Click here for Full Issue of EIR Volume 17, Number 16, April 13, 1990

'Brilliant Pebbles' are not that smart

Charles B. Stevens and Carol White show why the future of the Strategic Defense Initiative is at risk from the mistaken reasoning of "Brilliant Pebbles" proponents.

Two weeks ago, *EIR*'s *National* section covered the status of the Strategic Defense Initiative (SDI) as conference participants reported to the annual meeting of the American Defense Preparedness Association. The situation they reported looked pretty grim because of the reality that the Bush administration is killing the program with not-so-benign neglect. This week, we intend to analyze the hegemonic Brilliant Pebbles Program from a scientific standpoint.

To state our conclusion in advance: The idea of going with a kinetic energy weapons (KEW) ballistic missile defense as a first stage to precede deployment of an ABM system based upon directed energy weapons was devised by Dr. Edward Teller and his associate Dr. Lowell Wood, in collaboration with other SDI scientists, as a means of breaking through the apparent impasse which had stalled the SDI as the pace of disarmament negotiations with the Soviets increased. These 100-pound missiles would each have advanced computing capabilities which—so the proposal went—would obviate the problems of centralized systems control for targeting, allowing for flexibilities and significant cost reduction.

Since 1982, and particularly after President Reagan's March 23, 1983 policy statement which established the SDI, as such, Lyndon LaRouche and, we his associates, have been extremely critical of basing an anti-ballistic missile defense system on kinetic energy weapons. LaRouche's original proposals, which had been instrumental in President Reagan's original definition of the Strategic Defense Initiative, had all been based upon the use of new physical principles—lasers, electron beams, and other applications of what are fundamentally plasma processes. We were particularly critical of proposals by the High Frontier grouping, whose major spokesman was Lt. Gen. Danny Graham.

High Frontier advocated the use of off-the-shelf KEW technology for a spaced-based anti-missile defense system. At that time, we proved conclusively that his system would not be effective, and would also be prohibitively expensive. Recent studies have shown that despite their apparent advantages, the Brilliant Pebbles design bears all of the hereditary flaws of a KEW system. We therefore submit that going with a flawed system, as a means of keeping the SDI alive politically, is the reverse of having one's cake and eating it. It's a situation of: If I win I lose.

The resources required to put the Brilliant Pebbles into place would prove, in the not too distant future, to have been misspent. This would not redound to the political benefit of the program, and, most important, it would not give the United States, and any allies who adopt it with us, an adequate defense against a Soviet missile attack.

We dismiss any notion that a space-based ABM defense is needed to protect against accidental launch or Third World aggression. A missile which is out of control can be detonated in flight by the country from which it originates. Third-party IRBMs can be hit from the ground. As the events of Lithuania are unhappily underscoring, the Soviets are, and in the immediate future will remain a serious military problem, to ourselves, and to those nations, to whose freedom we should be committed to defend.

© 1990 EIR News Service Inc. All Rights Reserved. Reproduction in whole or in part without permission strictly prohibited.

A pebble in the wind

A well-known Warsaw Pact military defector to the West once characterized the heart of Russian military doctrine as the axe strategy: Simply put, if your enemy can attack you with a knife, you strike him with an axe; if he attacks with a sword, you shoot him with a gun. In other words, superior firepower, overwhelming firepower is an essential predicate of a victorious military strategy. Even a passing glance at the Soviet arsenal of strategic nuclear weapons, compared to those of the West, demonstrate that this doctrine remains the existing and continuing guiding principle for the U.S.S.R.'s military strategy.

And when it comes to strategic defense, defense against nuclear-tipped missiles included, the Russians have been left with a monopoly of deployed capabilities and a growing, significant research and development edge.

It is now being proposed that the U.S. deploy a first phase of a missile defense consisting of ground-based interceptors and space-based rocket interceptors, which are called Brilliant Pebbles. The problem with this old type of missile defense is that it is like trying to hit a bullet with a bullet. And it does not even come close to the firepower potential offered by directed energy beam weapons, like lasers and relativistic particle beams, which hit their targets over ranges of thousands of miles at the speed of light. The Brilliant Pebbles proposal appears to be a deployment of rock catapults when the enemy is preparing to deploy gunpowder artillery.

