protection Systems

PROJECT DESCRIPTION

Limited Protection Systems

The Ground-Based Surveillance and Tracking System (GSTS) will be a ground-based, fast response, two-stage rocket launched. long wavelength infrared (LWIR) sensor system boosted into suborbital flight for use in the midcourse SDS mission. GSTS is a midcourse sensor element with primary missions of midcourse precommit and early attack characterizations.

PROJECT NUMBER: **2103**
PROJECT TITLE: **Ground-Based Surveillance and Tracking System (Continued)**

The GSTS is being pursued as an element of the GPALS architecture with the potential for growth to a Phase I architecture. Growth would be accomplished by adding additional sensor capability and proliferation. However, GSTS is funded under the Limited Protection Systems (LPS) Program Element as the combination of GBI and GSTS could form the basis for one alternative for a non-space-based LPS.

In the midcourse precommit role, GSTS provides independent, autonomous, wide field-of-view coverage to ensure high confidence threat acquisition, resolution, track and discrimination with sufficient quality to support interceptor engagements. In the early attack characterization role, GSTS provides regional surveillance of the threat attack for status and situational assessment. GSTS is an integral part of a midcourse suite that could also include Brilliant Eyes (BE) and Ground-Based Radar (GBR). GSTS augments BE viewing to enforce full threat coverage, provides an alternative technology independent surveillance capability, and thereby creates robustness in the midcourse sensor suite. For the GBR, GSTS reduces the requirements to do autonomous search by providing effective handover information to the radar.

PROJECT NUMBER: **2104**
PROJECT TITLE: **Ground-Based Radar**

PROGRAM ELEMENT:	0603214C	Phase I Defenses
	0603216C	Theater and ATBM Defenses

PROJECT DESCRIPTION

Phase I Defenses

Ground-Based Radar-Terminal (GBR-T): An exoatmospheric capable GBR (GBR-T) is required to provide: 1) Limited exoatmospheric search, interceptor precommit against short time of flight ballistic missiles, initialization and kill assessment for shoot-look-shoot and adaptive firing doctrines, and additional phenomenology as a hedge against reactive response to optics elements; 2) An early deployment option against limited attacks, including accidental, unauthorized, or deliberate launch of a small number of ballistic missiles; 3) To perform late midcourse exoatmospheric discrimination as an independent underlay to space-based elements in addition to acquisition, interceptor support, and kill assessment functions; and 4) Be modularly growable to a more capable GBR-Midcourse (GBR-M) as a sensor element in possible SDS Phase I defenses (post-GPALS) against large scale ballistic missile attacks.

PROJECT NUMBER: 2104
PROJECT TITLE: **Ground-Based Radar (Continued)**

Theater and ATBM Defenses

Theater Missile Defenses-Ground Based Radar (TMD-GBR): The immediate SDI requirement is to develop and DEM/VAL a more capable theater missile defense radar GBR (TMD-GBR), derived from current GBR technology. Required functions include attack early warning, threat type classification, interceptor fire control sensor queuing, launch/impact point estimation, threat classification against theater/tactical ballistic missiles. The TMD-GBR would have fire control support capabilities against tactical ballistic missiles, cruise missiles and other air breathing threats.

Technical Development Concept (change from previous CDS): The design and fabrication of all three radars (GBR-T, TMD-GBR, and GBR-M) will be based upon the concept of a family of X-Band radars modularly related. Modularity will be achieved through a common Phased Array Antenna Module (PAAM) serving as the basic building block for the family of radars. The TMD-GBR will be composed of one PAAM. The GBR-T would be growable, with additional PAAMs, from the TMD-GBR, as would the GBR-M. The advanced development phase (DEM/VAL) of these radars is supported by the GBR-X radar program conducted through FY1990 which provides an option for travelling wave tube (TWT) and ferrite phase shifters for the DEM/VAL PAAM design as well as the receiver/transmitter, signal processor, waveform generator and software design supporting the required functions.

PROJECT NUMBER: 2201
PROJECT TITLE: **Space-Based Interceptor**
PROGRAM ELEMENT: 0603215C Limited Protection Systems

PROJECT DESCRIPTION

Limited Protection Systems

The Space-Based Interceptor program was directed at resolving the technical issues involved in developing various space-based interceptor concepts for interception of ballistic missiles during boost, post-boost and midcourse phases, as well as providing satellite defense against direct attack. Brilliant Pebbles has replaced SBI as the space-based tier of GPALS and SBI would have been terminated except for certain development activities which will provide substantially increased confidence in the development of GBI. Thus, the SBI program is funded under the LPS Program Element to permit Martin Marietta to complete its hardware development and integration efforts and hover testing. A number of interceptor components will be incorporated into the Ground Based Interceptor (GBI) effort, supporting GBI technology development and reducing GBI risk.

PROJECT NUMBER: **2202**
PROJECT TITLE: **Ground-Based Exoatmospheric Interceptor Development**
PROGRAM ELEMENT: 0603215C Limited Protection Systems

PROJECT DESCRIPTION

Limited Protection Systems

The objective of the Ground-Based Interceptor (GBI) development effort is to demonstrate technology for a ground-launched exoatmospheric interceptor designed for hit-to-kill (non-nuclear) intercepts of Intercontinental Ballistic Missile (ICBM) and Submarine Launched Ballistic Missile reentry vehicles in the midcourse of their trajectories. Midcourse sensors will acquire, track, and pass threat cluster information to the Command and Control Element, which will cue the interceptors. Using onboard sensors, the interceptors will home in on the cluster and discriminate between reentry vehicles (RVs) and decoys. The deployed GBI Element could include from hundreds to several thousand interceptors based in the U.S.

GBI will compete with E^2I, the Exo-Endo Interceptor, for a position in the ground tier of Global Protection Against Limited Strikes (GPALS). However, as the combination of GBI and the Ground-Based Surveillance and Tracking System (GSTS) could provide a stand alone LPS capability, GBI is funded under the LPS Program Element.

GBI development is separated into three tasks: 1) ERIS Functional Technology Validation (FTV), 2) GBI Baseline Design and Engineering Development, and 3) Exoatmospheric Test Bed (XTB).

Task 1. The ERIS FTV effort consists of a series of 3 exoatmospheric interceptor experiments to validate the concept of discrimination and intercept of an RV in the presence of decoys. The three flight test missions will be flown in FY1991.

Task 2. The GBI effort will validate the concept of a semi-autonomous, discriminating midcourse interceptor that can be effective against a range of increasingly sophisticated threats. Through a competitive Concept and Technology Integration (CTI) effort, it will evaluate proposed interceptor designs and hardware through ground testing, hardware-in-the-loop testing, hover testing, and flight testing. It will identify the optimum interceptor sensor/image processor configuration to provide the most cost-effective solution to the threat. There will be a Milestone II at the end of FY1996.

Task 3. The XTB effort will ensure that the $100M investment made at USAKA in support of the FTV program will not be lost, and that the experience gained by the launch support personnel is retained for subsequent testing at USAKA. The four GBI flight tests planned for Task 2 above will utilize the XTB launch facilities and services in FY1993-1996. Other SDIO and Armed Services programs should realize a significant cost savings in future exoatmospheric testing through use of the XTB vehicle.

PROJECT NUMBER: **2203**
PROJECT TITLE: **HEDI (Endo/Exoatmospheric Interceptor [E^2I])**

PROGRAM ELEMENT: 0603214C Phase I Defenses
0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

Phase I Defenses

The concept for performing the High Endoatmospheric Defense Interceptor (HEDI) mission is the Endo-Exoatmospheric Interceptor (E^2I) which operates against the terminal phase of attacking ballistic missiles. It is designed to engage Intercontinental Ballistic Missile (ICBM) and depressed Submarine-Launched Ballistic Missile (SLBM) attacks. The E^2I is a passive multi-color infrared seeking hypersonic hit-to-kill interceptor with large maneuver and divert capabilities. E^2I can be launched before or during RV reentry with data provided by the acquisition sensors through the battle manager. It is inertially guided and can be updated in flight.

Theater and ATBM Defenses

The Theater & ATBM Defenses program element is funding a portion of the KITE flight tests, as the data collected in these tests will be beneficial to ATBM interceptor efforts, particularly to Arrow and THAAD.

PROJECT NUMBER: **2204**
PROJECT TITLE: **DEW Concept Definition**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

Directed Energy Weapon (DEW) Concept Definition programs exist for the four principal DEW concepts: the Space-Based Laser (SBL), the Ground-Based Laser (GBL), the Neutral Particle Beam (NPB), and Nuclear-Directed-Energy Weapons (NDEW). DEWs are being developed as advanced weapons systems for possible integration into a follow-on Strategic Defense System (SDS). DEW Concept Definition efforts will establish and maintain concept performance requirements and technical characteristics that are traceable to the requirements of the evolving SDS architecture. This work will include development and analysis of alternate system designs, definition of weapon platform subsystem performance requirements, critical technology issues identification, technology program plan development, and theoretical analyses. A data base will also be developed to allow timely preparation and revision of System Concept Papers (SCPs)/Decision Coordinating Papers (DCPs) and Test and Evaluation Master Plans (TEMPs), and to ensure responsiveness to Defense Acquisition Board decision requirements. The data base will provide the basis for technology development and demonstration plans. If executed, these would furnish the technology base and demonstrations to resolve critical DEW issues on a scale that establishes technical feasibility if extrapolated to weapons level performance.

