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# *SDI: Is Its Future Past?*

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MASTER

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# SDI: Is Its Future Past?

by

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ABSTRACT

This paper reviews likely threats and the ability of known defenses to address them, concluding that initial deployments should be affordable and development could improve the effectiveness of each of several layers. Current research and development appears to be a prudent hedge against an uncertain future. Effective defenses would provide a positive incentive for the reduction of offensive forces and hence a direct, stabilizing influence that could shift the threat in directions in which they could be more effective and mutually useful.

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## I. INTRODUCTION

This note reviews the goals, concepts, and options for strategic defense; discusses their strengths and weaknesses; and identifies the fundamental factors that define options for strategic defense. It is a useful time to conduct such a review. A growing number of nations or subnational groups could find nuclear missiles an appropriate vehicle for addressing their grievances, and a growing commerce in missile and nuclear technology has developed. These factors have produced a number of visible threats at the low end of the spectrum for which strategic defenses are suited.

Instability also exists at the high end of the spectrum. Perestroika has caused important steps toward freedom, but in the process, it has fundamentally destabilized the political and economic systems of a large fraction of the communist world. The resolution of those issues could either alter the role of strategic nuclear weapons or make their application possible. The resolution will take time, during which defenses could provide not only a positive incentive for the reduction of offensive forces but also a direct, stabilizing influence that could shift the threat to move in directions in which defenses could be mutually useful and effective.

## II. GOALS

The ultimate goal of strategic defense has been to shift from deterrence through the threat of retaliation to deterrence through defense, i.e., the ability to negate the other's strategic offensive forces. The goal has both moral and practical dimensions. Intentional destruction of innocent people is not moral, and current developments question whether the threat of retaliation will continue to deter attacks in future decades. This long-term goal has now been supplemented with near-term goals that could be addressed along the way.

### A. Long-Term Goals

Negating the Soviet Union's strategic offensive forces requires the ability to destroy most or all of their offensive missiles. That task is stressing because it involves large numbers of objects, short timelines, a mix of attacking systems, and an intelligent adversary. We could not meet it today; it is not known if we ever will be able to meet it. Such a task is, however, the ultimate goal that should guide interim developments.

To achieve this goal defenses must meet the Nitze criterion that they be cost effective at margin, i.e., cheaper to deploy than to destroy. Current concepts would appear to be cost effective. If so, their deployments should be stabilizing, induce decreases in offensive forces, and improve crisis stability. Whether the defensive concepts have those characteristics can only be determined by detailed examination of the concepts' characteristics, performance, and costs. Such an examination could take one or more decades.

B. Near-Term Goals

For its first few years, the strategic defense initiative (SDI) was somewhat of an anomaly. Most military systems start with roles they can accomplish and enlarge their goals as their technical capabilities improve. The SDI initially had only long-term goals, no near-term missions. Recognizing that, the Joint Chiefs of Staff developed near-term goals, or "phase-one" goals, which essentially required the defense to destroy a sufficient fraction of the missile threat to make U.S. retaliatory forces more survivable. While such a move would extend the period over which the current retaliatory deterrent remained viable, it would be consistent with the long-term goals because it would be a step toward security and the elimination of the utility of strategic missiles. Moreover, near-term goals would also involve technologies similar to those for long-term goals.

The current emphasis is on the elimination of intercontinental missiles, which are now viewed as the principal military threat, but with research and development, submarine-launched missiles, airbreathing carriers, and other means of delivery could be addressed in turn. They are discussed in part below.

One should evaluate current concepts against current threats and future concepts against the threats they would face--not current concepts against future threats, as is commonly done. Estimating the evolution of defensive concepts is difficult; estimating the evolution of realistic threats is harder. Thus, in the long term, the defenses and threats become uncertain, as do technical goals. However, near- and long-term goals and concepts do appear consistent and commensurate today.

### C. Limited Goals

There are no formalized missions below that for the partial missile-threat negation of phase one, and less thought has been given to them. There are, however, limited goals that are both significant and tractable.