The Brilliant Pebbles appear, at first sight, to have a certain attractiveness because, being light and relatively inexpensive, they can be deployed in relatively large numbers. Two aspects of SDI which are rarely brought out in discussion are surveillance and survivability. As we know, the Soviets have a KEW ASAT system and are working on ground-based laser (GBL) anti-satellite (ASAT) systems.

The U.S. ballistic missile surveillance capability—our early warning system, known as the Defense Satellite Program (DSP)—is limited to only a few satellites; and these are satellites which are incapable of defending themselves from enemy attack. Obviously it is highly advantageous for the Soviets to be able to knock these out and blind U.S. defenses. To improve the survivability of this system, the Air Force is considering dispersing the capability among many satellites.

Thus, instead of accomplishing the ballistic missile surveillance mission with a few very expensive satellites, the same mission would be accomplished with many relatively cheaper satellites. This approach makes the Brilliant Pebbles attractive, if they are to be put to the purpose of becoming Brilliant Eyes.

At about the same cost, the Soviets would be presented with many relatively low-value targets as opposed to the present situation in which they face just a few high-value targets. The loss of individual units is not such a blow to the effectiveness of the whole system, and can be compensated for while leaving the system otherwise intact. As a weapons system, Brilliant Pebbles are not all that great; however, as a surveillance system (Brilliant Eyes) the system is more survivable than that presently in use. In fact, it is in the sensor, signal processing, and onboard computer areas that the Brilliant Pebbles push technology the most.

While this proposal seems attractive on its face, we would agree with some of its Air Force critics who would prefer to go the route of the initially more expensive, but in the end far more capable sensing devices.

It would appear that the real reason for the proposal to deploy the kinetic-kill Brilliant Pebbles, as a first-phase for a U.S. missile defense, has more to do with trying to patch up the increasingly precarious position of U.S. surveillance, communications, and intelligence satellites. Within the context of the existing U.S. strategic doctrine of Mutually Assured Destruction through Flexible Response, these satellites provide the means of early warning against a Soviet surprise first strike with intercontinental ballistic missiles.

The surveillance satellites would see the takeoff of the Soviet missiles in time to provide sufficient warning time to allow the U.S. to either get off a launch-on-warning retaliatory strike of its own, or to provide missile field commanders enough data on the incoming strike to mount a last-ditch defense, or both.

What defense? Today it would be the dust defense. The missile field commander would simply have to detonate some of his own warheads on the missiles in their silos at the right moment to loft rocks and dirt up in the air. The incoming Soviet warheads would then collide with the debris, and hopefully either be destroyed or detonated at sufficient standoff ranges to ensure the operational survivability of most of the U.S. missiles in that particular missile field. In any case, the surviving members of the U.S. National Command Authority would have realtime video tapes of the results of the initial engagement—in order to do proper damage assessment!

Soviet capabilities

It is well known that for many years the U.S.S.R. has tested and deployed a kinetic kill anti-satellite missile, that is a kinetic energy weapon anti-satellite (KEW ASAT). The Soviets launch a "killer" satellite into orbit which contains an explosive device. They then issue commands to the satellite to cause it to rendezvous with its target. When the satellite and target converge, they detonate the explosive.

More recently, the Soviets have deployed a ground-based laser with significant anti-satellite (GBL ASAT) capabilities as well. Given that laser light travels at the speed of light, many U.S. surveillance satellites—those over the Soviet Union at the time—could be destroyed or essentially disabled within seconds, instead of the hours apparently required for the KEW ASAT missile interceptor.

Despite the potential advantage of Brilliant Eyes over the existing early warning system, the U.S. Defense Satellite Program (DSP), competent military commanders—among whom the Soviet High Command are emphatically to be numbered—know that military superiority over an adversary requires constant scientific and technological advance. The faster the advancement the greater the superiority. Thus they welcome a high rate of technological attrition, which is built into their military budget.