PROJECT NUMBER: **2205**
PROJECT TITLE: **Brilliant Pebbles (BP)**
PROGRAM ELEMENT: 0603214C Phase I Defenses

PROJECT DESCRIPTION

Phase I Defenses

The Brilliant Pebbles (BP) Program is directed to develop a combined sensor and interceptor technology concept for space-based interceptors. BP is the space-based tier of the Global Protection Against Limited Strike (GPALS) System and provides early warning notification for Brilliant Eyes, which is a key element of the ground-based tier of GPALS. The BP system can be expanded to achieve the Phase I Strategic Defense System objectives. The BP concept will employ a single type, cost-effective interceptor deployed in space with a unique suite of sensors allowing it to perform a surveillance function as well as to track and to intercept ballistic missile targets. This space constellation is expected to be highly survivable in wartime. The BP will be under positive control from the United States Command Authorities. Once authorized, the constellation can operate autonomously to accomplish its defensive mission.

PROJECT NUMBER: **2300**
PROJECT TITLE: **Command Center**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603215C Limited Protection Systems
0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

SDS Surveillance and engagement activities are coordinated and controlled by the Command and Control Element (C^2E), which is a distributed system of facilities, equipment, software/algorithms, communications, personnel and procedures that support centralized decision making (command) and decentralized control and execution of the SDS while maintaining assured human control of the system. The C^2 Element is comprised of six segments: Consolidated Command Center/Ballistic Missile Defense (CCC/BMD); Mobile Operations Center (MOC); C^2 Communications Network; Fixed and Mobile Ground Entry Points (FGEP/MGEP); and Communications Network Management (CNM).

The development of a responsive C^2 capability for ballistic missile defense necessitates the incremental integration and validation of hardware and software combinations. A modular building block approach is being used that supports the evolutionary growth of C^2 capabilities/complexity from theater/tactical area defense, to GPALS. Modularity allows the maximum reuse of software and hardware as the C^2 grows in complexity, while supporting the use of unique modules tailored to the deployment scenario, with the other SDS elements. Prototyping allows the validation of technology integration and supports the user's development of operational procedures to satisfy MSII decision criteria.

PROJECT NUMBER: **2300**
PROJECT TITLE: **Command Center (Continued)**

The C^2E Program consists of two major tasks which address the definition, design, demonstration/validation, and Full Scale Development preparation of the C^2E for the Strategic Defense System (SDS). The tasks are: 1) Command and Control Prototype Development, which focuses on the development of ground based C^2 facilities to maintain human-in-control, and the C^2 multi-media terrestrial communication network; and, 2) C^2 System Integration, which defines and allocates to the sensor and weapons elements of the SDS, the basic processes, algorithms, interfaces necessary to integrate the Ballistics Missile Defense (BMD) C^2 aspects of the surveillance, discrimination, battle planning and execution, communication, and resource management functions.

The FY1991 information processing, decision (C^2) and communications requirements definition activities will support the FY1992-1993 initiation of command center and operations center prototyping activities to support GPALS. Activities funded under the Phase I, LPS and TMD PEs will be integrated to support the development of a GPALS C^2 prototype.

Phase I Defenses/Limited Protection Systems

Using funding from the Phase I and LPS PEs, C^2 DEM/VAL activities will focus on the demonstration and validation of the C^2 software and hardware alternative designs, and resolution of the implementation/operational issues identified in the C^2E Program Plan. C^2 System Integration activities are oriented toward evaluation of technologies that individually satisfy the segment level functional and performance requirements, and the development of the processes for integrating these functions into the sensor and weapons elements of the SDS. The resolution of C^2 and C^2 networking issues will lead to a viable allocation of system functions to the C^2E segments and provide responsive software and hardware that will be integrated and validated through C^2 Prototype activities. In addition to supporting the definition process through the refinement of C^2 segment software and hardware specifications, the C^2 prototype (leveraging TMD work) will provide the required resource for demonstrating and validating the effectiveness of the C^2 Concept of Operations.

Theater and ATBM Defenses

The element definition process develops top level system and segment level requirements specifications for an incrementally evolving C^2 design (e.g., TMD, GPALS). The concept is to maximize tactical prototype software and hardware reuse as more complex capability is required by larger defense systems. The C^2 System Integration task, where issues and performance requirements are resolved, provides a primary source of input to the element requirement and verification process. The specifics of multi-element interfaces and connectivity will be designed and used to support the prototyping/integration activities of task one.

PROJECT NUMBER:	**2304**	
PROJECT TITLE:	**System Software Engineering**	
PROGRAM ELEMENT:	0603214C	Phase I Defenses
	0603215C	Limited Protection Systems

PROJECT DESCRIPTION

Phase I Defenses/ Limited Protection Systems

GPALS will require a very large amount of reliable software that must be integrated and tested across multiple systems and developers. This project will provide the capability to specify, develop, acquire, integrate, test, and maintain a trusted software element for GPALS, which is supported by the Phase I and LPS. TMD will benefit from system software engineering development as a subset of GPALS.

PROJECT NUMBER:	**3102**	
PROJECT TITLE:	**System Engineering**	
PROGRAM ELEMENT:	0603214C	Phase I Defenses
	0603215C	Limited Protection Systems
	0603216C	Theater and ATBM Defenses
	0603218C	Research and Support Activities

PROJECT DESCRIPTION

Phase I Defenses

The Systems Engineering and Integration Contractor (SEIC) addresses GPALS architecture definition, requirements analysis, and design definition of the elements that are within the Strategic Defense System (SDS). The SEIC provides risk assessment and trade studies to optimize and balance the system. The systems engineering and integration task requires planning and participation in integrated testing and identification and resolution of key Demonstration/Validation (DEM/VAL) issues. An important task of the SEIC is to insure a growth path exists for expanding from GPALS to Phase I should such a decision be made in the future.

Limited Protection Systems

Limited Protection Systems (LPS) program element is also addressed by the SEIC. LPS is a subset element of GPALS. The mission requirement is to apply the principles of systems engineering and integration to the development of systems and components which, if deployed, could function in a limited defense role.

Theater and ATBM Defenses

Theater & ATBM Defenses (TMD) program element supports GPALS, and its mission requires the development of deployable and rapidly relocatable defenses against theater/tactical ballistic missiles. TMD is the theater underlay of the GPALS system. Systems engineering and integration (SE&I) provides significant engineering development for TMD, such as systems analysis and requirements identification. TMD benefits from the systems engineering and integration work that is done in other GPALS elements. As an important aspect of the integration efforts, the SEIC must

PROJECT NUMBER: **3102**
PROJECT TITLE: **System Engineering (Continued)**

assure compatibility between the TMD underlay and remaining GPALS elements. The element compatibility could be led by TMD element deployments followed by Endoatmospheric/Exo-atmospheric Interceptor (E^2I), Ground-Based Interceptor (GBI), Brilliant Pebbles (BP), Brilliant Eyes (BE), Ground-Based Radar (GBR) and others. The need to preserve growth options is well served by optimizing the use of modular element designs.

Research and Support Activities

Research & Support Activities (R&S) provide flexibility in supporting basic systems engineering, technical, and managerial support to the program elements of Phase I Defenses, LPS, and TMD, all of which become subsets of GPALS. The SEIC is responsible for examination of the Threat, as derived from the Systems Threat Assessment report (STAR), to identify, define and decompose the functions and interrelationships of SDS. The definition and decomposition process will be developed to a level of detail permitting unique element function/performance requirements allocations, and the definition of the interfaces between individual elements. Key 1DEM/VAL issues identified in the requirements definition process will be allocated to tests, analyses or technology development. Systems test requirements for data, demonstrations, and simulations will be generated for areas identified as low confidence to facilitate an informed Milestone II decision. As part of the demonstrations during DEM/VAL this project will support the design and development of the Pilot Command Center (PCC). The PCC will provide early system testing capabilities as well as demonstrate key system interfaces and communications capabilities. In addition, trade studies will be performed for mission analysis, discrimination, technical performance, cost analyses and technology insertion. This project also coordinates similar broad based support with the element programs through Project 4201, System Engineering Management. Prior to FY1991, this project was funded under Project Number 3100, and some of the FY1990 descriptions herein were incorporated previously under that number. Beginning in FY1991, the project number was changed to 3102 to improve the Program Element titles. This project is now funded under Project Number 3102.

PROJECT NUMBER: **3104**
PROJECT TITLE: **Integrated Logistics Support**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

The Integrated Logistics Support (ILS) project addresses the identification and quantification of the essential elements of a Global Protection Against Limited Strikes (GPALS) support system. It identifies the basic supportability costs, schedule, performance, and support technology drivers in each SDI project to ensure the minimum cost of ownership and maximum effectiveness of the SDS.