#### 1. Accidental Launches

Despite the safety mechanisms built into missile launches, an accidental launch of one or a few missiles could occur. Thus, the number of missiles in an accidental launch could be about a factor of 100 less than long- or near-term defenses could have to face. That number of missiles could, however, still cause unacceptable damage, and defending against them could still be stressing, because each one could have a number of weapons and penetration aids. Strategic defenses against accidental launch could thus require a few tens to hundreds of ground-based interceptors. If so, their cost should be small compared with the damage expected without them.

There are other ways of destroying accidental launches such as destruct-after-launch mechanisms. They have not been accepted by the military, partly because of concerns that the destruct code could be compromised and the missiles destroyed by the adversary. However, with improvements in computer security and permissive action link technology, it is quite possible that these reservations could be overcome.

Accidental submarine missile launches are also a concern. In port or bastion, their issues would be similar to accidental land-based missile launches. Submarines close to shore would stress the defenses more. Accidental launches of a single missile could probably be addressed with current interceptor and radar technology; for the launch of a full load of missiles, the technology could approach that required for phase one. Destruct-after-launch mechanisms would be desirable but are greatly complicated by the submarine's physical isolation from the missile after its launch and its intentional isolation from command and control elements for security and survivability. These problems appear to be of a different magnitude than those for land-based missile destruct mechanisms.

### 2. Unauthorized Launches

Unauthorized launches could be similar in size to accidental launches; the main difference is the involvement of an individual or group committed to their success. Such collaboration, if successful, could result in a whole launch complex, rather than a single missile, which would stress defenses much more. Destruct-after-launch concepts would be complicated, because a group capable of launching a missile without authorization might well be capable of disarming its destruct mechanism as well.

### 3. Third-Country or Subnational Launches

Third-country launches executed by a fanatic or irrational leader would not be susceptible to rational deterrence through the threat of retaliation. For launches by subnational groups, it might not even be possible to identify who to retaliate against. Nuclear and launcher technologies are now diffusing worldwide; thus, the probability of such launches will presumably grow in a secular manner in time.

Such launches should, for some period, involve at most one or a few missiles, at most a few weapons per missile, and few penetration aids. Launched from abroad, they would be less stressing than accidental or unauthorized launches, apart from their unexpected azimuth. Offsetting that is that their weapons would probably be aimed at value targets for greatest effect, whereas accidental or unauthorized launches would on the average be directed toward military targets.

Launches from midocean or offshore ships or barges would be less stressing to the attacker and much more stressing to undispersed defenses. At present, such a ship could simply sail into the harbor and explode the weapon. Currently, there are no defenses against that mode of delivery, but there could be if the direct threat of missile delivery was eliminated. The U.S. eliminated its air defenses because they could have been destroyed by missiles before the bombers arrived. But if missile defenses were developed, air defenses could and should be redeployed. Similarly, if unopposed third-country and subnational ballistic launches were addressed, there would be more of an incentive to secure other land and sea entry points. The technologies for doing so exist and are less demanding.

Accidental, unauthorized, and third-country or subnational launches are linked by the fact that the current deterrence through the threat of retaliation does not extend to irrational components, individuals, or groups.[1] For them deterrence through the ability to defend is required.

#### 4. Limited Attacks

In addition to accidental, unauthorized, third-country, and subnational launches, there is the possibility of rational attacks on the U.S. that are kept small to reduce the likelihood of counter strikes. Such attacks have primarily been discussed in the context of rapid reinforcement of theaters, principally Europe. Although such requirements seem to be diminishing today, the current climate could be reversed as quickly as it developed. Attacks on troops or points of embarkment could be executed with minimum collateral damage. Without defenses, roughly a dozen weapons could isolate the U.S. from Europe. With defenses, the number of weapons could increase into the hundreds, at which point the benefits of interrupting reinforcements might no longer justify the risk of further escalation.

Other targets are possible. The attacker could strike key command, control, and communication facilities to degrade the effectiveness of operational military forces. Again, this could involve a modest number of missiles and minimum collateral damage. In such attacks, submarines close to shore are a particular concern because of the short times of flight of their missiles. When submarines attain a hard-target capability, they could present a direct threat to both coastal bomber bases and land-based missiles that would leave almost no margin for response before impact. Such strikes could also undercut the effectiveness of deployments in which mobile missiles waited in garrison until alerted or dashed on warning for survivability.