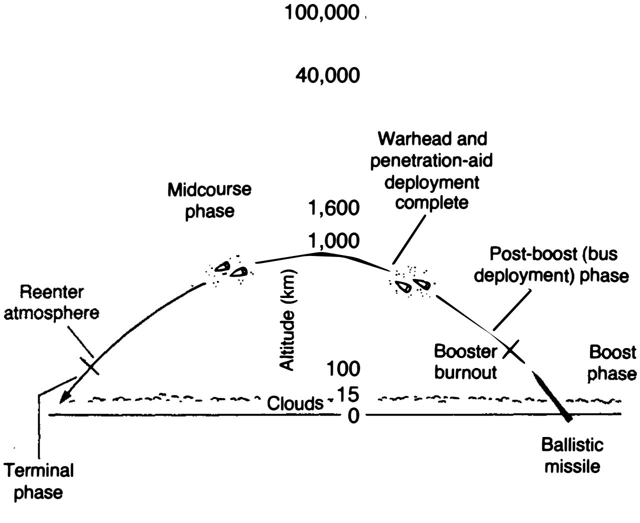
The problems with the Pebbles

Detailed simulations have already shown that Brilliant Pebbles don't make it as missile defense systems. Summarily, this can be stated as: Shooting bullets with bullets is a very hard thing to do, even in the case where the bullet—the Brilliant Pebble—is actually traveling at twice the speed of the missile which it is attacking.

A satellite traveling in low-Earth orbit travels at about 7.61 kilometers per second (kps). An ICBM at burnout travels at about 6.5 kps. The Pebble would pick up velocity with a ΔV of somewhere between 4 to 6 kps, giving it a velocity of 11 to 14 kps in comparison with the missile which it is attacking.

FIGURE 1

Phases of a typical ballistic missile trajectory

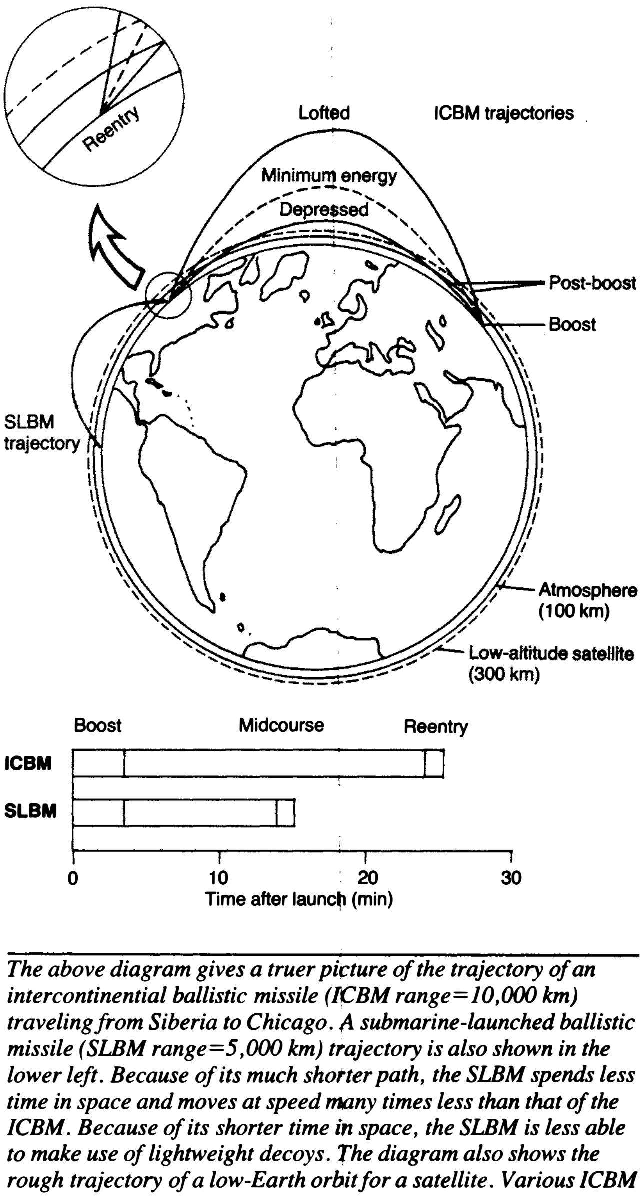


During the boost phase, the rocket engines accelerate the missile payload through and out of the atmosphere and provide intense, highly specific observables. A post-boost, or bus deployment, phase occurs next, during which multiple warheads and penetration aids are released from a post-boost vehicle. In the midcourse phase, the warheads and penetration aids travel on trajectories above the atmosphere, and they reenter it in the terminal phase, where they are affected by atmospheric drag.

