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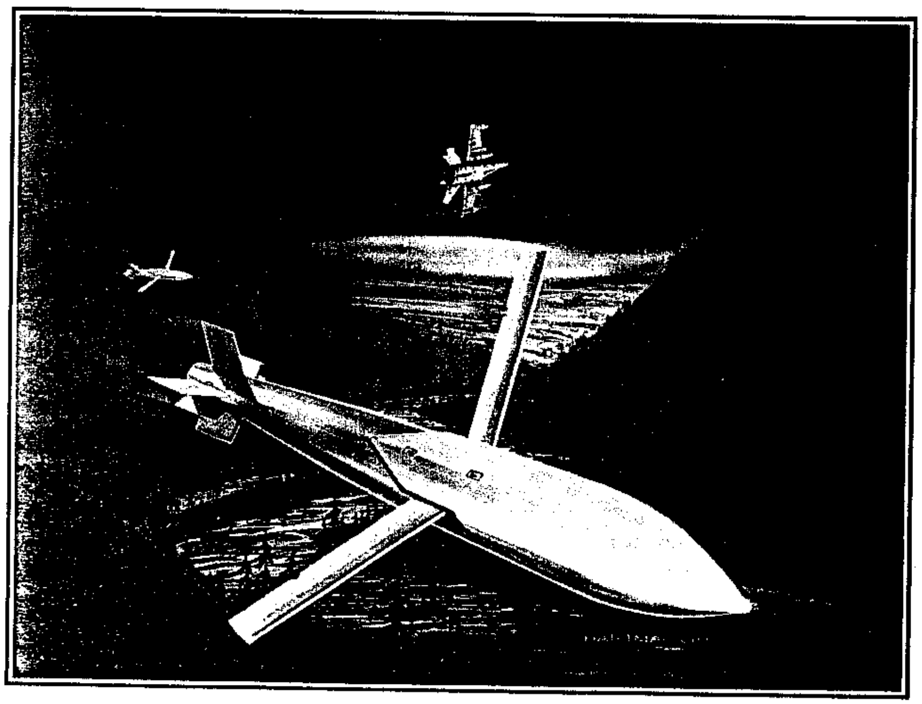

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SPACE-BASED DEFENSES AGAINST BALLISTIC MISSILES

Richard L. Garwin

In his diary for Thursday, 25 August 1960 President Eisenhower's science advisor George B. Kistiakowsky wrote,

> Had Si Ramo for lunch, who talked about STL's proposal for AICBM and its importance. It consists of a swarm of tens of thousands of little satellites that would pounce upon any missile as it is being launched. It think it is fantastically expensive, but I may be wrong and if I am, the whole idea may be important.

Since 1960, of course, we have had a third of a century of technological improvement, and the conclusion might well be different now. We have also witnessed the elimination of the Soviet empire, and the threat is also totally changed. What can be said about space-based defenses against ballistic missiles now?

Returning to fundamentals, ballistic missiles are launched from the ground or from submarines (or, in principle, from aircraft) and burn out early in flight. The rest of the trajectory is "ballistic," in that the missile or its warhead falls like a stone in its travel toward the target. Lobbed in this way on an elliptical trajectory with the center of the earth at the more remote focus, the long-range ballistic missile arches into space above the atmosphere and returns toward the target with the same reentry angle and velocity with which it left the atmosphere. The path approximates a parabolic curve at short range.

For an intercontinental ballistic missile (ICBM) of ten-thousand-kilometer range, launch and reentry of the elliptical path are at an angle of roughly twenty-two degrees to the horizontal. The sensible atmosphere stops at an altitude of about one hundred kilometers, so about two hundred kilometers of ground track at each end of the trajectory is within the sensible atmosphere.

For a fairly long-range (eight hundred kilometers) tactical ballistic missile (TBM) such as the Al Abbas, a longer-range variant of the Al Hussein launched by Iraq against Israel and Saudi Arabia, the launch and reentry angle is about forty-five degrees; the ICBM has a reentry speed of 7 kilometers per second (kps), whereas the TBM reenters at about 3 kps.

The midcourse trajectory is above the atmosphere for missiles of ranges greater than about six hundred kilometers, although it can be depressed so that apogee remains below one hundred kilometers without much penalty in range or aerodynamic heating for ranges below one thousand kilometers.