Each of these attacks exploit serious vulnerabilities. They provide a set of examples for which deterrence through the threat of retaliation would fail because the damage would not justify it. In each, strategic defenses could raise attack requirements to levels at which the attacker could see unacceptable risk.[2]

### D. Overall Goals

Plausible threats range from irrational attacks through rational, limited, and global strategic exchanges. Meeting that progression requires a corresponding progression in strategic defenses. The next section reviews current defensive concepts and the issues associated with their development, testing, performance, and deployment.

## III. DEFENSIVE LAYERS

The main defensive layers are boost, midcourse, and terminal.[3] The first takes place over the launch areas as the missiles accelerate and deploy their weapons and decoys;[4] the second is during the long exoatmospheric portion of the objects' trajectories;[5] and the third starts when they begin to reenter over their targets. The layers are discussed below in that order, which illustrates the impact of earlier layers on later ones.[6] Defensive concepts for the different layers have been discussed extensively.[7] The discussion below stresses the factors that determine their performance, differentiate between them, or limit their development toward long-range goals.

### A. Boost Phase

The boost phase is a preferred intercept layer during which missiles can be destroyed before their weapons and decoys are deployed. Offsetting that is the fact that the boost phase lasts only a few hundred seconds and has the potential for being compressed further in both time and space. The two main classes of boost-phase defenses are kinetic- and directed-energy defenders.

Kinetic-energy defenders destroy missiles by running into them at high velocity or, more properly, by maneuvering into the path of the missile, which overruns it. In such collisions, the defenders' probability of kill is high. Missiles' costs are much higher than those of the defenders', so the collisions' cost effectiveness is also high. However, only a fraction of the defenders are over the launch area at any given time; most of the defenders are elsewhere in their orbits. In extended engagements, all of the defenders would rotate over the launch area in the space of a few hours, so all of them could participate in the defense. However, in the simultaneous launch of all missiles, which is generally analyzed as a worst case, in the near term only about 20% of the defenders would be within range, which would reduce their effectiveness by a like amount.[8]

That 20% availability should be adequate initially, but the fraction of the defenders in range would decrease further if the attacker replaced retiring missiles with faster ones in more compact launch areas. By the midterm, that could reduce defender effectiveness by an order of magnitude. A direct offset would be for the defense to reduce the defenders' costs by a like amount. If their costs and availability fell proportionally, their cost effectiveness should stay about constant throughout the defensive transition. Countermeasures and mobile missiles could complicate intercepts, but should not significantly degrade defender economics. Reducing the cost of defenders by an order of magnitude or more is the thrust of current "brilliant pebble" research, which, if successful, would make kinetic energy a viable defense concept into the long term.[9]

Directed-energy lasers and particle beams scale similarly in the boost layer. Initially, their scaling, costs, and availability seemed confusing,[10] but it now appears that each could have favorable economics and significantly less sensitivity to launch time and area than kinetic energy concepts.[11] Space-based chemical lasers are developed, but large, limited in brightness, and sensitive to missile hardening.[12] Free-electron lasers have promising growth potential, costs, and scaling, but they are relatively undeveloped. They would appear to be the dominant boost-phase defensive concept in the long term because of their unbroken, effective scaling to large brightnesses.[13] Ground-based lasers are cheaper, but they have lossy, unprotected uplinks.[14] Thus, there are a number of options for providing laser power in any layer of the defense. Particle beams can penetrate targets,[15] but they have more stringent propagation constraints than lasers.[16] Although none of the concepts appear dominant, none are excluded. All could continue to compete usefully for a decade. If, however, time was of the essence, in a few years one of them could probably be picked for faster development on the basis of current projects.

Directed energy's main drawback is its perceived immaturity relative to kinetic energy. Discussion has centered on the time needed to develop large, bright platforms.[17] If, however, directed energy was used as a supplement or phased replacement for kinetic-energy defenders, rather than as an alternative, modest directed-energy platforms would suffice[18] and could be available when needed.[19] For directed-energy concepts, the main concerns appear to be reducing mass and cost while maintaining survivability.

