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# IN THE KEY BATTLE OF COMPARATIVE COSTS, STRATEGIC DEFENSE IS A WINNER

## INTRODUCTION

To its critics, Ronald Reagan's Strategic Defense Initiative is a dangerous and costly quicksand that will swallow ever greater U.S. resources while providing little new protection. The price of maintaining and improving the so-called Star Wars defense, say these critics, always will be substantially greater than Moscow's cost for countering or negating the defense. This would mean, in military argot, that the "cost-exchange ratio" always would be against the U.S. missile defense efforts and in favor of Moscow's attacking missiles.[1] For strategic defense critics, this unfavorable ratio is a major drawback of the Reagan proposal.

The critics would be right if their premise were valid. It possibly was, during the last national debate on missile defense, in the late 1960s. But since then, technological leaps have been shifting the offense-defense cost-ratio to favor defense. These changes include declining costs of computers, communications, sensors, and the lift of strategic defense components into space. At the same time, these advances are having far less impact on offensive ballistic missiles, because they depend on relatively mature technologies. There thus is evidence that most of the presumed Soviet countermeasures to Reagan's Strategic Defense

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1 Perhaps the most extreme statement on countermeasure costs has come, not unexpectedly, from a Soviet source: "A 'highly efficient countermeasure system' would cost only 1 to 2 percent of the cost of the Star Wars system...." Dusko Doder, "Soviets See U.S. 'Deception'," The Washington Post, January 7, 1985, p. A-1.

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Initiative (SDI) will be costlier, and probably less effective, than alleged by SDI critics.

The cost-exchange ratio therefore no longer is a sound reason for opposing SDI. Technology and doctrine, and hence costs, do not stand still. Assumptions that the offense will inevitably defeat the defense are based on old technologies and doctrine and need careful reexamination. Also needing reexamination is the much-cited trillion dollar cost[2] for SDI. If this figure, pulled out of the air, has any meaning, it is as the total system price tag over several decades and covers, among other things, an extensive system of several layers, including 21st century boost-phase defenses (the "long poles in the tent"). And there are many factors, moreover, such as increased Soviet emphasis on developing and deploying defenses rather than offensive countermeasures or an arms control agreement limiting offenses to relatively low levels, that could limit the required components and costs of SDI.

## NEW TECHNOLOGY

Some SDI concepts were considered and abandoned in the 1960s. It is the great technological progress since then that makes the current reconsideration very timely. Some of these developments may help the design of cheap countermeasures; but many more will help reduce the costs of ballistic missile defense (BMD), compared to those of strategic offense and countermeasures.

### General Technological Developments

The major areas of technology development and cost reduction have been:

- Microchips.[3] The cost of electronic devices may be measured in dollars per "digital logic gate," or basic computing unit. In the late 1950s, the best vacuum tubes were so expensive that each gate cost about $10. By 1963, early transistors had reduced this to less than a dollar. The subsequent revolution in solid state electronics and miniaturization has reduced the current cost per gate to two one-hundred-thousandths of a dollar (or $0.00002). This is expected to be cut in half again by 1987. The downtrend probably has not yet stopped.
- Computers. A $3,000 personal computer of today has essentially the capabilities of a $5 million IBM 360-40 "mainframe" computer of the mid-1960s (conser-

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[2] See, for example, "A trillion here, a trillion there," Oakland Tribune, August 26, 1984, and R. Jeffrey Smith, "Schlesinger Attacks Star Wars Plan," Science, November 9, 1984, p. 673.

[3] Data are based on private communication from W. Russell Young, SRI International, Washington, D.C., Strategic Studies Center.

vatively, $15 million in today's dollars). This is a reduction in cost by a factor of 5,000, or about 35 percent per year. Moreover, the 1960s machine required an air-conditioned room, plus a corps of trained operators and maintenance personnel; today's PC requires a desk top, one relatively briefly trained operator, and virtually no maintenance.

- Software. Increasingly, the labor-intensive programming requirements of computer systems are proving to be the bottlenecks and "cost drivers." This is particularly true of the computing for ABM tracking and battle management (as it was 15 to 20 years ago for the NIKE-X SENTINEL and SAFEGUARD systems). But increasing attention to cheaper "firm" or "hard" wiring of parts of the programming into the computer hardware, distributed computing in subsystems, more efficient algorithms (rules for solving problems), artificial intelligence, and computer processing and data management systems are contributing to eliminating software problems that might impede further development of effective strategic defenses.