Thermal and mechanical stresses on launch are tolerable only because an ICBM is launched from the ground with modest acceleration and achieves its necessary speed well above the densest part of the atmosphere. Upon reentry, no such gentleness is possible, and the reentry vehicle (RV) must absorb the fiery heat of reentry either in the early heat-shield-type RV, or, as in all modern reentry vehicles, a sacrificial layer must be ablated. Peak deceleration is typically sixty times that of gravity (60 g).

In any case, the launch phase is highly visible in the infrared and visible regions of the spectrum, as is clear from launches of the U.S. space shuttle, familiar on television. The reentry phase of a long-range (hence fast) missile is also highly visible, because of the high temperature of the surface of the RV and of the gases around it. In addition to the enhancement in the optical, the radar cross section is vastly increased by the ionized gases produced by the high temperature, so that an RV which may have been specially shaped and treated to have a low radar cross section in space becomes highly visible on radar when it reenters.

The effectiveness of a defense is strongly influenced by the size of the ballistic missile raid, by the simultaneity of launch or reentry, and by the clustering of launch sites. A ballistic missile

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attack is not a natural phenomenon; human intelligence made the missiles, and human intelligence (not benign to the recipient or to the potential defense) decides how, when, and against which targets to launch. At least, this is so in many cases, if not in the special case of accidental launch.

Most ICBMs and submarine-launched ballistic missiles (SLBMs) are equipped with nuclear warheads. More common are the familiar high-explosive (HE) warheads on the theater-range Al Abbas and on the hundreds of Scuds and Al Husseins fired in the Iraq-Iran war. Ballistic missiles may also be equipped with chemical or biological payloads, although the lethality of chemicals is far less than that achievable with nuclear weapons. In addition, there are serious problems of effective dispensing of biological or chemical agents, which, however, are considerably less stressing for TBMs, where the agent may be divided among a large number of bomblets or submunitions not only to reduce vulnerability to defenses but to achieve the dispersal of the agent required to improve its lethality.

Similarly, inaccurate HE terror weapons have improved performance if the explosive is divided among a substantial number of bomblets.

Typically, a ballistic missile defense (BMD) capability can be enhanced if one can view the launch — the large rocket plume which, for a long-range missile, radiates typically megawatts of power in the infrared and the visible spectra. Henry F. Cooper, Jr., the head of the Strategic Defense Initiative Organization (SDIO), revealed that U.S. DSP (Defense Support Program, a name assigned long ago, when the purpose of the satellites had not been disclosed) early warning satellites detected every missile launch in Iraq during the Kuwait War. In addition to alerting defenses and enhancing passive defense by providing warning to take shelter or to don gas masks, the mere fact and the rough location of a launch provide extremely valuable information to enhance active defense. For instance, every small-area terminal defense then knows the azimuth from which a warhead might arrive and has a good idea of the elevation and arrival time as well. This was particularly the case with Al Hussein missiles, which apparently were fired always from fixed range. Although the DSP satellites and their software and communication systems were not optimized for providing timely and precise measurements of launches, improvements either have been made or could readily be made in linking such warning systems in real time and in a secure fashion to commanders in the field, providing them with additional information on the launch, such as azimuth of the trajectory. This would enable alerting only specific defensive systems or regions.

There is substantial leverage associated with such alerting and cuing of a sensor. For instance, if the space that must be searched by a ground-based radar (GBR) is reduced by a factor sixteen, the radar range (for a given power and RV radar-scattering cross section) is increased by a factor two, perhaps providing additional intercept opportunity or a larger local "footprint" of defensive coverage by a given interceptor. Alternatively, the GBR power could be reduced by the same factor sixteen, if cuing is assured. This would enable fielding more radars at lower cost at an earlier time, for instance. Of course, such a launch is visible not only to an early warning satellite in geosynchronous orbit but also to a potential interceptor. As we shall see, an orbiting interceptor would be provided with a reach-out speed of some 6 kps, and might thus reach out one thousand kilometers (from its projected orbital position) in intercepting an ICBM with a boost time of two hundred seconds.

During this powered portion of flight, the boost phase, not only is the missile highly visible to a potential interceptor, but it is also highly vulnerable. It is large and also relatively fragile, because the structure of the missile must be made relatively light for it to have a significant payload at intercontinental range. Not only does the TBM have a shorter burn time in order to achieve its lesser velocity, but also it can be substantially tougher, in view of the lower velocity and the admissibility of a greater deadweight fraction without severe reduction of the payload.