This question of the relative speed of the Pebble versus its target missile, means that a considerable number of missiles must be orbiting over the Soviet Union at all times, in order to have any chance of effectiveness. The ratio of missiles in position to fire at ICBMs, to those in orbit in more distant locations is known as the absentee ratio. For every 10 Brilliant Pebbles which are deployed, about 1 will have an oppor-

FIGURE 2

Trajectory phases



The above diagram gives a truer picture of the trajectory of an intercontinential ballistic missile (ICBM range=10,000 km) traveling from Siberia to Chicago. A submarine-launched ballistic missile (SLBM range=5,000 km) trajectory is also shown in the lower left. Because of its much shorter path, the SLBM spends less time in space and moves at speed many times less than that of the ICBM. Because of its shorter time in space, the SLBM is less able to make use of lightweight decoys. The diagram also shows the rough trajectory of a low-Earth orbit for a satellite. Various ICBM trajectories can in principle be utilized: 1) depressed, 2) minimum energy—the trajectory that involves the least amount of rocket fuel, 3) lofted.

tunity to intercept a Soviet booster.

It is necessary to consider all four of the phases of flight of a ballistic missile (see **Figure 1** and **2**). In its first, booster stage, it is an extremely attractive target. This phase can last up to five minutes. The large missile is launched and is slowly accelerated to the velocity of 6-7 kps needed to travel "ballistically" from the Soviet Union to the United States.

During this boost phase the missile with its large engine exhaust makes an easy target to see and track. In the second, post-boost phase, the post-boost reentry vehicles (RVs), which actually carry the thermonuclear warheads, are deployed by the last rocket stage of the missile—what is called the post-boost vehicle (PBV). It resides in the nosecone of the intercontinental ballistic missile (ICBM). This deployment leads to having each RV take an entirely independent course, which sometimes means toward separate targets that are hundreds of miles apart.

This final stage of the rocket and its PBV is much more difficult to detect and track than the booster, because there is no large, hot, rocket-engine exhaust. The post-boost phase can last up to 10 minutes.

In the third phase—midcourse—the RVs fly ballistically, that is they literally fall to their targets in the United States. Because the RVs are flying through the relative vacuum of space, light-weight balloons and other decoys, which look like or hide the RV, can be deployed and fly along with the RV until the atmosphere is reentered. This is the most difficult phase for detection and tracking. The RV is cold and has no exhaust. Sensors designed to find and track RVs can even mistake stars for RVs. Decoys and other penetration aids greatly increase this difficulty.

Finally, in reentry or terminal phase, RVs return to the Earth's atmosphere traveling at high speed. This causes a large heat wave to engulf the RV which makes it easy to see and track again. This phase lasts only a few minutes.

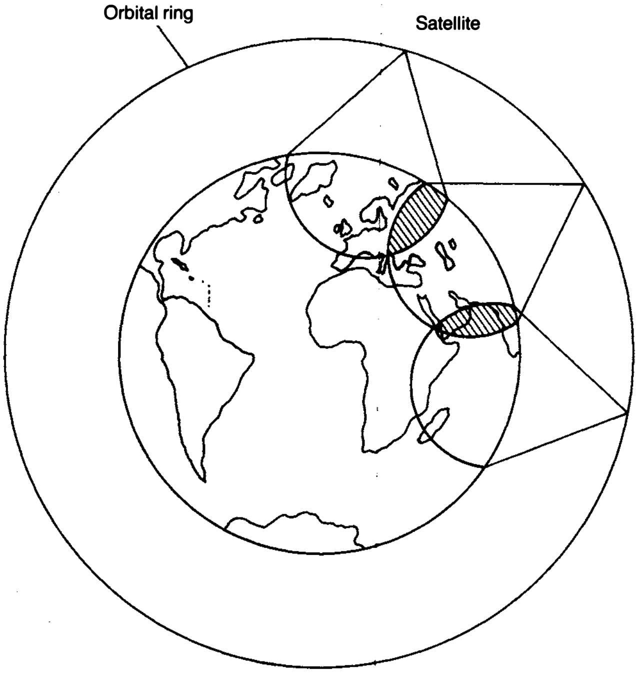
Absentee ratios

Brilliant Pebbles are thousands of small satellites that orbit the Earth once every 90 minutes. All of these orbits taken together form a constellation. This constellation can be considered to lie on the surface of a sphere whose radius is the radius of the Earth plus the Pebbles' altitude. The orbit of each Pebble forms a ring around the sphere. Relative to the center of the Earth, the sphere and the orientation of each Brilliant Pebble orbit or ring is fixed; it never changes.