Booster signatures are complex, but bright, and they are hard to mask or simulate. Dark post-boost vehicles are more difficult to see and intercept, but it can be done with modest active measures. Battle management is a concern for kinetic-energy concepts. Letting kinetic-energy defenses operate autonomously would degrade defenses only a few percent in the near term, but in the midterm the degradation could reach 30%. Efficient allocation is required; the issue is whether this allocation could best be synthesized by the defenders or provided by external platforms. In making that choice, the cost of the external sensors is a significant concern, but survivability is a greater concern because of the size and inflexibility of the platforms available.

B. Midcourse

In midcourse the main concern is discrimination rather than lethality. Ground-based interceptors appear to be an efficient way to negate weapons in midcourse. Their costs are modest, and they could make effective nonnuclear intercepts over most of the objects' trajectories. In the near term, space-based kinetic-energy defenders would have the time to maneuver and intercept the threat from almost anywhere on the globe. Space-based defenders would, however, be at an economic disadvantage relative to ground-based defenders because of the additional major burn required. Lasers are relatively ineffective in attacking reentry vehicles, which must be intrinsically hard to survive the heat loads of reentry. Particle beams could attack reentry vehicles effectively because they can deposit energy in depth.[20]

The greatest concern is the numerous decoys possible in midcourse. Heavy decoys could be addressed effectively by ground-based defenders even without discrimination, but light decoys could be too numerous and cheap to shoot. If so, they would have to be discriminated. For that, there are three leading candidates: (1) passive infrared sensors, (2) active lasers and radars, and (3) interactive directed energy.

Passive infrared sensors have been developed and are affordable. They should be good bulk filters; they can detect small differences in emission, area, and motion. However, all three could possibly be matched accurately. There is a race between passive sensors and decoys. At present it is relatively even, but even by midterm, it is not clear that any surface features that are useful as passive-sensor discriminants will remain.

Because lasers and radars can examine objects with high resolution, they can detect subtler differences. However, those differences are superficial, so they can be masked. Thus, both active and passive sensors share the limitations that come from seeing only the object's surface. It would be difficult in the near term to provide the power in space that active sensors would require. Ground-based radars would relax that constraint but would do so at the price of sharing the vulnerabilities that were ultimately debilitating to earlier ground-based antiballistic missile (ABM) sensors.[21]

Directed energy can deliver enough energy to remote objects to perturb their motion or probe their interior. Lasers create blowoff, which causes objects to recoil. Detecting the blowoff would, however, require motion sensors that could be countermeasured, and some materials absorb energy with little recoil. Thus, laser discrimination rates are modest. Particle beams can probe the object's interior and, hence, determine its mass, which is the one parameter of a weapon that decoys cannot afford to duplicate. Modest particle-beam constellations could discriminate heavily decoyed threats.[22] The principal concern with particle beams is their availability; they are delayed relative to other directed-energy concepts. That might, however, be overcome by pop-up deployments, i.e., launching ground-based platforms onto efficient suborbital, inverse trajectories on warning, which significantly reduces constellation sizes, energies, and currents.

In midcourse, there are adequate interceptors; the concern is discrimination--particularly in the mid and long terms. There is arguably a progression from passive concepts in the near term, through active concepts in the midterm, to interactive concepts in the long term. That progression is, however, critically dependent on progress in advanced sensors and on unobservable developments in the threat. Survivability is a concern, and connectivity must be maintained if information is to flow forward to improve the performance of later phases.

### C. Terminal

Terminal, endoatmospheric intercepts are potentially the least expensive kind, but they are subject to a number of atmospheric limitations that limit their effectiveness.[23]

Nonnuclear counterparts to the interceptors of earlier ABM systems have been developed. They could add roughly one more layer of attrition to a multilayer defense, which is useful but not pivotal.[24] Loitering systems could reduce cost, increase coverage area, and increase the terminal phase's overall contribution significantly, but these systems have not been pursued.

### D. Overall Effectiveness

In the boost phase, there are many defensive concepts, few decoys, and reasonable survivability. The attacker does, however, have fundamental countermeasures available in the form of his ability to compress the launch in space and time. The defense can counter with cheaper defenders, which should offset those offensive countermeasures. That competition could be a close race; its outcome is unknown. In midcourse, the issue is discrimination. There is a progression of sensors, but they are uncertain, delayed, and sensitive to excursions in the threat.