The boost phase would be the most desirable time to intercept, except that it is over quickly and it is "over there" rather than where one has one's own greatest capability. Indeed, local and cooperative boost-phase intercept may be a possibility in order that Kazakhstan, for instance, be able physically to veto the launch of an ICBM based in Kazakh territory but commanded by the Russian Republic. That boost-phase intercept is very special, since it could be carried out by teams of gunners a few hundred meters from the silo, equipped with tripod-mounted anti-tank missiles.

As the missile burns out, it enters its relatively long midcourse coast — a longer time for intercept, but a time during which the missile is typically less vulnerable and less visible. Although the crudest short-range missiles, such as the Scud and the Al Hussein, do not separate the warhead from the missile body, such separation is essential in longer-range missiles, for which it would not be possible to provide reentry for the missile body as well. Heating by aerodynamic friction on ascent may have warmed the outer shell of the RV, but the designer could well have provided a protective shroud, to be shed in the last stage of powered flight, or just before the RV is separated from the rest of the missile. Advanced payloads are stabilized in angle so that minimum error is introduced on reentry, but crude systems do not, in general, need such stabilization. Thus one has a room-temperature reentry vehicle, about the size of a person and weighing a few times as much, coasting through the void of space.

Reentry comes as gravity brings the warhead to the one-hundred-kilometer altitude level, at which point significant aerodynamic forces act, beginning to retard the RV and to heat its surface. In midcourse, a balloon the same shape as the RV could follow or accompany it without being readily distinguished, although precision observation of the RV could discriminate it from a balloon of a different shape or surface texture. Countermeasures to such assessment or to intercept have been known for a very long time and have been much discussed in the last decade or so of consideration of the Strategic Defense Initiative (SDI). Antisimulation is now widely recognized as an effective countermeasure. An inflated balloon decoy (lightweight and readily stowed and deployed, so that several or many can be afforded) is not required to simulate in every way a precision RV, because the RV itself is enclosed in a similar cheap balloon so that the decoys are cheaper to make.

The RV, of course, weighs hundreds of kilograms and has substantial thermal energy even at room temperature, whereas a balloon at night is quickly cooled by its own thermal radiation. This difference is readily masked by the use of balloons coated with multilayer insulation (MLI), material commonly used for "superinsulation" in terrestrial applications. An RV enclosed in such an MLI balloon provides no thermal signature to contrast it with or to distinguish it from an empty MLI balloon. This particular lily can be gilded by the addition of battery-heated resistive patches on the surface of one balloon or another.

Following the midcourse, the terminal phase of the trajectory brings a different regime for intercept. The atmosphere strips away the light decoys, and the RV is once again highly visible to optical sensors and to radar. However, an interceptor now must itself reckon with the heat and stress of high-speed passage through the atmosphere, although its speed need not exceed a few kilometers per second if a ground-launched interceptor is defending a small region by low-altitude intercept. Nevertheless, the time available is short, and the area that can be covered by a single intercept launch site is restricted.

It should be noted that in many cases of BMD, one is trying to protect only a very small and hardened target, so that for such instances it would be exceedingly useful to have an effective intercept capability even if the standoff range were only tens or hundreds of meters. For instance, in all of the discussion of ICBM vulnerability to Soviet nuclear warheads, if one could have enforced a keep-out distance of 0.5 kilometer the goals of silo defense would have been achieved. Indeed, systems specialized for silo defense were proposed, such as Swarmjet, which would involve firing thousands of few-pound unguided rockets from an expendable launcher near each silo, with RV detection and launcher aiming provided by expendable close-in radars. Of limited, but adequate, capability and modest cost, the Swarmjet system was never seriously explored in competition with the technologically more challenging systems that had some potential for large-scale defense and which were therefore highly questionable from the point of view of strategic stability and fueling the arms race.

WHAT IS NEW WITH SPACE-BASED BMD?