The Earth spins on its axis within the Brilliant Pebbles constellation sphere once every 24 hours. At any moment of the day there is roughly a fixed number of Brilliant Pebbles over any part of the Earth, such as the U.S.S.R. In general they must be in the vicinity of their targets if they are to achieve a kill (**Figure 3**).

FIGURE 3

Requirements for global coverage by satellite



Brilliant Pebble space-based interceptors would be limited to intercepting missiles which fly through their cone of action. This cone—three of which are shown—is determined by the maximum velocity of the BP and its available flight time. To intercept a target anywhere over the Earth, the cones must intersect without gaps.

This is particularly so for the easiest kill, the boost-phase missile. Only Brilliant Pebbles near or over the U.S.S.R. during ICBM launches can intercept boosters. Roughly, only 1 in 10 pebbles are over the U.S.S.R. during a ten-minute ICBM launch and are able to intercept boosters. This 1:10 figure is known as the boost-phase absentee ratio. Only about 2 out of 10 Pebbles will have an opportunity to intercept the final rocket-stage PBVs, and only about
Pebbles will be able to intercept RVs in their midcourse.

These intercept capabilities can be found by knowing the flyout range of the Brilliant Pebbles, the volume of space encompassing the trajectories of the targets, and the distribution of Pebbles over the Earth. For example, take the case of the absentee ratio for boost phase interception. We begin an approximate calculation by taking the land area of the Soviet Union compared to that of the entire Earth: 8,650,000 square miles divided by 197,000,000 square miles. (A more detailed calculation of this and other technical issues brought up in this article are discussed in the following technical appendix.) This equals 0.04, or 4%. This means that, given a Brilliant Pebbles deployment to cover the entire Earth, only 1 in 25 will be over the U.S.S.R. at any given time.

Since a Brilliant Pebble passes over the U.S.S.R. in about six minutes, the entire set of Brilliant Pebbles over the U.S.S.R. is replaced by a new set every six minutes. If boost phase lasts for about six minutes as well, then 2 out of every 25 Brilliant Pebbles will be able to engage the boosters.

Countermeasures

Because Brilliant Pebbles achieve kills by colliding at high speed with their targets—a kinetic energy kill—they are highly susceptible to countermeasures and decoys. Since a PBV can deploy decoys, flares, and other countermeasures, and since RVs are surrounded by penetration aids and the like, the probability of Pebble kill against PBVs and RVs is much less than against boosters. Countermeasures for boosters are not practical since they are such a "hot," i.e. easily located, target. A decoy for a booster would have to essentially be a booster itself.

In midcourse, the RV deployed by an ICBM is a cold target. This means that countermeasures, decoys and the like, need not expend much energy to be effective. If decoys or countermeasures can confuse the Brilliant Pebble just enough so that its intercept trajectory is slightly in error, it will miss its target.

Boosters are the highest value targets for Brilliant Pebbles. The booster carries upwards of 10 to 20 RV warheads. Therefore, one Brilliant Pebble intercept of a booster is equal to 10 to 20 Brilliant Pebble intercepts of RVs. Also, the probability of a kill is highest for the booster stage.

If the boost-phase kills of the Brilliant Pebbles can be mitigated, the effectiveness of the entire Brilliant Pebble defense constellation can be called into question. This is especially the case when decoys and countermeasures are utilized during the PBV post-boost and RV midcourse phases.

Soviet possibilities for response

One way to mitigate Pebble booster kills would be for the Soviets to modify their existing deployed ballistic missile defense system.

The existing Soviet ABM defense system consists of short-range rockets deployed on the ground. These ABM interceptors could be easily converted into low-altitude anti-satellite ASAT systems, or what are called direct ascent ASATs (DAASAT). The missiles could be targeted to destroy the low orbital Brilliant Pebbles. (Brilliant Pebbles must fly in relatively low-Earth orbits in order to achieve boost-phase intercepts.)

This would work in much the same way in which the Soviet ABM interceptors are programmed to intercept incoming RVs which are reentering the Earth's atmosphere. And since Soviet ABM interceptors destroy their targets with a nuclear warhead detonated in the vicinity of the target, rather than by attempting to collide with only one target, U.S. countermeasures to defeat the Soviet potential nuclear DAASATs would probably have to be more sophisticated than U.S.S.R. countermeasures to defeat Brilliant Pebbles.