- Fiber Optics. In communication by light waves, digital data are transmitted by means of laser-driven signals sent through glass fibers, or "lightwave guides." (Optical computation technologies are also in the offing.) Detailed figures on the costs of fiber optics are hard to come by, because the technology has been moving so rapidly since its commercial introduction in 1980. However, the cost per channel per kilometer, where demand is heavy, is already a small fraction of that of microwave transmission,[4] and the rate of continuing cost reduction appears to be even greater than that of computing. Other advantages--translating into cost savings--include the lightness and compactness of the material, the resistance to electromagnetic pulse (EMP) damage and interference, the security of the system against "tapping" or eavesdropping, and its suitability to digital transmission. Fiber optics are being used for satellite ground station systems and communications.

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[4] The cost of the fiber itself is declining at almost 30 percent per year, while the number of channels per fiber and the distance between "repeaters" for reamplification--a high-cost system element--are increasing rapidly and the rate of data transmission is rising even more rapidly as both laser and transmission advance. Executive Briefing, "Optical Communications and Mobilization: A Case Study," for the Undersecretary of Defense for Policy, F.P. Hoeber, et al., SRI International, Strategic Studies Center, May 1982.

- Satellite Communications. Boost-phase intercept systems will still require two-way satellite-ground and inter-satellite communications. Satellite communication costs are coming down, albeit less rapidly than other SDI-related technologies. Increased satellite lifetimes (from 3 years or so around 1970 to 10 years today), multichannel and multifrequency transponders, single-side band AM transmission, and other technological advances are contributing to the dropping costs.

## Implications of General Technology Development

The evidence suggests that the technologies cited already have advanced strategic offense capabilities as far as they can. On the other hand, they can still contribute substantially to defense improvements. Example: while these technologies are the key to missile guidance and accuracy, 97 percent of what can be done in offensive missile accuracy already has been accomplished. The average distance by which missiles miss their targets has declined from roughly five miles in the early 1960s to under 100 meters for the Pershing II today. Guidance packages are now such a small part of the throw-weight of missiles that further improvement in miniaturization will be of marginal value in multiple warhead missiles.

ABM technologies, on the other hand, are still underdeveloped. ABM systems will be heavily dependent on computing and communications to discriminate real missiles and warheads from decoys, determine trajectories, determine which targets to shoot at and in what order, and "hand off" data on the nature of the threat to other layers of the system. The huge reductions in the cost and weight of these computing and communications technologies therefore will yield enormous savings for strategic defensive systems evolving from SDI research and development.

Savings will result not only from the reduced cost of the defensive system components but also from reduced weight, which lowers the cost of lifting the components into space. Effective battle management, command, control, and communications (BM-$C^3$) also will allow more efficient use of weapons, potentially further reducing lift requirements. The cost savings from effective and lightweight BM-$C^3$ will play a large role in shifting the offense-defense cost-exchange ratios toward defense.

## Strategic Defense Technology Developments

Other major technology developments include:

- Smaller, cheaper phased-array, solid-state, electronically steered radars for tracking rather than just early warning.[5]

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[5] For a simple description of these mechanisms, see Ashton B. Carter and David N. Schwartz, eds., Ballistic Missile Defense (Washington, D.C.: The Brookings Institution, 1984), pp. 68-69.

- Directed-energy weapons (DEW), from lasers to particle beams.[6]

- Homing capabilities against missile warheads, which were not feasible when the NIKE-ZEUS and NIKE-X ABM systems were developed in the 1960s.

- Kinetic energy weapons (KEW), utilizing homing capability, which destroy the target missile or warhead by direct impact with fragments from an explosive warhead or with a small, self-guiding warhead. These may be rocket-launched, as in the successful HOE (Homing Overlay Experiment) of June 10, 1984, rocket-powered, or electromagnetically launched (the "EM rail gun").

- "Distributed," or decentralized, ground-based systems, which remove the vulnerability of the system to a hit on a main radar and/or computer-processing unit.