PROJECT NUMBER: **3105**
PROJECT TITLE: **Producibility and Manufacturing**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

This project will identify producibility and manufacturing risks associated with the new technologies and designs being proposed for Global Protection Against Limited Strikes (GPALS) and will coordinate and implement a structured, unified approach to risk reduction and production assurance for Strategic Defense Systems.

The approach involves the following four efforts:

- Manufacturing Strategy Development -- This effort develops and implements a capstone Strategic Defense System Manufacturing Strategy, providing leadership and direction as the Elements and Systems Engineer develop their manufacturing strategies. This strategy development will flow down to the Element Contractors and subcontractor levels.
- Industrial Resource Analyses -- Analyses and Risks of the shortfalls of industry's capability to manufacture key SDS design technologies.
- Initiating critical producibility programs with industry in a number of high-priority areas to complement on-going technology or Element producibility and manufacturing efforts.
- Manufacturing Operations Development and Integration Laboratories (MODILs) -- MODILs serve to address and ultimately mitigate high producibility risks. This involves accelerating the development, integration, and introduction of modern, cost-effective manufacturing technologies into the design and the industrial base.
- Development of National Standards for SDI Elements. This involves projects with the National Institute of Science and Technology to develop critical metrology unique to SDI requirements.

These efforts combine to assure that commitment and emphasis will be placed on risk reduction and design-for-manufacturability during the appropriate design or development phase.

PROJECT NUMBER: **3107**
PROJECT TITLE: **Environment, Siting and Facilities**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

Provide environmental impact analysis documentation and facility acquisition support for the SDIO systems and technical development projects. Plan, program, budget and monitor facility acquisition of all Military Construction projects. Provide guidance and prepare Environmental Assessments and Environmental Impact Statements, as applicable, for SDIO actions. Develop guidance for Executing Agents on facility acquisition and environmental matters. Develop and execute siting and basing plans for system deployment.

PROJECT NUMBER: **3108**
PROJECT TITLE: **Operational Environments**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

The purpose of this project is to identify, integrate, coordinate, and resolve natural and nuclear environmental issues. The program will focus on characterizing natural, debris, and nuclear environments from a systems perspective. DOD and DOE programs will be reviewed to identify specific areas where additional effort is needed to support GPALS and growth options to Phase I, thus providing an adequate understanding of natural, debris, and potential nuclear environments within which a missile defense system must operate.

PROJECT NUMBER: **3109**
PROJECT TITLE: **System Security Engineering**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603215C Limited Protection Systems

PROJECT DESCRIPTION

Phase I Defenses/Limited Protection Systems

The objective of the project is to insure that Information Security (Communications and Computer Security) is integrated into the Global Protection Against Limited Strikes (GPALS) which include Theater Missile Defense programs. Achievement will be verified by integrating Communications Security (COMSEC) and Computer Security (COMPUSEC) equipment, techniques, methodologies, and Information Security (INFOSEC) design into the development of GPALS elements, whether funded under the Phase I or LPS PEs.

PROJECT NUMBER: 3110
PROJECT TITLE: **Survivability Engineering**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

System Survivability Program is responsible for oversight and management of the GPALS Survivability Program. This oversight activity includes coordination of the SDIO's survivability-related activities to support the GPALS acquisition process, ensuring that the proper interfaces are established and maintained within the system, element and component levels of the Program.

The Program provides for the generation of system and top-level element survivability requirements that are directly traceable to SDIO-approved mission requirements and threat scenario(s). Additionally, the system survivability program ensures that the element survivability requirements are consistent with system survivability requirements and that elements are able to effectively pass DAB and other critical reviews. The Program is also responsible for defining requirements for and performing system-level survivability-related tests, namely through system simulations and testbeds within the National Test Bed (NTB). Finally, the Program is responsible for defining, assessing and testing critical survivability-related operational concepts that are consistent with system and element survivability requirements.

PROJECT NUMBER: 3111
PROJECT TITLE: **Surveillance Engineering**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603215C Limited Protection Systems

PROJECT DESCRIPTION

Phase I Defenses

Surveillance/discrimination (bulk filtering, tracks initiation, tracking, track correlation, discrimination, sensor management) is one of the most difficult and fundamental problems for any missile defense system and specifically for the SDIO. Under the GPALS portion of the program a wide range of surveillance/discrimination issues from a system perspective will be addressed. This task establishes and develops the appropriate set of algorithms to accomplish the above objectives. TMD will benefit from surveillance engineering development as a subset of GPALS.

Limited Protection Systems

This task establishes and develops the test environment known as the Surveillance Test Bed (STB) and provides integration of algorithms into the STB. Specifically, the test environment developed will be linked to an appropriate set of algorithms. In addition, discrimination schema will be developed and tested, and system/element analysis will be performed to verify requirements and measure performance.

PROJECT NUMBER: **3201**
PROJECT TITLE: **Architectures and Analysis**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

This project develops, evaluates, and compares alternative architecture concepts for all phases of the Strategic Defense System (SDS), including Limited Protection Systems (LPS), Global Protection Against Limited Strikes (GPALS), Phase I, and Follow-on Architectures. Emphasis is on the insertion of newly emerging technologies into the system elements to reduce system cost and increase effectiveness. Includes upgrading and maintaining simulation tools which are necessary to conduct architectural level analyses, such as the Mission Effectiveness Model (MEM) and the exoatmospheric discrimination simulation (XoDis). Provides direct program management and technical support to the SDS Engineering Deputate. Element task areas are: Follow-on Architecture Analysis, Alternative Architectures, Analysis Tools, and Direct Support.

PROJECT NUMBER: **3202**
PROJECT TITLE: **Operations Interface**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

These tasks will analyze strategic and tactical effectiveness in light of the ability of a potential SDS architecture to meet mission requirements. Particular focus will be given to GPALS considerations. The results will be used to analyze and define USSPACECOM systems operational requirements and to explain SDS impacts on the U.S. deterrence posture. This will also support activities required for Defense Acquisition Board requirements, on-going arms control negotiations, and Army operational requirements development and analysis. These tasks also will analyze strategic effectiveness in light of a potential SDS capability to meet AFSPACECOM mission requirements. Potential SDS Phase I capability will be analyzed with particular consideration given to GPALS. The results will be used to analyze and define AFSPACECOM systems operational requirements and to explain SDS impacts on other AFSPACECOM systems and operations. They will also provide a technical interface between SDS and AFSPACECOM concerning BM/C3 architecture development and assessment. These tasks also will analyze SDS interaction with strategic offensive force capability in terms of missions, connectivity, force execution, and concepts of operations. Analyses will be conducted that will provide a technical interface between SDIO architecture studies, the Joint Strategic Target Planning Staff (JSTPS) and the Strategic Air Command (SAC) by identifying, evaluating and refining BM/C3 architectures that enhance US deterrence.

PROJECT NUMBER: **3203**
PROJECT TITLE: **Intelligence Threat Development**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

The purpose of the SDI Intelligence Threat Development project is to provide an up-to-date Intelligence Community-validated threat description against which system-specific "design-to" threat specifications, lethality designs, and target objects are developed. The primary vehicle for providing this threat description is the System Threat Assessment Report (STAR), which is updated and validated by the Intelligence Community annually under this project. The Intelligence Threat Development Program divides the threat into two major categories--Delivery Vehicles and Payloads--and three levels of detail within each category. The delivery vehicle category includes Soviet boosters (ICBM and SLBM), Soviet post-boost vehicles (buses), and Third World missiles, while the payloads category includes Soviet re-entry vehicles (warheads), penetration aids, and Third World warheads (both nuclear and non-nuclear). The STAR addresses the threat faced by a Global Protection Against Limited Strike (GPALS) system from two points of view. First, the descriptions of Soviet threat vehicles, warheads, and penetration aids are equally applicable whether under limited or all-out nuclear attack. Second, the Third World threat descriptions in the current STAR and the Third World missile and warhead design studies being developed for the next STAR update address the threat from the Third World both against CONUS (strategic) and theater (tactical) elements. All of these threat objects are described at the form, fit, and function level, Level 1, necessary to produce the SDI "design-to" threat specifications and at the more detailed Level 2, where actual materials and structures are described for use in lethality studies and actual target designs.

PROJECT NUMBER: **3204**
PROJECT TITLE: **Countermeasures Integration**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

The purpose of the SDI countermeasures project is to identify likely countermeasures to strategic defense system concepts such as MATTR and GPALS (and/or individual system components) to assist defense systems designers to make their systems robust against potential countermeasures. The countermeasure may be technical--directed specifically against the hardware of the defense system, or tactical--designed to avoid or suppress the defense. The countermeasures project uses a Red-Blue Team methodology. On an annual basis, an independent Department of Energy SDI Countermeasures Review Board will make recommendations on the existing extensive DOD and DOE countermeasures program and necessary improvements.

PROJECT NUMBER: 3205
PROJECT TITLE: **Theater Missile Defense (TMD) Special Studies**
PROGRAM ELEMENT: 0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

Theater and ATBM Defenses

Theater Missile Defense Special Studies includes two distinct efforts: continuing architecture studies and technology development studies and tests to form the cornerstone of an essential layer in the development of a global defense against ballistic missiles of all ranges.