In answering the important questions, Will it work? and At what cost and schedule? we must take into account not only the change in technology over the last few years, but also the change in the threat, with the collapse of the Soviet Union and the general recognition in the republics that the United States has no aggressive goals against them. Indeed, the Missile Defense Act of 1991 (MDA-91) authorizes the deployment of a one-hundred-interceptor ground-based BMD system, looks clearly toward the deployment of additional ground-based sites beyond those permitted by the 1972 Anti-Ballistic Missile (ABM) Treaty between the United States and the Soviet Union, and all but encourages the deployment of space-based interceptors. The threat cited is that of accidental or unauthorized launch of nuclear weapons from the republics of the former Soviet Union, the threat of Third World ICBM attack on the United States or its allies, and TBMs armed with any kind of warhead and directed against U.S. military forces abroad or against our allies.

Cost and schedule are important, as is the competition with ground-based systems (and with other means) to achieve the same goals. For instance, Kazakhstan, Belarus, and Ukraine have all committed themselves to be nuclear free, and all tactical nuclear weapons are expected to be returned to Russia by 1 July 1992. As for the strategic weapons on the soil of these three republics, they are now nominally under control of the joint leadership. In any case, protection against accidental or unauthorized launch of these strategic weapons can far more readily and more effectively be achieved by working with Russia and any of the republics that continue to host strategic nuclear weapons, in order to enhance the permissive action link (PAL) or even to implement an additional control (passive destruct after launch [P-DAL]) which would actually destroy the missile after launch if it were launched without the appropriate code. It is a matter of choice whether this is termed DAL or enhanced PAL, but in any case, the Commonwealth of Independent States and the United States could implement this far sooner and at much lower cost than active BMD systems.

The same is true for control over any former Soviet SLBMs remaining to the Commonwealth of Independent States. Recent congressional testimony gives assurance that Commonwealth SLBMs cannot be launched without appropriate codes from Moscow; but even that control could be enhanced if desired. So the remaining threats from MDA-91 are protection against long-range nuclear-armed ICBMs from third nations and defense against TBMs. I will put these threats in perspective below, but I continue now with a description of components of a potential space-based BMD system.

As indicated, the current DSP early warning infrared launch detection satellite system is being improved and will probably be replaced with the Follow-on Early Warning System (FEWS). Surely this will not lack the demonstrated capability of essentially instantaneous warning and tracking of ballistic missiles in boost phase essentially anywhere in the world.

Familiar from all of the SDI discussions are space-based interceptors (SBIs), which might be deployed singly or in "garages," as SDIO proposed early in its career. Garage basing in space saves on housekeeping but is particularly unsuitable for either a light or a heavy threat. Against a heavy threat, such as the former Soviet Union, garage basing of multiple SBIs presented an unacceptable vulnerability to space mines or antisatellite weapons (ASATs); whereas against a small threat, the clustering of defensive interceptors increases their unavailability. Better to deploy them as individual interceptors, "hornets" or "brilliant pebbles."

Space-based interceptors will, on the average, collide with their quarry at a speed well above 8 kps orbital velocity, although if lethality is strongly dependent upon collision speed, one might impose additional constraints on which interceptor should be selected. A 1987 report from Lawrence Livermore National Laboratory derives under simple assumptions the "most effective" reach-out speed for an SBI, by minimizing the mass on orbit for a given number of interceptors able to participate within a given time assumed to be set by the duration of boost phase, for instance. This tacitly assumes that a very large portion of the cost of an SBI is associated with launching its mass (including reach-out propellant) into orbit. With this assumption, the optimum reach-out speed is twice the exhaust velocity of the interceptor's rocket motor, or about 6 kps. The rocket equation then gives an interceptor mass on orbit some ten to twenty times the payload (sensor and maneuvering mass), depending on the dry-weight fraction of the propulsion system. For example, an SBI propulsion system of zero mass for tankage and rocket motor would require a fueled interceptor of 7.4 times the payload mass. To the extent that launch cost does not dominate, the optimum reach-out speed is higher than 6 kps.

Although much is made of "layered defense" to compensate lack of reliability or other deficiencies in an individual layer, for the most part, targeting one layer or another (boost phase, midcourse, or terminal) is likely to be far more effective or cheaper than targeting the others. Under these circumstances, it is normally better to strengthen defenses aimed at that layer, if necessary through "shoot-shoot" by using two or more interceptors against a single target rather than to rely on "shoot-look-shoot" in multiple layers (where "look" really means to look and evaluate, with the requirement for assessment as to whether the incoming weapon was killed or not.)