- Long-wave infrared (LWIR) detection and tracking systems, which can be an adjunct to or substitute for radar in the midcourse regime.

- Feasible improvements in heavy-lift launch vehicles for space-borne assets. The cost of Shuttle launches is falling as usage increases and turn-around time is reduced. Costs of expendable launchers are also declining. Follow-on systems for heavier lift should be much cheaper per pound lifted, because of better technology and economies of scale.

These and other new technologies offer real promise for reduced defense system costs as well as higher performance.

The most basic changes in technology may prove to be advances in ABM potential for space-borne boost-phase and early-midcourse intercept, and for ground-based terminal and late-midcourse defense. These should be compared to the relatively mature state of offensive ballistic missile (especially booster) technology. In particular, the Soviets have invested billions of dollars in their current intercontinental ballistic missile (ICBM) systems. New systems might have to be started from scratch and paid for in costly future outlays. At the same time, current Soviet systems would have to be maintained.

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6 See Brian Green, "Strategic Defense: The Technology That Makes It Possible," Heritage Foundation Backgrounder No. 375, August 23, 1984.

## SOVIET COUNTERMEASURES TO EACH DEFENSE LAYER

SDI has envisioned a defense that can intercept missiles at different phases of their flights. These phases include:

- the boost phase, lasting three to five minutes, from the time the missile is launched until the missile burns out;

- the post-boost phase, lasting up to 10 minutes, during which the post-boost vehicle (the "bus") sets the multiple warheads and penetration aids on their independent courses;

- the midcourse phase, lasting up to 20 minutes, during which the warheads and penetration aids glide along their flight trajectories;

- the terminal phase, which lasts only a minute or so, during which the warheads reenter the atmosphere and arrive at their targets. In the context of a defense against ballistic missile attack, the terminal phase can be subdivided into "low exoatmospheric" (just before the warheads reach the atmosphere; there is no sharp dividing line between the midcourse and terminal phases), "high endoatmospheric" (just after the warheads reach the atmosphere) and "low endoatmospheric" (just before the warheads reach their targets).

Intercepting missiles and their warheads in each phase of flight by deploying what amounts to vertical layers of defenses complicates the task of the attacker and should permit high attack attrition rates. It is not yet clear, however, how the layers should be proportioned or, when costs are considered, what the optimal number of layers would be.

A complete vertically layered defense must await development of weapons to intercept missiles in the boost- and post-boost layers. This probably will take a dozen years or more. Meanwhile, different layers using different technologies could be deployed as they became feasible. Recent cost estimates are $60 to $100 billion for a terminal defense that protects the U.S. missile silos combined with a boost-phase intercept defense. These could be ready by the early 1990s.[1]

Soviet countermeasures would take considerable time and rubles for Moscow to develop and would require knowledge of U.S.

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[1] Zbigniew Brzezinski, Robert Jastrow, and Max Kampelman, "Defense in Space Is Not 'Star Wars'," New York Times Magazine, January 27, 1985, p. 28ff, gives a figure of $60 billion through the early 1990s, and "Two Analysts Put Cost of Antimissile Program at $70 Billion by 1993," The New York Times, February 12, 1985, gives a range of $70 to $100 billion.

defense plans. While the Soviets would be expending considerable resources trying to counter the first phase of U.S. defenses, the U.S. could be working on counter-countermeasures.

Boost-phase Countermeasures

Intercepting a missile shortly after it is launched (the boost-phase) is potentially very cost-effective. With one interception, all of the missile's multiple warheads and/or penetration aids (devices carried and released by the missile to fool the defense) can be destroyed.

One way that Moscow could try to foil U.S. boost-phase intercept is to develop a new generation of fast-burning, high-acceleration solid-fueled boosters. These would make interception by the U.S. more difficult by shortening the time available for the space-based defenses to acquire, track, and attack the boosters. This timespan could be cut from the current 3 to 5 minutes to perhaps 1 to 2 minutes. These faster boosters would also burn out within the atmosphere. Thus the U.S. would be limited in the kinds of boost-phase technologies that it could utilize since X-ray lasers and some types of particle beam weapons cannot penetrate the atmosphere.