1. These studies will accomplish system engineering, technology analyses, and examination of theater missile defense (TMD) concepts leading to the definition of TMD architectures that meet the mission objectives against the postulated threat. TMD architecture analyses include: UK Architecture Study to develop a cost-effective ballistic missile defense system against the Euro-strategic and Third World threats as defined by the United Kingdom; and global architectures studies to develop mission requirements and TMD architecture for global regions of interest. The UK study, which builds on their previous analysis of the relationship between this theater defense architecture and the U.S. strategic defense, is designed to provide this insight for GPALS. This effort will lead to the development or refinement of a variety of technologies required for defense against TBMs.

2. The objective of these analyses and experiments is to improve technical understanding of the TMD problem and alternatives for defense architectures. The intent is to accomplish systems engineering, analyses, and examination of TMD concepts; manage direct TMD architecture analysis; and conduct independent evaluations of these concepts and provide recommendations. These studies include: the WESTPAC Architecture Study to develop a complete missile threat characterization of the Western Pacific Region, the United Kingdom Artificial Intelligence (AI) Discrimination Research Program to examine AI techniques for discrimination of reentry vehicles and penetration aids, and a study to accomplish engineering and integration analysis in support of a future Israeli missile defense system. A series of generic Future Air Defense studies will be used to help determine the requirements and potential technologies for Future Air Defense capabilities. These studies will be conducted within the framework of the Air Defense/Anti-Tactical Ballistic Missile (AD/ATBM) capability mission need statements. Analyses will include evaluation of requirements for a balanced capability against both tactical ballistic missiles, as well as air breathing threats, identification and trade-offs of alternative technologies, assessment of the value/requirements of interoperability with existing/planned air defense systems, and assessment of potential contributions by external systems (sensors, communications, data fusion centers, etc.) to future air defense capabilities. Theater air and missile analyses as well as studies of Navy and Air Force theater assets capable of being integrated into a tactical ballistic missile architecture will be initiated in 1991.

PROJECT NUMBER: 3206
PROJECT TITLE: System Threat
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

The proper development, utilization, management, and control of threat data projections is vital to successful SDI Program research and development activities. A stable, unambiguous, and qualified threat definition is needed to focus all SDI development programs. The SDI Program presents a unique challenge because it is a system of systems with the complex issues of responsive/reactive offensive and defense suppression threats. The complexity and importance of these factors demand a focused and carefully managed threat development approach.

Faced with the need to make assessments and decisions concerning Soviet responses to SDS, the SDIO has adopted a branch and block approach to ensure responsive system development and continued operational effectiveness while minimizing the resource expenditures required to counter Soviet responses. The branch and block concept is an analytic and planning approach, whereby incremental program steps are defined and analyzed relative to possible Soviet strategic options. Soviet options responding to the SDS may be countered by US initiatives that either neutralize the Soviet response or preclude it from even being pursued. For example, if the Soviets deploy penetration aids, the US improves its ability to discriminate RVs from decoys.

The goal is to foresee all likely Soviet options and to initiate US counter-actions as soon as possible and effectively enough to forestall those options. Ultimately, the US wants to convince the Soviets that their best chance for security and stability is to move from their present offense-dominated military strategy toward a defense-dominated one. This approach to countering Soviet responses will also dictate that the US develop and maintain the technology base needed to ensure that it has the technical means and capability to respond rapidly and effectively to block future Soviet responses.

With the changing world situation and the proliferation of ballistic missiles among countries other than the US and Soviet Union, it is imperative that an accurate characterization of global threats be developed. This accurate characterization of Nth country ballistic missiles and the appropriate development and integration of scenarios using these characterizations is critical to the development of a strategic defense system that is capable of providing Global Protection Against Limited Strikes (GPALS).

The System Threat development project is an integral part of SDIO's three-part SDS Threat Program. The System Threat project uses as a baseline the System Threat Assessment Report (STAR) developed under the Intelligence Threat Development project (#3203) and the likely Soviet countermeasures identified in the Countermeasures Integration project (#3204). The System Threat project adds system-specific engineering characterization details described in the form of scenarios characterizing particular timing, targets, and tactics.

PROJECT NUMBER: **3207**
PROJECT TITLE: **System Architecture**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603215C Limited Protection Systems
0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

Phase I Defenses/Limited Protection Systems/Theater and ATBM Defenses

The objective of this project is to define an evolving architecture for the phased deployment of the strategic defense system within each of the established Program Elements. This evolution will start with Global Protection Against Limited Strikes (GPALS) and evolve to a full Phase I BMD capable system if conditions warrant. This project will also define stand alone architectures for a ground-based Limited Protection Systems (LPS) and Theater Missile Defense (TMD) and show how they integrate into the evolving architecture.

SDI has had a number of previous studies addressing the full Soviet threat to the Continental U.S. (CONUS). These studies have focused on specific issues such as the midcourse, the space-based elements, the terminal tier, etc. The changing climate in world relations and the onset of increasing capabilities of third world nations have made it more important to address issues such as protection of the United States and allied countries against limited strikes and theater missile defense. This project will address those issues and their integration into an evolving, time phased, architecture. The MATTR, OSD GPALS, and TPALS studies will be the point of departure for this project.

PROJECT NUMBER: **3302**
PROJECT TITLE: **System Test Environment**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

The mission of the Strategic Defense Initiative (SDI) National Test Bed (NTB) Program is to provide a comprehensive capability to experiment and evaluate alternative SDI system concepts, architectures including battle management/command, control and communications (BM/C^3) and key defensive technologies and to finally integrate the ultimate SDS architecture elements. This mission supports the SDS system evolution by the modeling of program elements into a cohesive architecture beginning with TPALS, through GPALS, and culminating with Phase I. The NTB consists of a network of integrated, geographically distributed, simulation and support facilities. The National Test Facility at Falcon AFB, CO is the hub and central experiment and simulation facility. The network nodes include Strategic Defense Initiative Organization, Army Strategic Defense Command, Air Force Space System Division, Air Force Electronics Systems Division, Strategic Air Command, Los Alamos National Laboratory, Naval Research Laboratory, and General Electric Corporation - Blue Bell,

PROJECT NUMBER: **3302**
PROJECT TITLE: **System Test Environment (Continued)**

PA. This integrated network provides the capability to address system integration and performance evaluation capabilities.

PROJECT NUMBER: **3303**
PROJECT TITLE: **Independent Test and Evaluation (T&E) Oversight and Assessment**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

Provide independent T&E oversight and assessment of all (SDS) element tests to ensure that comprehensive T&E programs are implemented to support SDS design, development, construction, operational capability, and deployment. This effort provides SDS wide T&E programmatic and technical management, verification and validation (V&V), certification, status monitoring, and targets to support SDI test programs.

PROJECT NUMBER: **3304**
PROJECT TITLE: **Test and Evaluation Resources**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

This task provides for overall coordination of Test and Evaluation throughout the SDI Program. Currently, three tasks are included in this project: the SDIO Targets Program, Space Test Range, and Studies and Analyses.

The objective of the Targets Program is to provide engineering and threat representative test targets for experiments and for Developmental Test (DT) for the GPALS/Phase I program. These targets must meet SDS performance, engineering, and threat characteristics requirements to provide test articles that will adequately emulate the expected threat and support engineering and development tests. Test and Evaluation is the staff function designated to provide for the design, development, characterization, validation, production, acquisition, and support system tests. The targets of concern are Boosters, Re-entry vehicles (RV), Post Boost Vehicle (PBV), Decoys and Penetration aids (Penaids).

PROJECT NUMBER: **3304**
PROJECT TITLE: **Test and Evaluation Resources (Continued)**

Targets will be designated and developed based on element and system level development tests/experiment requirements. Initial target design and development will include an engineering and threat representative target set approved by the Test and Evaluation Working Group (TEWG), and validated by the intelligence community. Testing will be conducted on the test targets to ensure that they meet the characterization and validation requirements of the standard/threat target set. This characterization will ensure the proper data is available, post test, for accurate and timely test evaluation.

The T&E Facilities program will ensure needed test capabilities are in place to support FSD testing of the SDS. This program will accommodate the development of Environmental Assessments and Impact Statements (EA's and EIS's) as well as design and construction of various test facilities. Specific upgrades to the Space Test Range (STR) required to support SDS testing will also be funded under this program.

Products resulting from this effort will include:

- Pre-production Prototypes (booster, PBVs, RVs, Decoy/Penaids).
- Flight-qualified hardware.
- Pre-production, validated test articles (PBV/RVs Penaids/Decoys).
- ERIS, E^2I, GBI-X, MSX, AOA targets, ARE-2 Payload.
- Launcher Boosters.
- Range Telemetry and Communications Equipment.