MIDCOURSE INTERCEPT REQUIREMENTS

While a system designed against all-out Soviet nuclear attack would have to be highly redundant and perhaps autonomous, such is not the case for a system to handle a nonnuclear threat or a few nuclear warheads. Accordingly, midcourse interceptors do not need to scan all of space for their quarry, but could be cued by information derived from DSP or FEWS, thereby greatly reducing their requirement to search for their target. For an illustrative ICBM trajectory, approximately 1,500 seconds of which is midcourse above the atmosphere and in free-fall, something like 20 percent of SBIs with an orbital velocity of 6 kps would have the opportunity to intercept an ICBM with a range of eight thousand kilometers, as contrasted with about 1.2 percent which might be able to attack a missile with a range of eight hundred kilometers, assuming that the entire trajectory is above the atmosphere, which is certainly not the case.

Greatest attention is being given to self-guidance by the interceptor. During the day, the RV would be scattering incident sunlight, but at night one would need to rely on the heat radiated from the RV or on infrared earthshine scattered by the RV. The homing task is far simpler if the sensor has the sky as background, although there is still the task of rejecting the stars and homing in on the RV. A costly maneuver is involved to ensure that the interceptor would look up at a TBM RV that barely leaves the atmosphere, but the problem is not constraining against an ICBM in normal trajectory.

Although it is in principle possible for an SBI to intercept an RV in terminal phase, the time is so short and the additional requirements placed on the SBI are great enough that this is probably not a useful approach. In general, at least two and probably three SBIs will have to conduct intercepts to reduce the probability of survival of an uncountermeasured RV to a sufficiently low value — say, 1 percent under the best of circumstances. Nevertheless, and even considering nuclear-armed ICBMs launched by a Third World country, it is not at all clear that the defense can achieve an effective intercept. The problem arises because these intercepts require actual hits in order to kill, and while it may be beyond the technology of an emerging ICBM power to provide a stealthy RV, it is relatively simple to enclose the RV in an inflated balloon. Even if there are no decoy balloons, a balloon substantially larger than the RV would force the SBI to attack the balloon blindly, thereby probably missing the RV.

The defense also has options: an SBI with a "lethality enhancer" (in the form of an umbrella or a mass-loaded mesh) could be designed specifically to strip away the balloon, even though there would be little probability of destroying the RV. A second SBI could then see the RV without its balloon, although there would presumably remain a large and potentially confusing cloud of debris.

Although it is generally considered that lethality against an RV can be ensured only with many megajoules of impact energy, this may not be the only kill criterion. For instance, ten megajoules of energy is resident in a projectile with a mass of two hundred grams traveling at a relative speed of 10 kps. However, the collision with only fifty grams at the same relative velocity will impart to an RV with a mass of five hundred kilograms a velocity change of ten meters per second, or an acceleration exceeding one hundred times that of gravity, even if the internals of the RV are mounted on damping units and allowed to move five centimeters. Assuming an RV collision cross section of one square meter, a mesh of surface density fifty grams per square meter and with a total mass of five kilograms would correspond to a square approximately ten meters on a side as the effective lethal area of an SBI.

An alternative countermeasure of a considerable number of small MLI balloons spaced as much as one hundred meters from one another might still be destroyed by a very light and very large fabric net carried by the SBI. It may be that the SBI should look back at the collision site to report the results and to aid fine homing of another SBI that might be on the way. Thus, countermeasures in the form of widely spaced MLI balloons may be most effective, since they would need to be attacked individually.

COMPETITION WITH GROUND-BASED INTERCEPTORS

Authorities as diverse as SDIO director Henry F. Cooper, Jr., and G. H. Canavan and J. C. Browne of Los Alamos National Laboratory agree that ground-based interceptors (GBIs) would be effective and even preferable for defense of the United States, if midcourse discrimination can be achieved. Previous discussions have emphasized that the territory of the forty-eight contiguous states could not be defended from a single site of GBIs at Grand Forks, North Dakota (the one site allowed by the ABM Treaty), especially against SLBM launch fairly close to U.S. shores. However, given a willingness to launch interceptors on DSP-derived trajectory information and to conduct the intercept autonomously against an object to be found in the assigned "basket," the job is still far easier than with space-based interceptors. The same approaches to countering large balloons or multiple close balloons could perfectly well be taken with the GBIs, with the advantage of saving the 8 kps (at least a further factor of thirty in launch mass) required to put the SBI into orbit. Furthermore, GBIs can readily be provided with liquid helium or another cryogen just before launch to improve the performance of infrared sensors and with battery power for the duration of the flight, so the entire system must be a lot cheaper than an SBI system, without even beginning to count the absentee ratio for SBIs.