Such a countermeasure, however, would be costly, particularly in terms of weight, since fast-burn boosters of a given size must carry more fuel and thus have less room for their weapons' payload. To launch the same number of warheads and penetration aids, therefore, would require the launching of more missiles. The cost of these new missiles, each burdened by the added weight for fast-burn boosters, could well be greater than that of some boost-phase defensive systems. Further, their deployment would be at least ten years after Moscow learned that the U.S. had selected this defense system for development, which would mean a significant lag between the deployment of a given defense and specific countermeasures.

Shielding, Spinning, and Maneuver

Another means suggested for neutralizing anti-missile weapons is to add shielding to offensive missiles, which would reflect lasers and absorb other types of beam weapons. It is very uncertain, however, whether reflective coatings could defeat lasers. Shielding against particle beams also would add substantially to missile weight. And such shielding would offer no protection against kinetic-energy weapons, which are propelled at speeds of 15,000 or more miles per hour and shatter almost anything they hit.

Another possible way to defeat an ABM system, it is said, is to spin the booster of the offensive missile. Spinning minimizes the amount of energy absorbed at any given spot, and thus the lasers and other beams aimed at the missiles would fail to disable them. Yet spinning should not be hard to counter. The U.S. could design beam weapons to deliver huge energy bursts in very short pulses, destroying their targets by impulse or shock rather than with heat.

It further is suggested that Soviet missiles could be designed to maneuver to evade U.S. anti-missile devices. But this would require completely redesigned, throttled rocket engines, as well as more elaborate guidance systems. Not only does this appear impractical in terms of cost, it very likely would reduce the Soviet missile's accuracy. Maneuver also would be ineffective against directed-energy, "speed-of-light" weapons, which reach their targets very quickly, before they can maneuver evasively.

Direct Attack

Direct attack on U.S. BMD satellite battle stations is also mentioned as a potential Soviet countermeasure. However, because Soviet anti-satellite missile boosters would be similar to ICBMs in boost phase, and since U.S. BMD satellites would be designed to intercept missiles in boost phase, the U.S. system could intercept anti-satellite boosters as easily as ICBM boosters.

Blinding or destroying the BMD satellites with Soviet ground-based lasers would be a more formidable threat. However, the U.S. satellites could be shielded, and Moscow's ground-based lasers might be counterattacked. The technological uncertainties are such that the cost-exchange ratios in this case probably cannot yet be estimated. One long-range proposal for defense has been the mining of asteroids for materials to shield U.S. BMD satellites, a process potentially much cheaper than lifting the mass required from the earth; however, the technological and arms control implications of this, too, cannot yet be evaluated.

None of these Soviet countermeasures thus has any certainty of success. The only certainty is that they are all very costly. Most current Soviet ICBMs could not be modified to accommodate the countermeasures effectively. For example, the liquid-fueled SS-18 burns relatively slowly and cannot burn out at low altitudes. Consequently, the Soviets would have to redesign their ICBM force to a significant degree and deploy an almost brand-new ICBM force in order to obtain any countermeasure benefits available from fast-burn boosters. Their ICBM production lines would have to be rebuilt or extensively modified--all at substantial cost. This new missile force almost surely would have to be larger than the current Soviet force, since the added weight of shielding would mean that each missile could carry fewer warheads.

The enormous cost of redesigning and rebuilding the Soviet missile force, combined with the lack of certain success, makes the cost ratio very promising for defense. Since the cost ratios would seem to favor the anti-ICBM systems, the marginal cost of ICBM kills by U.S. satellites could be expected to be below the marginal cost to Moscow of adding new weapons to attack the satellites.

Post-boost phase

This phase is important for defense against missiles carrying a number of warheads, or multiple-independently targeted reentry vehicles (MIRVs). Such missiles take up to ten minutes to dispense their reentry vehicles or RVs. A U.S. strike against the "bus" that carries the MIRVed warheads midway through the post-boost phase could potentially knock out half of the missiles' reentry vehicles (RVs) and penetration aids. The difficulties for the U.S. in attacking a Soviet weapon in the post-boost period are the brief duration of this phase and the bus's smaller "signature" (the specific radiation characteristics--heat, light, or reflected radar waves--that can be detected by defensive sensors).