PROJECT NUMBER: **3305**
PROJECT TITLE: **Theater Test Bed**
PROGRAM ELEMENT: 0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

Theater and ATBM Defenses

The Theater Test Bed effort will develop computer based analysis centers to evaluate the component and overall system designs postulated for Theater Missile Defense. This effort will develop a common base for simulation software and the means to augment it with location unique software for the specific, local analysis; provide the capability for man-in-the-loop/hardware-in-the-loop experiments and the networking of test bed centers. In addition, the effort will identify, design, and evaluate appropriate joint and unilateral experiments. The Theater Test Bed program will provide the capability for operational, doctrine, and material developers, and systems engineers and analysts to address the issues associated with Theater Missile Defense, and working interactively with the NTB, address issues between TMD and other GPALS elements. Major testbed characteristics include real-time operations, a friendly highly interactive user environment, user direct control, Ada and maximum software portability and security requirements compatible with multinational participation.

PROJECT NUMBER: **3306**
PROJECT TITLE: **Advanced Research Center**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

This project provides funding for the Advanced Research Center (ARC) for ongoing operations and maintenance. The ARC is an advanced computation technology system providing the operational test bed for resolving battle management and command, control and communications (BM/C3) issues for GPALS. It also serves as a development & test capability for other USASDC programs, to include the Surveillance Test Bed and Extended Air Defense Test Bed. The ARC is a major node in the National Test Bed (NTB).

PROJECT NUMBER: **3307**
PROJECT TITLE: **Midcourse Experiment**
PROGRAM ELEMENT: 0603215C Limited Protection Systems
0603216C Theater and ATBM Defenses

PROJECT DESCRIPTION

Limited Protection Systems

The Airborne Optical Adjunct (AOA) program has been expanded to use the AOA as an Airborne Surveillance Testbed (AST) to conduct experiments that will help GPALS elements resolve critical issues throughout all phases of a ballistic missile trajectory. The AST program provides for the design and deployment of an infrared (IR) sensor which, together with the appropriate data processing, display control, communications, and ancillary equipment, will be installed on a modified Boeing 767 commercial aircraft. It supports other longwave infrared (LWIR) sensors with collection of multi-target data, verification of sensor operation, and validation of processing techniques and algorithms. The major issues to be addressed by the AOA/AST are those of sensor to sensor correlation, discrimination, resolution of closely spaced objects, bulk filtering, target and background signature, handover to other sensors, and signal and data processing requirements for LWIR sensor performance. The AST will provide a design and performance data base for on going as well as future programs in the areas of design, system performance and operation of LWIR sensors, real-time on-board signal and data processing, performance of an integrated LWIR payload in an aircraft environment, and signatures of atmospheric backgrounds, targets, and aero-optic effects. The need to perform these functions accurately and reliably place great demands on a system that is the most complex and capable of its kind ever built. Initially, the integrated system will be tested on the ground, then in flight tests over the Continental United States (CONUS), and finally be used to conduct SDI experiments at United States Army Kwajalein Atoll (USAKA) and other national test ranges.

PROJECT NUMBER: 3307
PROJECT TITLE: **Midcourse Experiment (Continued)**

Theater and ATBM Defenses

The sensor functions for theater ATBM missions, part of the GPALS concept, are the same as those sensor functions for BMD missions. AOA/AST will be integrated as an optical sensor with the U.S. Army's Patriot Air Defense System to validate the applicability of LWIR sensors in an ATBM role. In addition to the basic sensor functions, AOA/AST's integration with radar sensors and interceptor missiles will provide useful combinatorial experience that will be translatable into the BMD integration mission. Generally speaking, the required sensor performance for BMD application is greater than the performance requirements for theater application. As a result, there are no required modifications to AOA/AST to address theater issues. ATBM missions will be conducted at White Sands Missile Range.

PROJECT NUMBER: 3308
PROJECT TITLE: **System Simulator, Level II**
PROGRAM ELEMENT: 0603214C Phase I Defenses
0603215C Limited Protection Systems

PROJECT DESCRIPTION

Phase I Defenses

The Level II System Simulator (L2SS) will provide a critically needed capability to perform necessary trade studies and analyses in support of an informed deployment decision and to define more precisely the SDS element and system designs prior to Milestone II Full Scale Engineering Development decisions. The L2SS will incorporate design concept-specific representations of the various elements. The performance of key element subsystems will be simulated at selected levels of detail. These levels will be specified by the System Engineer, based upon the best estimate of which features of the element concepts affect critical system-level demonstration/validation issues, and recognizing the desire to leave a detailed examination of critical issues to the testbeds being developed to address them. This tool will be used to validate the element design concepts of the current SDS architecture and ensure that they can perform in the integrated system. The initial implementation of L2SS will represent the latest iteration of the proposed GPALS architecture, namely Brilliant Pebbles, Brilliant Eyes, Exo-Endoatmospheric Interceptor, Ground-Based Radar (Terminal), and Command Center. Theater Missile Defense (TMD) will benefit from this system simulator development as a subset of GPALS.

Limited Protection Systems

Some selected elements of the L2SS may have applicability to a simulation of an LPS, but this capability is not being addressed in this PMA. The funding breakout herein is strictly an arbitrary determination. The L2SS program will lead not only to a certified, validated tool capable of evaluating SDS performance of System Demonstration/Validation testing but additionally will provide a test bed for establishing and refining the SDS integration process. Consequently, the development of the L2SS

PROJECT NUMBER: **3308**
PROJECT TITLE: **System Simulator, Level II (Continued)**

will be the first critical test case for the strategic defense community to demonstrate its ability to functionally integrate the elements comprising an SDS.

PROJECT NUMBER: **4000**
PROJECT TITLE: **Operational Support Costs**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

This project provides system engineering and program control support common to all other projects within this PE. Typical system engineering tasks include review and analysis of technical project design, development and testing, test planning, assessment of technology maturity and technology integration across SDIO projects; and support of design reviews and technology interface meetings. Program control tasks include assessment of schedule, cost, and performance, with attendant documentation of the many related programmatic issues. This project supports funding for civilian personnel and expenses for travel (TDY), training, rents, communications, information management, utilities, printing, reproduction, supplies, and equipment. FY1993 funding includes $103.3M for Defense Contract Management Services (DCMS).

PROJECT NUMBER: **4102**
PROJECT TITLE: **Sandia Construction**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

This project provides funding for the Strategic Defense Facility at Sandia National Laboratory. This facility provides a research and testing laboratory for SDI programs requiring pulsed power technology. Programs and research activities that will use this facility include advanced electromagnetic acceleration concepts, particle beam acceleration, plasmoid propagation, electrical energy sources, and laboratory x-ray laser physics. Testing activities at this facility will include examining the effects of lasers, high power microwaves, and x-rays in support of SDI target lethality and survivability efforts. The Sandia funding will provide the equipment required to complete the facility.

PROJECT NUMBER: **4302**
PROJECT TITLE: **Technology Transfer**
PROGRAM ELEMENT: 0603218C Research and Support Activities

PROJECT DESCRIPTION

Research and Support Activities

The Technology Applications Program was established in 1986 to make SDI technology available to federal agencies, state and local governments, and U.S. business and research interests.The objective of this program is to develop and support the transfer of SDI-derived technology to Department of Defense applications as well as to other federal, state, and local government agencies, federal laboratories, universities, and the domestic private sector.

PROJECT NUMBER: **4305**
PROJECT TITLE: **Miniaturized Accelerators for PET**
PROGRAM ELEMENT: 0603217C Follow-On Systems

PROJECT DESCRIPTION

Follow-On Systems

The Medical Free Electron Laser (MFEL) program seeks to develop and enhance free electron laser technology and to assess how the unique characteristics of FELs may be exploited for applications in medical, biophysical, and materials science research. After FY1990, SDIO transferred total responsibility for the MFEL program to DDR&E/Environmental and Life Sciences.

The Positron Emission Tomography (PET) accelerator program, initiated in FY1988 by Congressional direction, is a research project that will reduce the size, weight, and cost of current particle accelerators used to develop radio-pharmaceuticals for Positron Emission Tomography medical diagnoses.

NOTE: $2M was appropriated separately in PE 603231D to allow for two distinct contracting efforts for PET.

TMDI Program Elements Projects

PROJECT NUMBER: **2106**
PROJECT TITLE: **Advanced Contingency Theater Sensor**
PROGRAM ELEMENT: 0604225C Tactical Missile Defense Initiative Full Scale Development

PROJECT DESCRIPTION

Tactical Missile Defense Initiative Full Scale Development

This project supports the development of a technology base for a rapidly deployable, survivable sensor system to support defense against a theater missile threat (tactical air-to-surface missiles, ballistic missiles of all ranges, cruise missiles, and aircraft) in a variety of contingency theaters of operation. Development of a required sensor suite, called the Advance Contingency Theater Sensor (ACTS), and a technology demonstration of one or more of the individual sensors comprising the ACTS system will be accomplished. PMA A1206 provides funds in FY1991 for SDC to begin an in-house concept definition for an FY1995-deployable ACTS. SDC's concept definition effort will support the issuance of a concept validation RFP in mid-FY1991. The ACTS program then transitions to TMDI funding (PE 0603744C) in FY1992 and will move to the PMA covered under this summary.