This discussion is not adequate to support adopting an ABM system based on DSP or FEWS and GBIs in the United States for protection of the continental United States. In addition, such a treaty-compliant system does not protect Hawaii or Alaska, although a few interceptors based there or on ships nearby could do that job. Such an approach would, however, require approval by the Commonwealth of Independent States to amend the ABM Treaty. More about these political aspects below. However, this brief discussion demonstrates that weapons based in space are neither necessary nor desirable for protection of the United States against ICBM attack.

It is a general observation that specific solutions to specific problems are usually preferable to a generic solution that does not do anything particularly well or that requires a major investment before it provides any return and that latter is the characteristic of space-based weaponry that would be needed for the more difficult task of MDA-91 — protection of friendly or neutral nations, including cities, against attack by TBMs.

DEFENSE AGAINST THEATER-RANGE BALLISTIC MISSILES

A bit of reflection shows how much the situation has changed. Five years ago, my evaluation of the feasibility for defense against nuclear-armed TBMs in NATO was a firm negative, for the following reasons. Assuming that such defense would be achieved by upgrade of the Patriot interceptor and system, the interceptor already costs at least $500,000; presumably it would not cost less if upgraded. The Soviet Union and Warsaw Pact had vast numbers of conventionally armed TBMs and could have made more for on the order of $10,000 each. Accordingly, if the Warsaw Pact had persevered in wishing to achieve nuclear-armed TBM capability for attack on airfields, it could clearly have overwhelmed such a defense by using full-scale TBMs with HE warheads as decoys, among which would be relatively few nuclear-armed TBMs.

It is not expected that the United States, even alone, would face opponents in the foreseeable future with the productive capacity and military capability of the entire former Warsaw Pact. Nevertheless, the hundreds of missiles available in Iraq could have been vastly increased in number, and one must always reckon with exhaustion of the defense, particularly if a large area must be defended with a large keep-out range. A recent Stanford University study emphasizes that weapons carried by aircraft remain a threat, with much greater payload available and better delivery accuracy than is available with current TBMs. However, the beginning of wisdom is to recognize that even a perfect ABM system would not provide perfect protection (perhaps none at all) if it simply displaces the attack to the use of air-breathing vehicles. Furthermore, the nuclear threat includes smuggled nuclear weapons as well.

In the absence of absolutely guaranteed security, one must deploy limited resources efficiently, and surely the best place to begin against the threat of chemical and nuclear warheads is with political actions, sanctions, and military activity, if need be. The same may also be true against missiles with HE warheads, if the United States decides that it is in its interest to expand the bilateral Intermediate-Range Nuclear Forces (INF) Treaty worldwide, thus banning all ground-based missiles, whether conventionally or nuclear armed, of ranges between 500 and 5,500 kilometers.

Beyond that, the news for space-based anti-TBMs (ATBMs) is not good, as evidenced by the fact that the Al Hussein missile launched by Iraq against Saudi Arabia and Israel (maximum range of some six hundred kilometers) had a burnout altitude lower than sixty kilometers and so is certainly no candidate for boost-phase intercept by brilliant pebbles.

The analysis presented above for increased effectiveness of GBIs relative to SBIs for defense of the United States applies with even greater force for the ATBM problem. With boost-phase intercept from space precluded (although not necessarily precluded from GBIs deployed in or near the launch sites), the greatest ATBM capability would be obtained from midcourse intercept. In most cases this would be available from GBIs launched anywhere in the target area, covering hundreds of kilometers, and in some cases (for example, Libyan launch against Europe) from ships in the Mediterranean. GBIs or sea-based interceptors would provide a much greater density of firepower against TBMs than would SBIs, in addition to being substantially less costly and more capable. They would be launched on cue from DSP or FEWS.