In each layer there are a number of lethal concepts, which appear to be evolving properly but at rates limited by resources. Meanwhile, projects that were started before the SDI continue even after their effectiveness is no longer clear, apparently at the expense of the cheaper defenders and better discriminators needed. The boost and midcourse layers could provide effective layers independently; together they could approach the levels required to begin to address SDI's long-term goals.

## IV. SURVIVABILITY AND STABILITY

To be effective, defenses must survive; to be deployed, they must be stabilizing. The two are related through the concepts' cost effectiveness. Stability requires cost effectiveness, which is strongly dependent on survivability.

### A. Survivability

Defenders and sensors would be subject to sustained attrition attacks in peacetime and intense suppression attacks before launch. The main suppression threat is ground-based lasers, which can generate power more cheaply than the satellites can replenish the shielding they ablate. Heavy, inexpensive shielding would not solve the problem, but it could provide time for a reasoned response.

In suppression, the defender's absenteeism gives anti-satellites about an order of magnitude advantage, but small defenders can still achieve about an order of magnitude overall cost effectiveness relative to the offensive missiles even when they are attacked by nuclear antisatellites through proper combinations of hardening, maneuver, and decoys.[25]

Decoys for heavy-sensor and directed-energy platforms become heavy and difficult to deploy deceptively, so their survivability depends on self-defense and other techniques. If both sides deployed directed- or kinetic-energy constellations, their co-occupancy of space should be stable simply because it is cheaper for a satellite to add shielding than it is for the attacker to orbit the fuel needed to attack it.[26]

B. Stability

The main stability concerns are arms control and crisis stability. The former addresses whether or not defensive concepts would induce the adversary to increase his offenses; the latter addresses whether it would make him more likely to use them deliberately or in extremis. The rational deployment of cost-effective defenses should not cause the other to increase his offenses. There is now reasonable agreement on the qualitative and quantitative requirements for arms control stability.

Crisis stability is in a more academic phase, but its essence is that during the transition from offensive to defensive dominance, one should not press one's adversary too close to the point where his remaining forces would have inadequate retaliatory impact. Such approaches should, however, be observable and avoidable.[27]

## V. OPTIONS

The options for strategic defense range from research and development only to limited, partial, or phased deployments. The paragraphs below discuss them in order of increasing risk, cost, and rewards.

### A. Research and Development Only

Performing research and development only would amount to returning to broad research, no demonstrations, and no commitment to deployment. Historically, research and development has been conducted at $1 to $2 billion per year level since Sputnik.[28] That level of spending could be recovered by returning expensive projects such as space sensors to the agencies that were developing them for other purposes before SDI.

The research need not be unstructured. Enough has now been done to define the focused efforts in discrimination, cost reduction, and survivability needed to resume development efficiently, should the need arise. Currently, no meaningful distinction exists between near-term research on kinetic energy and long-term research on directed energy. An appropriate mix aimed toward a viable defense at some future date would undoubtedly require both.

### B. Limited Deployments

Limited deployments against accidental, unauthorized, third-country, or subnational launches could be addressed by modest deployments of kinetic-energy, ground- or space-based defenders of the types currently under development. They should be feasible, affordable, and justifiable. Their incremental costs of a few billion dollars could be available in five to ten years.[29] The issue is priority.

The principal defenses against limited deployments would be a subset of those for fuller defenses. Thus, these defenders should neither be a technological dead end nor a programmatic dead end, unless the funds for their deployment were taken from research on concepts for more capable defenses.

C. Boost Phase Only

A single boost-phase layer is not generally thought of as a candidate for deployment, but kinetic-energy defenders are relatively insensitive to decoys, so they represent an alternative approach to configurations requiring good midcourse discrimination, about which there are serious questions. They have relatively low technical risk; thus, if concerns about costs can be resolved, they could remain viable into the mid or long terms.