PROJECT NUMBER: **2207**
PROJECT TITLE: **Patriot**
PROGRAM ELEMENT: 0603744C Tactical Missile Defense Initiative Demonstration & Validation
0604225C Tactical Missile Defense Initiative Full Scale Development

PROJECT DESCRIPTION

Tactical Missile Defense Initiative Demonstration & Validation/Tactical Missile Defense Initiative Full Scale Development

The Patriot project will fund both demonstration/validation and full scale engineering development of improvements to the Patriot air defense system through the Demonstration & Validation and Full Scale Development program elements.

PROJECT NUMBER: **2207**
PROJECT TITLE: **Patriot (Continued)**

Theater tactical ballistic missiles (TBM) with significantly improved range and accuracy have increased the threat against Patriot air defense sites and defended assets. This could result in the destruction of Air Defense sites and provide the enemy air superiority once an attack is initiated. Patriot must be able to acquire, identify, track, engage, and destroy incoming TBMs as an element of active defense and unit survivability. Patriot near-term, anti-tactical missile (ATM) capabilities (PAC) consist of two phases: modifications to the system software (PAC-1) and modification to missile hardware (warhead and fuze assembly) (PAC-2). The PAC-1 software changes fielded in June 1988 provide a self-defense capability. The PAC-2 changes will extend the self-defense capabilities to a limited, corollary, asset defense capability and were fielded beginning in January 1991. The Multi-Mode Seeker (MMS) program, a cooperative development with Germany, expands the limited critical asset defense capability of the PAC-2 Program by incorporating an active seeker into the Patriot missile. The MMS also includes changes to the missile auto-pilot to improve data handling and improvements in signal-to-noise performance in the missile receiver. These system changes are needed to counter TBM with low radar cross section, high terminal velocity, and high angle of attack.

PROJECT NUMBER: **2208**
PROJECT TITLE: **Extended Range Interceptor (ERINT)**
PROGRAM ELEMENT: 0603744C Tactical Missile Defense Initiative Demonstration & Validation
0604225C Tactical Missile Defense Initiative Full Scale Development

PROJECT DESCRIPTION

Tactical Missile Defense Initiative Demonstration & Validation/Tactical Missile Defense Initiative Full Scale Development

The purpose of this project is to fund both the demonstration/validation and full scale engineering development of the Extended Range Interceptor (ERINT-1) Technology Program through the Demonstration/Validation and Full Scale Development program elements.

The ERINT-1 will demonstrate a small, agile, hit-to-kill missile that will provide an asset defense against incoming maneuvering and non-maneuvering TBMs. A secondary objective of the Program is to provide defense against the air-breathing threat. The missile features an on-board active millimeter wave seeker that provides endgame guidance, advanced flight control technologies for agility in terminal maneuvers, lethality enhancement technologies, and a lightweight composit case solid rocket motor. The ERINT has been designed to easily integrate with existing air defense capabilities, such as Patriot.

PROJECT NUMBER: **2209**
PROJECT TITLE: **Arrow Continuation Experiments (ACES)**
PROGRAM ELEMENT: 0603744C Tactical Missile Defense Initiative Demonstration & Validation

PROJECT DESCRIPTION

Tactical Missile Defense Initiative Demonstration & Validation

The ACES interceptor (a follow-on to the Arrow) will be developed under a joint US-Israeli program and will provide valuable experimental data for a number of U.S. interceptor programs and conduct those experiments needed to establish a sound basis for decisions concerning full-scale development and deployment of this component of a missile defense system in Israel. A Memorandum of Understanding (MOU) between the U.S. and Israeli Governments, which will be used to direct the program, is being negotiated. The ACES program will be initiated in FY1991 with the design of a scaled-down interceptor vehicle. The Israeli-designed ACES interceptor will be smaller and lighter than the present Arrow, with an extended intercept range and enhanced lethality. In addition, an ACES Support Program, to be initiated in FY1991, will provide independent analysis and review of the ACES Program.

PROJECT NUMBER: **2210**
PROJECT TITLE: **Theater High Altitude Area Defense Interceptor**
PROGRAM ELEMENT: 0603744C Tactical Missile Defense Initiative Demonstration & Validation
0604225C Tactical Missile Defense Initiative Full Scale Development

PROJECT DESCRIPTION

Tactical Missile Defense Initiative Demonstration & Validation/Tactical Missile Defense Initiative Full Scale Development

This project supports the demonstration/validation and full scale engineering development of an area defense, hypervelocity, ground-launched interceptor capable of engaging reentry vehicles in the upper atmosphere and over large ground regions through the Demonstration & Validation and Full Scale Development program elements.

THAAD will be designed as an overlay to planned asset defense systems such as PATRIOT or ERINT, to defend against the post-INF, year 1995 and beyond threat. It will be compatible with existing air defense hardware (i.e., launchers, BM/C^3, sensors, etc.) and will be capable of supporting contingency force operations. The missile will use SDI-derivative and other technologies to the fullest extent possible. A follow-on P^3I program will improve THAAD capabilities for the year 2000 and beyond threat.

PROJECT NUMBER: **2210**
PROJECT TITLE: **Theater High Altitude Area Defense Interceptor (Continued)**

Concept definition for the THAAD is being performed in FY1991 under PMA 1206, using PE 0603216C funds. The THAAD program then transitions to TMDI funding (PE 0603743C) in FY1992 and will move to the PMA covered under this summary.

PROJECT NUMBER: **3208**
PROJECT TITLE: **Interservice Integration**
PROGRAM ELEMENT: 0603744C Tactical Missile Defense Initiative Demonstration & Validation

PROJECT DESCRIPTION

Tactical Missile Defense Initiative Demonstration & Validation

The purpose of this project is to undertake a series of studies to develop and demonstrate the means to counter tactical ballistic missiles through a centrally managed anti-tactical ballistic missile research program concentrating on command, control, communications and intelligence (C^3I) and other technologies. This effort will lead to the development or refinement of a variety of technologies required for defense against tactical ballistic missiles. The study and development program will be centrally managed and directed by the Joint Tactical Missile Defense Management Office (JTMDMO), which will report to the SDIO.

Nine research programs will initially be undertaken in this project. The Enhanced Kinetic Energy (EKE) Warhead program is developing and testing warheads to neutralize chemical and biological threats. Research into promising sensor technologies, with concentration on overhead assets and passive sensor concepts, will yield technical design requirements for both theater fire control and warning functions. The Extended Air Defense C^3I Simulation (a simulation tool depicting theater missile defense (TMD) performance in the total battlefield environment) will continue to be enhanced and analyzed; development of the "Tool", a commander's C^3I decision support system, will be continued. Short Range Ballistic Missile (SRBM) vulnerability and warhead effectiveness analyses will be funded, as will hardware-in-the-loop evaluations of critical C^3I technologies. The Surface-to-Air Missile Operations Center (SAMOC), which will be a major interoperability node and will act as a central data distribution system for TMD C^3I information in NATO and other theaters, will continue to be supported, as will the Tactical Information Broadcasting Service (TIBS).

TMDI Procurement Projects

APPROPRIATION: Procurement Defense Agencies
PROCUREMENT TITLE: TMDI-Patriot

PROJECT DESCRIPTION

The Multimode Seeker incorporates a ka-Band active radar into the current PATRIOT Missile forebody. The Multimode Seeker will give the PATRIOT Missile an autonomous firing capability, enhance Electronic Counter Countermeasure capabilities, and improved performance against low Radar Cross Section targets, both aircraft and tactical missiles. The Multimode Seeker will expand the limited asset defense capability of the PATRIOT PAC-2 program by incorporating an active seeker into the PATRIOT Missile. The Multimode Seeker also incorporates changes to the missile auto pilot which improves data handling and improvements to signal to noise performance in the missile receiver. These changes are needed to counter Tactical Ballistic Missile with low radar cross section, high terminal velocity and high angle of attack.

Modification to PATRIOT launchers and radar in support of TMDI that will increase PATRIOT effectivity, survivability, flexibility of defense design, footprint and detection of smaller low radar cross section targets.

APPROPRIATION: Procurement Defense Agencies
PROCUREMENT TITLE: ERINT-1/Canister-Launcher

PROJECT DESCRIPTION

ERINT-1 is a program to demonstrate the capability of a hypervelocity missile that will provide hit-to-kill accuracy against tactical missile and air breathing threats. The missile provides an on-board high performance active doppler tracking radar seeker, increased impulse, lightweight attitude control motors, low expansion velocity radial disk lethality enhancer, and fire control system integration into existing operational fire control radars. The ERINT-1 system provides realistic mission profiles against potential targets in the ballistic and maneuvering tactical missile classes. The system is proposed as an adjunct to the PATRIOT or HAWK Missile systems to provide fast, agile, and high rates of fire against the above threats. Its small size makes ERINT an excellent system to maneuver with firepower.