Evidently, intercept of a nuclear-armed weapon by means of a nonnuclear interceptor is easier than intercept of one with an HE or chemical payload for which both effectiveness and immunity to intercept are conferred by breaking up the payload into bomblets dispensed on the ascent phase, as soon as the missile clears an altitude of one hundred kilometers.

To the extent that one expects to need to counter existing TBMs which have unitary warheads and wishes to have a deployable and reasonably effective defense, reliance should be placed on DSP or FEWS detection and immediate communication to the U.S. field commander. Intercept should be made near apogee from remote-fired GBIs or sea-launched interceptors based in the target countries or nearby. If additional sensing capability is desired beyond that which can conveniently be carried on the interceptor (as if it were a ground-based brilliant pebble), a short-lived optical probe could be launched from a similar area.

COOPERATIVE SECURITY

Since the security of the United States and the world depends heavily on the continued operation of observation satellites in low Earth orbit and since other costly satellite capabilities contribute also to national and international security, it would be a clear net gain to the world and to U.S. security to enact a strict ban on the use or test of ASATs, whether based on land, at sea, in the air, or in space. In February 1992, Edward Sheafer, the director of naval intelligence, testified that the U.S. Navy was no longer demanding an ASAT capability: "The degradation of [Soviet] military space and intelligence program [means that no country] will have the capability to monitor U.S. Navy movements at sea." Of course, any ABM capability will provide an effective ASAT system against satellites in low Earth orbit, but satellites may be protected by universal treaty with considerable effectiveness.

If progress is made toward an open skies regime, the disparity between nations with expensive and capable satellite observation systems and those without them will diminish, as nations or groups of nations can receive what they are willing to pay for, if not by satellite observation then from aircraft overflight. An international open skies agreement is one example of a tool for cooperative security, but there are many others, even easier and less controversial.

Reduction of the alert status of bombers and of some missiles was ordered by President Bush on 27 September 1991 and reciprocated by then-President Gorbachev; heaping twenty meters of earth on some silo covers would be visible assurance that those weapons could not be launched promptly.

The constellation of intermediate-altitude Soviet early warning satellites has, at times, had gaps preventing the reliable detection by that means of all U.S. ICBM launches; this deficiency could be remedied by placing on the silo covers of U.S. ICBMs small specialized radio units which would transmit an unspoofable code so long as they were not displaced by removal of the silo cover. While these could clearly not be counted on to reveal actual ICBM launch, so long as the signals were being received, they would give high confidence that ICBMs have not been launched.

Another example is the benefit to the United States and to the Commonwealth of Independent States (which has inherited the obligation under the INF Treaty) of a possible extension to all nations of the world of the total ban on land-based missiles of short and intermediate range to which the United States and the Soviet Union obligated themselves in bringing into force the INF Treaty. This treaty bans the possession, worldwide, by the United States or the Soviet Union (and now by any of the successor republics) of ground-launched missiles of ranges between 500 to 5,500 kilometers, whether cruise or ballistic and whether nuclear or conventionally armed. Obviously, U.S. and Commonwealth security would be enhanced if this treaty were extended universally.

A ban on weapons in space and on anti-satellite testing would serve to protect satellites important to our security, against weapons that are easier to make in many cases than nuclear weapons, and which are, at present, barred to no country, even to those which have committed themselves never to make nuclear weapons.

This is only a sampling of cooperative security measures which can have great benefit to international security. It may be that real brilliance lies not in the weapons, but in the balance between weapons and other tools for achieving U.S. security.

SUMMARY

Opportunities abound to protect specific targets against specific types of missile attack, for instance, to protect ICBM silos against attack by nuclear-armed ICBMs. But only pre-boost-phase intercept (that is, destruction of the missile before launch) or intercept from near the launch site itself shows promise of denying theater-range terror attack with chemical or HE bomblets. The current infrared early warning satellites in geosynchronous orbit provide a good basis on which to build a useful theater-range or strategic missile defense system, but SBIs seem clearly inferior in capability and presence to GBIs either in the target nation or under the missile trajectory. The problem of discrimination against decoys and antisimulation efforts in midcourse is serious, but GBIs in any case dominate SBIs. "Cooperative security" offers hardheaded benefits; tools to this end include silo-top monitors providing assurance of nonlaunch of ICBMs and possible extension of the U.S.-Soviet INF Treaty to the status of a universal international treaty.