But for little or no additional cost to the U.S. anti-missile system, weapons designed for boost-phase and midcourse intercept also could generally attack the bus. Specific possible Soviet countermeasures are limited. Since each RV must be placed on a very precise, preplanned trajectory, the only maneuvering possible for the offensive vehicle is aiming at the target, and it thus could not overcome U.S. defenses. Hardening or shielding RVs would add weight and thus cost. If the Soviets design the bus to maneuver, the extra fuel needed adds even more weight to the bus.

Of course, the bus's vulnerability could be avoided if the missile dispensed its multiple warheads on their flight paths while still within the atmosphere. This would be very difficult, however, involving additional cost, some additional weight penalty, and potential degradation of accuracy.

Midcourse

The midcourse phase begins after all RVs and potential penetration aids are separated from the ICBM. The cost ratios in this phase also appear to favor the anti-missile system.

One possible Soviet counter to midcourse interceptions by the U.S. would be to use large numbers of penetration aids to overwhelm, or "saturate," the U.S. systems. Such penetration aids could be balloons, heated to simulate RVs, or possibly other lightweight devices (since light and heavy objects travel at the same speed in the vacuum of space). The problems and costs of inflating and dispensing balloons in space, however, are significant. The balloons must be equipped for delayed inflation, heating, and altitude control with small jet motors.

There also could be "natural" penetration aids, or "space junk"--shrouds, buses, and miscellaneous parts destined to follow similar paths until they burn up upon reentry into the atmosphere. Reverse, or anti-simulation, in which RVs are made to look like decoys or junk is also possible.

Midcourse interception of an ICBM has long been regarded as the most difficult phase for anti-missile defenses. On the other hand, it is the longest phase, giving the U.S. systems some 15 to 20 minutes to distinguish the RV from decoys and other objects, a process known as "discrimination."

Techniques for such discrimination are progressing rapidly. Long-wave infrared (LWIR) sensors, for example, which can detect the very faint heat of a warhead against the cold background of space (and, very likely, the distinct heat "signature" of a warhead, in contrast to those of decoys or space junk) were used in the successful June 1984 U.S. Homing Overlay Experiment intercept of a dummy warhead. Sensors to "discriminate" warheads from decoys are in development.

Maneuver in midcourse does not appear to be a cost-effective Soviet countermeasure. For one thing, it has the same disadvantages and added costs as maneuver in the boost-phase. And more important, maneuvering RVs would distinguish themselves from decoys and space junk by virtue of their movement.

"Active" U.S. measures for discriminating or destroying decoys and space junk are also possible. There is a real possibility of "jinking," or displacing, the trajectories of decoys and even space junk with a sweeping ground-, air-, or space-based laser. This would be too weak to disturb the heavier RVs perceptibly, but would affect the decoys, which then would be spotted by radar and/or optical detection. If the number of false targets were large, such active measures might be well worth the cost.[8] If the RVs were sorted out from the decoys, they might be killed from satellite battle stations or from the ground. The cost of the kill itself would likely be low enough to justify hitting some of the decoys as well as the real targets. With the several responses available for a U.S. anti-missile system, the Soviets might even be deterred from paying the cost of deploying decoys and hardening their RVs.

Terminal

If terminal defense is exoatmospheric (interception taking place outside the atmosphere), it overlaps with midcourse defense; in fact, it may be called "late midcourse." The cost ratio considerations for exoatmospheric terminal interception are thus very similar to those for midcourse interception. The principal difficulty remains how to discriminate real RVs from decoys, chaff, and space "junk." With a layered defense, however, there would be maximum time to accomplish this during the midcourse phase.

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8 It could prove cheaper to use nuclear weapons to clear decoys, though this is currently ruled out by the non-nuclear kill policy of the SDI. Nuclear weapons launched by submarine (far enough away from U.S. borders to minimize damage to U.S. military equipment from electromagnetic pulse) could destroy lightweight balloon decoys through a 60-mile swath, and could require the offense to harden all of its warheads to blast and EMP effects. If one defending warhead could destroy several decoys as well as an offensive warhead, the cost exchange ratio might well be quite favorable to the defense.