APPROPRIATION: **Procurement Defense Agencies**
PROCUREMENT TITLE: **Theater High Altitude Area Defense (THAAD) Missile with Canister-Launch**

PROJECT DESCRIPTION

The Theater High Altitude Area Defense (THAAD) is a program to develop a near term capability to provide area defense against the evolving theater/tactical missile threat that will include short and medium range missiles that may be able to maneuver prior to impact. The program has two principle components, first the development, then the test and evaluation of this hypervelocity missile at high altitude and long range. The system will be an autonomous missile that requires target queuing and handoff but no command guidance. Development programs will resolve the warhead design with regard to hit-to-kill versus blast fragmentation concepts. This missile will be an adjunct to the PATRIOT and Navy AEGIS Standard Missile System and provide significant required Strategic (Wide Area) defense that is more than 10 times that of current systems.

List of Acronyms

List of Acronyms

ABM	Anti-Ballistic Missile
ACES	Arrow Continuation Experiments
ACS	Attitude Control System
ACTS	Advanced Contingency Theater Sensor
AFB	Air Force Base
ALDP	Advance Launch Development Program
ALI	Alpha/LAMP Integration
ALS	Advanced Launch System
APLE	Average Power Laser Experiment
ASAT	Anti-Satellite
ASM	Anti-Ship Missile
AST	Airborne Surveillance Testbed
ATBM	Anti-Tactical Ballistic Missile
ATP-FC	Acquisition, Tracking, Pointing, and Fire Control
AWACS	Airborne Warning and Control System
BA	Budget Activity
BE	Brilliant Eyes
BM/C^3	Battle Management/Command, Control, and Communications
BMD	Ballistic Missile Defense
BP	Brilliant Pebbles
BSTS	Boost Surveillance and Tracking System
C^3	Command, Control, and Communications
C^3I	Command, Control, Communications, and Intelligence
CC	Command Center
CEATM	Cost-Effectiveness at the Margin
CIRRIS	Cryogenic Infrared Radiance Instrumentation for Shuttle
CM	Countermeasures
CMT	Common Module Tracker
CO_2	Carbon Dioxide
CONOPS	Concept of Operations
CRRES	Combined Radiation Release Experiment Satellite
CSM	Core Support Module
CWDD	Continuous Wave Deuterium Demonstrator
DAB	Defense Acquisition Board
Dem/Val	Demonstration/Validation
DEPD	Directed Energy Power Demonstrator
DEW	Directed Energy Weapon
DOD	Department of Defense
DOE	Department of Energy
DST	Defense and Space Talks
EADTB	Extended Air Defense Test Bed
EML	Electromagnetic Launcher
EDX	Exoatmospheric Discrimination Experiment
E^2I	Endo-Exoatmospheric Interceptor
ERINT	Extended Range Interceptor
ERIS	Exoatmospheric Reentry Vehicle Interceptor Subsystem
ESD	Electronic Systems Division, Air Force
EXCEDE	Electron Accelerator Experiment
FEL	Free Electron Laser
FPA	Focal Plane Array
FSD	Full-Scale Development

FTV	Functional Technology Validation
FY	Fiscal Year
GBI	Ground-Based Interceptor
GBL	Ground-Based Laser
GBR	Ground Based Radar
GBR-M	Ground-Based Midcourse Radar
GBRT	Ground-Based Terminal Radar
GBR-X	Ground-Based Radar - Experimental
GHz	GigaHertz
GPALS	Global Protection Against Limited Strikes
GSTS	Ground-Based Surveillance and Tracking System
GTA	Ground Test Accelerator
HEDI	High-Endoatmospheric Defense Interceptor
HIP	Hot Isostatic Press
HPM	High-Power Microwave
HVG	Hypervelocity Gun
IBSS	Infrared Background Signature Survey
ICBM	Intercontinental Ballistic Missile
ICS	Interceptor Computer System
IMU	Inertial Measurement Unit
INF	Intermediate-Range Nuclear Forces
IR	Infrared
IST	Innovative Science and Technology
KBS	Knowledge-Based System
KEW	Kinetic Energy Weapon(s)
KHILS	Kinetic Hardware-in-the-Loop Simulator
KITE	Kinetic Energy Kill Vehicle Integrated Technology Experiment
KV	Kill Vehicle
LACE	Low-power Atmospheric Compensation Experiment
LAMP	Large Advanced Mirror Program
LATS	LWIR Advanced Technology Seeker
LDS	Lexington Discrimination Systems
LEAP	Lightweight Exoatmospheric Projectile
LHEML	Laser Hardened Materials Evaluation Laboratory
LODE	Larger Optics Demonstration Experiment
LoSAT-X	Low Altitude Satellite Experiment
LPS	Limited Protection System
LWIR	Long-Wavelength Infrared
MATTR	Midcourse and Terminal Tiers Review
MIGS	Micro-Mechanical Inertial Guidance System
MIRV	Multiple Independently Targetable Reentry Vehicle
MIT	Massachusetts Institute of Technology
MM	Minuteman
MMS	Multi-Mode Seeker
MMW	Millimeter Wave
MOA	Memorandum of Agreement
MOD	Ministry of Defense
MODIL	Manufacturing Operations Development and Integration Laboratory
MOPS	Million Operations Per Second
MOU	Memorandum of Understanding
M&S	Materials and Structures
MSX	Midcourse Space Experiment
MTCR	Missile Technology Control Regime
MW	Megawatts
MWIR	Medium-Wavelength Infrared
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NDEW	Nuclear Directed Energy Weapons
NPB	Neutral Particle Beam
NPBSE	Neutral Particle Beam Space Experiment

NPG	Nuclear Planning Group
NTB	National Test Bed
NTF	National Test Facility
OAMP	Optical Airborne Measurement Program
ODES	Operational and Developmental Experiments Simulator
PAAM	Phased Array Antenna Module
PAC	Patriot ATBM Capability
PBV	Post-Boost Vehicle
PBW	Particle Beam Weapon
PCC	Pilot Command Center
PE	Program Element
PET	Positron Emission Tomography
P^3I	Pre-Planned Product Improvement
PMA	Program Management Agreement
P&M	Producibility and Manufacturing
R&D	Research and Development
RCS	Radar Cross Section
RDT&E	Research, Development, Test and Evaluation
RF	Radio Frequency
RME	Relay Mirror Experiment
ROC	Regional Operations Center
RV	Reentry Vehicle
SA/BM	System Analysis/Battle Management
SABLE	Scaled Atmospheric Blooming Experiment
SALT	Strategic Arms Limitation Talks
SAMMES	Space Active Materials Modular Experiments
SATKA	Surveillance, Acquisition, Tracking, and Kill Assessment
SAVI	Space Active Vibration Isolation
SBFEL	Space Based Free Electron Laser
SBI	Space-Based Interceptor
SBIR	Small Business Innovative Research
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SDS	Strategic Defense System
SE&I	Systems Engineering and Integration
SLBM	Submarine-Launched Ballistic Missile
SLKT	Survivability, Lethality, and Key Technologies
SLV	Space Launch Vehicle
SPEAR	Space Power Experiments Aboard Rockets
SPICE	Space Pointing and Integrated Controls Experiment
SPIRIT	Space Infrared Imaging Telescope
SPPD	Signal Processor Packaging Design
SRMP	Sounding Rocket Measurement Program
SRT	Strategic Red Team
SSBN	Ballistic Missile Submarine
SSTS	Space-Based Surveillance and Tracking System
STAR	System Threat Assessment Report
STARS	Strategic Target System
START	Strategic Arms Reduction Talks
SUPER	Survivable Solar Power Subsystem Demonstrator
SWIR	Short-Wavelength Infrared
TAIS	Technology Applications Information Systems
TBM	Theater Ballistic Missile
TFE	Thermionic Fuel Element
TFE	Tracking Field Experiments
T&E	Test and Evaluation
THAAD	Theater High Altitude Area Defense
TMD	Theater Missile Defense
TMD-GBR	Theater Missile Defense Ground-Based Radar
TMDI	Theater/Tactical Missile Defense Initiative
TPALS	Theater Protection Against Limited Strikes

TPALS	Theater Protection Against Limited Strikes
TW/AA	Tactical Warning/Attack Assessment
TWG	Threat Working Group
U.K.	United Kingdom
U.S.	United States
USAKA	U.S. Army Kwajalein Atoll (Range)
USASDC	U.S. Army Strategic Defense Command
USD(A)	Under Secretary of Defense (Acquisition)
VHSIC	Very High-Speed Integrated Circuit
VLSIC	Very Large-Scale Integrated Circuit
VUE	Visible/Ultraviolet Experiment
WAVE	Wideband Angular Vibration Experiment
WSMR	White Sands Missile Range
XLINK	Cross Link

Glossary

Glossary

ABM Treaty—Formal title of the 1972 ABM Treaty is *"Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems."*

Acquisition—The process of searching for and detecting a potentially threatening object in space. An acquisition sensor is designed to search a large area of space and to distinguish potential targets from other objects against the backdrop of space.

Algorithms—Rules and procedures for solving a problem.

Anti-Ballistic Missile (ABM) System—A missile system designed to intercept and destroy a strategic offensive ballistic missile or its reentry vehicles.