Defenses against accidental, unauthorized, or subnational launches could require a few tens to hundreds of defenders. A partially effective phase one would require a few thousand. A highly effective layer could require ten thousand or more in the midterm. In the long term, several times more could be required. Their costs could range from under a billion dollars for thin defenses against third-country or accidental launches to a few tens of billions for effective defenses against limited attacks. Such layers could be available within the decade, given the success in current testing.[30]

Space defenses are thought to be politically threatening,[31] but they actually present little threat to anything in the atmosphere.[32] Treaty concerns have been reduced by the recognition that the technology is not physically threatening, should be stabilizing, and could be shared. The technology for near-term defenses against theater or accidental launches is largely standard, so it is potentially transferable to other nations without undue risk of compromise. If so, that could fulfill SDI's commitment to reduce the threat of missiles to all nations--not just one.

D. Midcourse Only

Midcourse is tractable because of the long time and simple defenses possible, but it is unattractive because of the many decoys possible there. Midcourse defenses require that the appropriate set of discrimination sensors be developed and demonstrated in space, which could take much of a decade. The overall cost of limited, partial, or full space-based midcourse defenses should correspond roughly to those for the respective boost-phase only deployments. With pop-up sensors, the cost could be an order of magnitude less.

Near- and midterm sensors depend heavily on empirical target data, but it could probably be shared or controlled jointly as black boxes, which is how they are used in any case. Long-term midcourse sensors should be shareable, because their principal signal, the object's mass, is predictable from first principles.

### E. Redefinition of the Development Phases

Over time the earlier distinctions between near- and long-term technologies, which were the bases for dividing proposed deployments into phases, have been blurred. Initial deployments would need some of each. Thus, there is some justification for dropping the current definitions of phased deployments and developing mixes of kinetic- and directed-energy technologies that would come to maturity together.

Offsetting the advantage of better mixes is the argument that a reorientation at this time might further confuse popular debate and dissipate program momentum and focus altogether. A counter argument is that bringing the concepts identified as high leverage into step with the other elements could probably be affected within existing resources and could produce a better mix of programs that would be more defensible.

### F. Continuation of the Current Program

Continuing the current program would involve risk. Technologies in development could produce useful capabilities within this decade. The funds required are roughly those initially projected, although the specific technologies have shifted to reflect development and tests. The main concerns are the cost of current space-based defenders and the inability of current sensors to discriminate improved decoys.

If funding or priority fell, it would be difficult to continue the current program structure. Although the tendency would be to delay everything, it would be more effective to down select aggressively in each functional area. However, history suggests that if budgets fall, shortfalls fall disproportionately on the long-range research, which could be needed even earlier for plausible variations in the threat.

The current program is addressing its main uncertainties, and it should develop useful options for the goals discussed above, if priority and funding continue. Both depend on the threat. If current political trends in Europe and the Soviet Union continued, limited protection could suffice, in which case the current program could be oriented to produce too much. If those political trends reversed and current military deployments continued, even the full program would produce too little protection. The future is highly uncertain; considerable adjustment will probably be needed. For any eventuality, however, the current level of research and development with options to deploy and improve limited defenses is apparently a prudent hedge.

## VI. OBSERVATIONS

Previous ABM programs underscored the importance of survivability, performance, and cost. Those lessons have largely been learned. Infrared sensors overcame the transmission and size problems of radars, and multiple layers were accepted as a way to break up structured attacks and increase effectiveness. Those developments were useful but not a panacea. Space layers have cost, survivability, and discrimination concerns. Current concepts have largely solved the problems of the last system, but done so at the price of sensitivities to uncertainties in the next threat. Still, initial deployments should be affordable, and later developments could improve the effectiveness of each layer. Whether they would should be determined by objective questions about performance and cost that should be answered by current programs.

The ultimate effectiveness of strategic defense cannot be determined today; its effectiveness will require five to ten years of research, development, and testing. Whether they will be needed cannot be determined today either; that depends on external developments over which we have little direct control. It would appear, however, that current research and development is a prudent hedge against an uncertain future. Effective defenses would also provide a positive incentive for the reduction of offensive forces. Thus, they have the potential for providing a direct, stabilizing influence on the threat, which could shift it in directions in which defenses could be more effective and mutually useful.

It is too early to tell whether the SDI's path leads toward significant security contributions or back to research and development, but it is clear that the SDI is rapidly approaching a watershed that should largely determine the answer, which seems well worth the resources required.

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