Meanwhile, the U.S. is transforming a Boeing 767 jetliner into what is called an airborne optical adjunct that carries longwave infrared sensors plus computing and communications equipment. This would aid in discriminating decoys from genuine warheads. Initially, terminal phase interceptors surely will be of the kinetic energy type, already demonstrated in the Homing Overlay Experiment. Later, ground-based lasers may be available. As with space-borne, directed-energy weapons, there may be no effective limit on how often they can fire, and they thus may be able to afford wasting shots at decoys.

Endoatmospheric (interception within the atmosphere) terminal defense is the final stage of active defense (passive defense includes, among other things, making the defended target more resistant to the effects of a nuclear explosion). Terminal defense generates no trouble in discriminating decoys, for light objects will burn up or slow down as they enter the upper atmosphere, and there is little likelihood of the successful development of endoatmospheric decoys.[9] As such, a terminal defense can be designed to deal solely with genuine warheads. Such defenses are relatively inexpensive. For one thing, their interceptor booster and kill mechanism is relatively small. For another, the cost per intercept of the formerly expensive phased-array, solid-state electronically steered radars is declining. These factors should make the cost-exchange ratio highly favorable to the U.S. anti-missile defense systems.

Maneuvering their attacking ICBMs within the atmosphere is unlikely to be an adequate Soviet countermeasure. The world's first operational maneuvering reentry vehicle (MaRV), carried on the Pershing II, maneuvers in the terminal phase to improve accuracy. But evasion requires much greater maneuver capability than the Pershing II MaRV has. Because more capable maneuvering warheads would be heavier, fewer could be carried in each missile. The result: Moscow would have to build extra costly missiles to carry the same overall number of warheads. These warheads also would be more expensive than non-MaRV warheads. Because they would be technologically more complicated, they would be less reliable or certain of success.

There is a special "low-endoatmospheric" defense for "hard points," mainly missile silos. There are various schemes for such a system. These include firing clouds of pellets or steel flechettes and small rockets ("Swarmjets") at the approaching Soviet missile. Deployment by the U.S. of such systems might

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[9] It is true that the first deployable U.S. ABM system, the NIKE-ZEUS, was canceled by Secretary of Defense Robert McNamara in 1961 on the announced ground that it would be easy for the Soviets to design decoys that would fool the defensive radar, thus saturating the defense by forcing the defense to track and shoot at all the decoys. The Air Force, however, spent billions in the 1960s and never designed a decoy that could successfully fool U.S. test radars. Research in the 1960s all but concluded that the best "decoy" was an armed warhead.

require Moscow to expend more warheads per target than the current two. The cost estimates for point defenses are still preliminary, but one estimate for a system proposed by Sandia Laboratory suggests that, for a cost of about $3 to $5 billion, a terminal defense for the entire U.S. Minuteman III force could be deployed that would require the Soviets to use four warheads per target to overcome the defense. Additional penalties could be imposed on the Soviets at modest cost by proliferating terminal defense system components.[10] The Soviet cost of overcoming such a defense would likely be far greater than the U.S. cost of building one.

It is possible, suggest some critics of SDI, that Moscow could counter a U.S. terminal layer defense by using "precursor" warheads that would arrive on target before other warheads and destroy the terminal defense system with heat and blast or deflect the defensive U.S. weapons after they are launched by creating hurricane-force winds.[11] However, the U.S. could counter such an attempt by deploying in large numbers relatively inexpensive and expendable system components such as radars; further, in a layered defense, even with only a high endoatmospheric (just after the warheads reach the atmosphere) layer, the Soviet precursors would be subject to interception at earlier points.

## PREFERENTIAL DEFENSE

During the boost- and post-boost phases, it is not feasible to project Soviet missile trajectory and calculate the intended target. This is possible, however, in the midcourse and terminal phases. This gives the U.S. the option of preferential defense--or deciding which targets to defend. By this means, the defense can prevent the attacker from achieving its objectives, fully or perhaps at all, while at the same time economizing its use of defense resources and improving its cost-exchange ratio. This tactic is particularly effective when combined, synergistically, with such passive defense measures as using decoys, which in effect are fake missile silos.

The offense can also, of course, preferentially attack by concentrating its forces on particular targets. But it must then expend extra weapons per target to have high confidence in destroying the targets it "prefers." This in turn limits the objectives it can seek to fulfill, or it would require the expenditure of considerable funds in order to overcome the defense.