Anti-Satellite Weapon—A weapon designed to destroy satellites in space. The weapon may be launched from the ground or an aircraft or be based in space. The target may be destroyed by nuclear or conventional explosion, collision at high speed, or directed energy beam.

Anti-Simulated Reentry Vehicle—A reentry vehicle design whose inflight observable characteristics are modified to resemble specific decoy observable characteristics.

Architecture—Description of all system functional activities to be performed to achieve the desired level of defense, the system elements needed to perform the functions, and the allocation of performance levels among those systems elements.

Ballistic Missile—A guided vehicle propelled into space by rocket engines. Thrust is terminated at a predesignated time after which the missile's reentry vehicles are released and follow free-falling trajectories toward their ground targets under the influence of gravity. Much of a reentry vehicle's trajectory will be above the atmosphere.

Ballistic Missile Defense (BMD)—A defense system that is designed to protect against attacking ballistic missiles. Usually conceived of as having several independent layers of defense.

Battle Management—A function that relies on management systems to direct target selection and fire control, perform kill assessments, provide command and control, and facilitate communication.

Boost—The first portion of a ballistic missile trajectory during which the missile is being powered by its engines. During this period, which usually lasts 3 to 5 minutes for an intercontinental ballistic missile (ICBM), the missile reaches an altitude of about 200 km whereupon powered flight ends and the missile begins to dispense its reentry vehicles. Tne other portions of missile flight, including midcourse and reentry, take up the remainder of an ICBM's flight time of 25 to 30 minutes.

Booster—The rocket that propels the payload to accelerate it from the earth's surface into a ballistic trajectory, during which no additional force is applied to the payload.

Brightness—The unit used to measure source intensity. To determine the amount of energy per unit area on target, both source brightness and source-target separation distance must be specified.

Bus—Also referred to as a post-boost vehicle, it is the platform on which the warheads of a single missile are carried and from which warheads are dispensed.

Chaff—Strips of frequency-cut metal foil, wire, or metallized glass fiber used to reflect electromagnetic energy, usually dropped from an aircraft or expelled from shells or rockets as a radar countermeasure.

Chemical Laser—A laser in which a chemical action is used to produce pulses of intense light.

Communication—Information or data transmission between two or more ground sites, between satellites, or between a satellite and a ground site.

Cost-Effectiveness at the Margin—The ratio of increased offense costs to increased defense costs. As stated in Public Law 99-145, Section 222 "...the (defense) system is cost-effective at the margin to the extent that the system is able to maintain its effectiveness against the offense at less cost than it would take to develop offensive countermeasures and proliferate the ballistic missiles necessary to overcome it."

Decoy—A device constructed to simulate a nuclear-weapon-carrying warhead. The replica is less costly and much less massive; it can be deployed in large numbers to complicate enemy efforts to read defense strategies.

Directed Energy—Energy in the form of atomic particles, pellets, or focused electromagnetic beams that can be sent long distances at, or nearly at, the speed of light.

Directed Energy Device—A device that employs a tightly focused and precisely directed beam of very intense energy, either in the form of light (a laser) or in the form of atomic particles traveling at velocities at or close to the speed of light (particle beams). (See also Laser.)

Discrimination—The process of observing a set of attacking objects and differentiating between decoys or other nonthreatening objects and actual threat objects.

Electromagnetic Gun—A gun in which the projectile is accelerated by electromagnetic forces rather than by an explosion as in a conventional gun.

Endoatmospheric—Within the earth's atmosphere, generally considered to be at altitudes below 100 kilometers.

Engagement—1. A period of hostilities beginning when the first ballistic missile target undergoes fire from the first defensive weapon. 2. A period beginning whenever any hostile object is identified (designated) and ending after the last hostile object has been attacked.

Exoatmospheric—Outside the earth's atmosphere, generally considered to be at altitudes above 100 kilometers.

Ground Entry Point (GEP)—The point where sensor data and other information are received by a ground station.

Hardening—Measures that may be employed to render military assets less vulnerable.

Hypervelocity Gun (HVG)—A gun that can accelerate projectiles to 5 kilometers per second or more; for example, an electromagnetic or rail gun.

Imaging—The process of identifying an object by obtaining a high quality image or profile of it.

INF Treaty—Formal title of the 1987 INF Treaty is *"Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles."*

Infrared (IR)—Electromagnetic radiations of wavelength between the longest visible red (7,000 Angstroms or 7 x 10^{-4} millimeter) and about 1 millimeter.

Intercontinental Ballistic Missile (ICBM)—A land-based ballistic missile with a range greater than 5,500 kilometers.

Intermediate-Range Ballistic Missile (IRBM)—A land-based ballistic missile with a range of 1,000 to 5,500 kilometers.

Kinetic Energy—The energy from the motion of an object.

Kinetic Energy Interceptor—An interceptor that uses a nonexplosive projectile moving at a very high speed to destroy a target on impact. The projectile may include homing sensors and on-board rockets to improve its accuracy, or it may follow a preset trajectory (as with a shell launched from a gun).

Laser (Light Amplification by the Stimulated Emission of Radiation)—A device for producing an intense beam of coherent light. The beam of light is amplified when photons (quanta of light) strike excited atoms or molecules. These atoms or molecules are thereby stimulated to emit new photons (in a cascade of chain reaction) which have the same wavelength and are moving in phase and in the same direction as the original photon. A laser may destroy a target by heating, melting, or vaporizing its surface.

Layered Defense—A defense that consists of several layers that operate at different portions of the trajectory of a ballistic missile. Thus, there could be a first layer (e.g., boost) of defense with remaining targets passed on to succeeding layers (e.g., midcourse, terminal).

Leakage—The percentage of intact and operational warheads that get through a defensive system.

Lethality—State of effectiveness of an amount of energy or other weapon characteristic required to eliminate the military usefulness of enemy targets by causing serious degradation or destruction of a target system.

Midcourse—That portion of the trajectory of a ballistic missile between boost/post-boost and reentry. During this portion of the missile trajectory, the target may be no longer a single object but a swarm of reentry vehicles, decoys, and debris falling freely along preset trajectories in space.

Multiple Independently Targetable Reentry Vehicle (MIRV)—A package of two or more reentry vehicles which can be carried by a single ballistic missile and guided to separate targets. MIRVed missiles employ a warhead-dispensing mechanism called a post-boost vehicle which targets and releases the warheads.

Neutral Particle Beam (NPB)—An energetic beam of neutral atoms (no net electric charge). A particle accelerator accelerates the particles to nearly the speed of light.

Non-nuclear Kill—Destruction that does not involve a nuclear detonation.

Particle Beam—A stream of atoms or subatomic particles (electrons, protons, or neutrons) accelerated to nearly the speed of light.

Particle Beam Device—A device that relies on the technology of particle accelerators (atom smashers) to emit beams of charged or neutral particles which travel near the speed of light. Such a beam could theoretically destroy a target by several means, e.g., electronics upset, electronics damage, softening/melting of materials, sensor damage, and initiation of high explosives.

Passive Sensor—A sensor that detects only radiation naturally emitted (infrared radiation) or reflected (sunlight) from a target.

Penetration Aid—A device, or group of devices, that accompanies a reentry vehicle (RV) during its flight to spoof or misdirect defenses and thereby allow the RV to reach its target.

Post-Boost—The portion of a missile trajectory following boost and preceding midcourse.

Post-Boost Vehicle (PBV)—The portion of a missile payload that carries the multiple warheads and has maneuvering capability to place each warhead on its final trajectory to a target. (Also referred to as a "bus.")

Rail Gun—A device using electromagnetic launching to fire hypervelocity projectiles. Such projectile launchers will have very high muzzle velocities, thereby reducing the lead angle required to shoot down fast objects.

Reentry Vehicle (RV)—The part of a ballistic missile that carries the warhead to its target. The RV is designed to reenter the earth's atmosphere in the terminal portion of its trajectory and proceed to its target.

Responsive Threat—A threat that has been upgraded in quality or quantity or with added protective countermeasures in response to a projected capability of defeating (all or part of) the threat.

Sensor—A device that detects and/or measures certain types of physically observable phenomena.

Signature—The characteristic pattern of the target observed by detection and identification equipment.

Surveillance—An observation procedure that includes tactical observations, strategic warning, and meteorological assessments, by optical, infrared, radar, and radiometric sensors on spaceborne and terrestrial platforms.

Survivability—The capability of a system to avoid or withstand hostile environment without suffering irreversible impairment of its ability to accomplish its designated mission.

Tactical Ballistic Missile—A short range ballistic missile with a range up to about 500 nautical miles.

Terminal—The final portion of a ballistic missile trajectory during which warheads and penetration aids reenter the atmosphere. This follows midcourse and continues until impact or detonation.

Theater Ballistic Missile—A ballistic missile equivalent in range to an IRBM.

Tracking and Pointing—Once a target is detected, it must be followed or "tracked." When the target is successfully tracked, an interceptor, laser, or neutral particle beam is "pointed" at the target. Tracking and pointing are frequently integrated operations.

Warhead—A weapon contained in the payload of a missile. It can be a nuclear, chemical, biological or conventional weapon.

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