The Soviets have a high incentive for reprogramming their ground-based ABM interceptors as DAASATs against a Brilliant Pebble deployment by the United States. First of all, the Pebbles that are over the U.S.S.R., and are, therefore, possible DAASAT targets, are also the majority of Brilliant Pebbles that can attack Soviet ICBMs in their boost-phase. Secondly, if the Soviets punch a hole in the constellation directly over the Soviet Union, their ICBMs can fly through the hole unscathed, leaving the Brilliant Pebbles with only the harder-to-kill and less valuable PBVs and RVs as targets. And lastly, recalling that the effective absentee ratio for Brilliant Pebble boost-phase interception is 10:1, this means that for every Pebble that a DAASAT kills, 10 additional Pebbles must be launched into orbit to replace it. Or, in other words, the cost of a DAASAT can be up to 10 times the cost of a Brilliant Pebble for a breakeven cost exchange.

The overall result of detailed simulations is that the Soviets could probably defeat the Brilliant Pebbles as a missile defense through reprogramming their ABM interceptors into DAASATs for two major reasons: 1) Brilliant Pebbles limited to operating against the post-boost and midcourse phases would have very low kill probabilities and would not therefore offer an effective defense of any kind at the projected Brilliant Pebble deployment levels. 2) For each Brilliant Pebble that a DAASAT could potentially kill, 10 more Brilliant Pebbles must be placed in orbit in order to maintain a boost-phase kill capability. And a DAASAT could cost 10 times more than a Pebble and still be a very cost effective countermeasure to the Brilliant Pebble missile defense. Therefore the Soviets could defeat the Brilliant Pebble for less than it cost the U.S. to deploy it.

The proponents of the Brilliant Pebble have been confronted with these results of detailed simulations. These proponents argue that the sensor, signal processing, and computer on each Brilliant Pebble will be very sophisticated and have sufficient capability to implement state-of-the-art discrimination algorithms so that the Brilliant Pebble will be able to defeat any conceivable PBV or RV countermeasures.

But when these claims are scrutinized in greater detail, it turns out that the deployment level of Brilliant Pebbles contemplated is not sufficient to mount a significant interception of RVs during the midcourse. That is, given the absentee ratio, and the large number of RVs, around 10,000 (and the additional numbers of RV decoys), it is virtually impossible for the Brilliant Pebbles to mount a signficiant interception capability. And, in fact, detailed analysis has shown that the Army's ground-based ERIS and HEDI ABM rocket interceptors are probably more effective against RVs in the late midcourse and reentry phases.

This has forced Brilliant Pebble proponents to base their claims on only one phase of the battle—the post-boost phase. This means that the Brilliant Pebbles would be attacking PBVs which are still deploying RVs and therefore contain more than one warhead.

But as it turns out, the argument at this point degrades into an almost endless cycle of point versus counter-point. For example, the Brilliant Pebble critics point out that the Soviets could deploy fast-burn boosters and quick deployment PBVs so that RVs can be deployed almost immediately after booster burnout. This, together with DAASATs, would clearly defeat Brilliant Pebbles, but the Brilliant Pebble proponents argue back that this would be extremely costly for the Soviets.

The question of cost

In order to be an effective anti-ballistic missile weapon, the Brilliant Pebbles must prove that they are cost-effective relative to countermeasures. Are Soviet countermeasures potentially as costly as a Brilliant Pebble system? This is hard to answer, but likely not.

The more intelligent backers of Brilliant Pebbles do not directly address this cost issue, but go on to say, let the Soviets respond to Brilliant Pebbles with fast-burn boosters and single-RV PBVs. While they are switching over to these new ICBM systems and diluting their own directed energy beam weapons research and deployments, Brilliant Pebbles have bought us enough time—and have gotten the foot in the door—to begin deployment of Phase 2 of the SDI—lasers and particle beams.

That is, the Brilliant Pebble backers reply that directed energy weapons could then be deployed. Only these speed of light weapons have the firepower, range and mobility needed to shoot PBVs, RVs (and all their decoys and penetration aids if they have to) in an efficient, effective, and economic manner. And some Brilliant Pebble proponents then say that since the Soviets know that U.S. capability to go over to directed energy exists, this will dissuade them from converting their ICBM systems and leave Brilliant Pebbles forever as an effective defense against Soviet missiles. In other words: "We guarantee Brilliant Pebbles' effectiveness by threatening to deploy a more capable SDI." This is more reminiscent of Mutually Assured Destruction than of strategic defense.