## MULTIPLE-ATTACK

"Cheap" Soviet offensive countermeasures against U.S. anti-missile systems thus look problematic and risky at best. Their

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10 For a description of the Sandia concept, see "Low Cost ABM Radar Given Emphasis," Aviation Week and Space Technology, March 1, 1982, pp. 74-75.

11 Ballistic Missile Defense, op. cit., p. 395.

probable effectiveness would appear too low to give the Kremlin adequate confidence in the success of its attack. The alternative is for Moscow to multiply the number of RVs in its arsenal and attack. The challenge will be to devise ballistic missile defenses that cost sufficiently less than offensive efforts to overcome defenses such that Moscow would be discouraged from efforts to continue its massive offensive arms build-up--a goal that even the present state-of-the-art may achieve.[12]

If a U.S. defense system thus had a 90 percent probability (with one or more layers) of intercepting an attacking Soviet weapon, Moscow would need eight to ten RVs to feel highly confident that the target would be destroyed. This suggests a cost to the attacker of 15 to 20 times that of the defender. Even a defense intercept probability of only 50 percent--surely cheaper to the defense--would require trebling the attack (around three RVs per target), which would multiply the cost to the offense to at least six times that of the defense.

## OTHER CONSIDERATIONS

Such cost-ratio estimates are based on the latest and best estimates for systems already on U.S. drawing boards. If future defensive systems prove costlier, they will be deployed only as "thin layers" to complicate the task of the attacker, or they will not be built at all.

Calculations of the numbers of RVs the Soviets would need to offset the defenses are based on "expected values." These estimates themselves are highly uncertain: A "90 percent defense" may mean "between 60 and 95 percent," and 50 percent may be "between 25 and 70," especially given the confusion and unexpected developments of war. The uncertainty introduced by defenses thus reinforces deterrence; an attack planner would have to make "offense-conservative" assumptions about the probability of success for its mission. Moscow at great cost would have to add considerably more weapons and/or countermeasures than described above--and would still be uncertain about accomplishing the mission.

## CONCLUSION

Cost-exchange ratios, of course, are only one factor in decision making. The Soviets have shown in the past a willingness to spend on defenses even it is not "cost-effective."[13]

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[12] For discussion, see Edgar Ulsamer, "The Battle for SDI," Air Force Magazine, February 1985, p. 48.

[13] "...[T]he Soviets have probably spent $100 billion in an air defense system for their continental territory. This is an expenditure that we have not made, because we do not think it is necessary [in the absence of

They may do so simply to increase the uncertainty for the United States, to reassure their own people, to satisfy bureaucratic pressures, or for other reasons. The U.S. in turn might want to do so to reduce or eliminate the ballistic missiles threat, with the possibility of eventually reducing the numbers and cost of strategic offensive missiles.

The purported relative inexpensiveness of Moscow's developing countermeasures to U.S. missile defenses has not been proved by SDI critics, nor is it at this time probable that it can be. The clear advantage of offense over defense, demonstrated dramatically at Hiroshima and Nagasaki, now seems to be yielding to a defense advantage. For this reason, arguments using cost-exchange ratios no longer are credible in opposing long-term research and development, and intermediate deployments of a U.S. strategic defense system. Those aspects of the system that prove cost-ineffective, of course, need not be deployed.

If arms control should solve the problems of strategic instability, the Soviet first-strike capability, and U.S. vulnerability, so much the better. If it does, it may be because the U.S. did persist, as indeed the Soviets are doing, in research and development of anti-missile weapons.

Since it can never be certain that U.S. nuclear retaliation will be carried out or be effective in the face of a Soviet first-attack, the best way to enhance deterrence--of nuclear war, conventional war, or nuclear coercion--is by increasing the uncertainties of the costs and outcome for the Kremlin. The best means of achieving this would appear to be with a strategic defense.

Prepared for The Heritage Foundation
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defense against ballistic missiles]. And we also think that the Soviet massive expenditure for this purpose has not been well advised, looking at the situation from their point of view because we still believe that [with] our upcoming cruise missiles, our present bomber capability could penetrate this air defense system with relative impunity." President Carter at a Question and Answer Session, April 11, 1980, as reported in Presidential Documents, Monday, April 21, 1980, p. 660.

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