In conclusion, Brilliant Pebble does not offer the kind of missile defense advertised. It is also a poor substitute for an upgraded and more survivable DSP surveillance, intelligence, and communications satellite system. Most significantly, Brilliant Pebble does not involve the sort of breakthroughs in science and technology represented by directed energy laser and particle beam weapons—breakthroughs which promise to revolutionize the civilian economy and help lead to the reindustrialization of the United States.

In an age of lasers and particle beams, Brilliant Pebbles will be totally outgunned. The Soviets are developing these directed energy weapons. Our commitment,therefore, must be to outpace them there, not to delay U.S. laser and particle beam work with Brilliant Pebbles.

Glossary

The following lexicon is intended to give the reader some tools to understand the language in which questions of anti-missile defense are usually couched.

The **Brilliant Pebble** is basically a kinetic energy weapon—a bullet hitting a bullet, that is a missile which intercepts a missile (see **Figure 4**). Thousands of Brilliant Pebbles would have to be placed in low-Earth orbit to provide any significant level of missile defense. The ERIS and HEDI are ground-based missile missile-interceptors. ERIS would operate against incoming warheads which were still in space. The HEDI is designed for interception within the atmosphere during the reentry phase.

The Brilliant Pebble concept was the result of two long-term defense research projects: S-1, a computer R&D effort, and popeye, a major advance in sensor technology. The basic idea of BP is to combine breakthroughs in both areas of these "off-the-shelf" technology development programs to produce a cheap, small interceptor capable of intercepting missiles or their warheads during any phase of their trajectory.

Acquisition—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-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, by collision at high speed, or by directed energy beam.

Architecture—description of all 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 system 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.

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 communications.

Boost—the first portion of a ballistic missile trajectory during which it is being powered by its engines. During this period, which usually lasts 3 to 5 minutes for an ICBM, the missile begins to dispense its reentry vehicles. The 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.

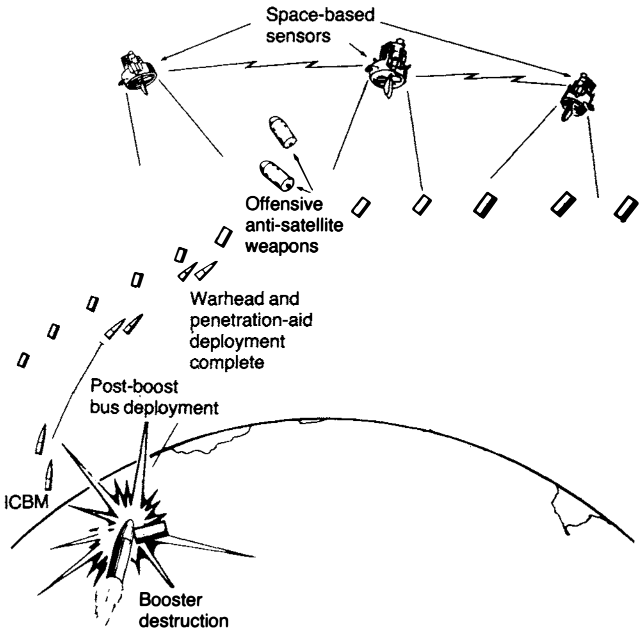
Brightness—the unit used to measure source intensity. To determine the amount of energy per unit area on target, both source brightness and source-target separation distance must be specified.

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.

Carrier vehicle (CV)—A space platform whose principal function is to house the space-based interceptors in a protective environment prior to use.

FIGURE 4a

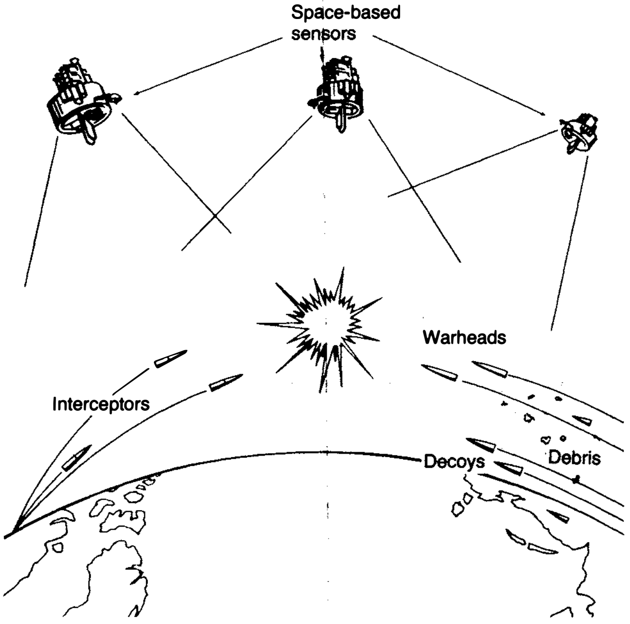
Strawman concept for ballistic missile defense during the boost phase



The above shows Brilliant Pebble interceptors deployed in low-Earth orbit. These would have to detect a missile that has been launched and then fly on a course to intercept the path of the missile.

FIGURE 4b

Strawman concept for ballistic missile defense during the midcourse phase



Chaff—strips of frequency-cut metal foil, wire, or metalized glass fiber used to reflect electromagnetic energy, usually dropped from 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 satellite and a ground site.

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 close to 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 non-threatening 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 time—the amount of time that a weapon platform takes to negate (destroy or incapacitate) a given target. This includes not only firing at the target, but all other necessary weapon functions involved that are unique to that particular target.

Excimer laser—also called "excited dimer" laser, which uses the electrically produced excited states of certain molecules, such as rare gas halides (which produce electromagnetic radiation in the visible and near-ultraviolet part of the spectrum).

Exoatmospheric—outside the Earth's atmosphere, generally considered to be at altitudes above 100 kilometers.

Exoatmospheric Reentry Vehicle Interceptor Subsystem (ERIS)—the original name that refers to the Lockheed variant of a ground-based interceptor (GBI) that could be used in a strategic defense system.

Fluence—the amount of energy per unit area on target. (It should be specified whether this is incident or absorbed fluence.)

Gamma ray—electromagnetic radiation resulting from nuclear transitions and reactions.

Ground-based interceptor (GBI)—the generic name for a ground-based interceptor, such as ERIS.

Imaging—the process of identifying an object by obtaining a high-quality image or profile of it.

Interception—the act of destroying a moving target.

Intercontinental ballistic missile (ICBM)—a land-based ballistic missile with a range greater than 3,000 nautical miles, or roughly 10,000 km.

Kinetic energy—the energy from the motion of an object.

Kinetic energy interceptor—an interceptor that uses a nonexplosive projectile moving at 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 or 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. Laser light can be much more efficient, in terms of required energy, than kinetic energy weapons. When the light has sufficient power density, the vaporization process generates a shockwave which rips a hole in the target. This process can require far less energy than a kinetic interceptor requires—and much shorter engagement times.

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, i.e., post-boost, midcourse, terminal.

Leakage—the percentage of intact and operational warheads that get through a defensive 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 is no longer a single object but a swarm of RVs, decoys, and debris falling freely along present trajectories in space.

Non-nuclear kill—a destruction of a target that does not involve the use of a nuclear explosion. While kinetic energy kills involve greater total energies than directed energy weapons, directed energy weapons can achieve power densities like those found with nuclear kills. But with a laser directed beam weapon, only the small spot of the beam on the target has this high-power density.

Nuclear kill—a nuclear explosion that destroys a target. Exploded at high altitudes or in space, nuclear detonations can destroy RVs and their warheads at up to distances of several kilometers from the detonation point. The kill mechanism is usually that of a shockwave-induced destruction generated by the intense x-ray burst deriving from the nuclear fireball. In fact, most of the energy of nuclear explosion is initially in the form of x-rays. But, when exploded in the atmosphere, the x-rays are absorbed by the air and the energy is converted into a shockwave. In space the x-ray burst can travel hundreds and even thousands of miles, though the burst intensity may only be sufficient for killing targets a few kilometers away.

Particle beam—a stream of atoms or subatomic particles (e.g. electrons, protons, or neutrons) accelerated to nearly the speed of light.

Penetration aid—a device, or group of devices, that accompanies a reentry vehicle during its flight to 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 called a "bus.")

Reentry vehicle (RV)—The part of a ballistic missile that carries the nuclear 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. The RV is usually shaped like a cone and has a very tough heat shield for atmospheric reentry and is thus a hard target to kill.