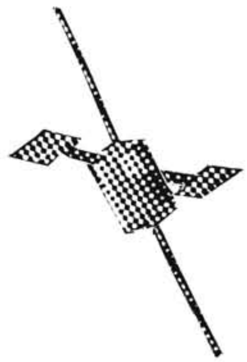

Space Weapons

History and current debate

Richard Garwin and John Pike

Effect on strategic stability

Yevgeny P. Velikov

*President Reagan's proposal to create a comprehensive space-based anti-missile defense system has been vigorously challenged by scientists on technical as well as strategic, political and even moral grounds. Richard L. Garwin has been prominent among the challengers. In February 1983 he and Carl Sagan authored a petition urging the United States, the Soviet Union and "other space-faring nations" to agree to ban weapons of any kind from space and in particular "to prohibit damage to or destruction of satellites of any nation"—a petition signed by dozens of other leading U.S. scientists (*Bulletin, *November 1983).*

In the following article Garwin and John Pike provide a comprehensive argument against the Reagan proposal, concluding with an urgent call for negotiations. Their article is followed by one from Academician Yevgeny P. Velikhov of the Soviet Union. While agreeing in essence with the Garwin-Pike analysis, Velikhov also calls for a diversion of funds from weapons research into such joint U.S.-Soviet projects as space exploration.

Several prominent scientific organizations share the Bulletin*'s concern with the militarization of space and either have published or are preparing studies of the military uses of space. A joint project of the Brookings Institution and the Massachusetts Institute of Technology has recently resulted in a book,* Ballistic Missile Defense. *In late March the Union of Concerned Scientists released the 106-page report of a study panel,* Space-Based Missile Defense. *The Federation of American Scientists has now made available a book-length study,* Anti-Satellite Weapons: Prospects and Implications. *The American Physical Society has established a task force to study and evaluate directed energy weapons. And finally, the American Academy of Arts and Sciences has begun a study of weapons in space, which is to be ready for publication by the end of this year. The* Bulletin *will continue to report on problems and developments in this area.*

History and current debate

by Richard L. Garwin and John Pike

THE QUESTION of space weaponry has become more urgent and much more widely discussed since one of the authors last wrote about the subject in these pages.[1] Two types of concerns are evident—those connected with anti-satellite capabilities and activities (ASAT) and those connected with global defense against ballistic missiles. This article will survey these two topics and their important, but limited interaction. Our conclusion, based upon many years of involvement with strategic offensive weapons, strategic defenses and military space systems, is that an effective ban on anti-satellite activities and capabilities and on weapons in space would best serve the national security interests of the United States. Furthermore, an effective ban is feasible and can be negotiated quickly.

Overview: history and present status

For the past 25 years, space weapons have remained largely in the realm of speculation. With President Reagan's Star Wars speech of March 23, 1983, their discussion assumed a certain immediacy, but underlying developments are equally to blame. Space weapons include systems that either are based in space or are intended for use against targets in space, such as satellites. In the past, the poor performance of such systems made it rather difficult to identify useful military missions for them. Now present and prospective improvements in sensor and computer technology, as well as in kill-mechanisms such as directed energy systems, have encouraged a reexamination of the case for space weapons.

The technology of space weapons might have changed, but the strategic and political questions concerning them have not. It is important to ask whether any missions for space weapons would result in a net improvement in U.S. national security or in the prospects for peace.

During the 1960s both the United States and the Soviet Union developed anti-satellite systems with marginal capabilities. Because of their limitations, and because of the newfound value of satellites themselves, these systems generally did not attract much interest.

The two early U.S. ASAT systems suffered from several common defects. Deployed in very small numbers, they were capable of rather modest rates of fire, and their limited range meant that they had to wait for an intended target to pass within a few hundred miles of their base before an interception could be attempted. The use of high-yield nuclear warheads furthermore posed the risk of considerable collateral damage to friendly satellites. Neither of their potential missions—defense against Soviet orbital nuclear weapons and deterrence or defeat of Soviet attacks on U.S. reconnaissance satellites—seemed particularly compelling by the early 1970s.

Although the early history of Soviet ASAT efforts remains clouded by official secrecy, their capabilities seem no more than slightly behind those of the United States. A clear indication of Soviet work in this area came in 1968, with the initial test of an orbital ASAT, colloquially known as a "killer satellite," reminiscent of the abandoned U.S. SAINT

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(Satellite Inspection Technique) program. The Soviet ASAT is launched by a modified version of the SS-9 ICBM. The intercept vehicle itself has a mass of 2,300–3,300 kilograms, and 1,000 kilograms of maneuvering fuel would give it a maneuvering velocity change of as much as one kilometer per second. The system has been tested 20 times, using a variety of trajectories that take from 45 minutes to several hours from launch to intercept, reported at a maximum altitude of 2,300 kilometers. Initial tracking of the target is reported to use ground-based radars. An on-board active radar guidance system achieved 10 successes in 14 attempts. Beginning in 1976, a more sophisticated passive system, perhaps using an optical sensor, has been tested six times with no more than one success. Several types of payloads might have been carried on the interceptor.

In 1979, Air Force Chief of Staff Lew Allen characterized the Soviet ASAT as "having a very questionable operational capability." The variety of anti-satellite components and techniques, as well as the fitful and irregular pace of the tests, suggest that the program is as much an effort to develop a generic military technology as it is to deploy a weapon to counter a specific set of targets. The limited maneuvering capabilities require that it be placed into an orbit that is generally similar in inclination to that of its intended target. Thus the interceptor cannot be launched until the orbital ground track of its target passes to within a few hundred kilometers of the launch facility. This requirement may not be satisfied for several hours, even as long as a day, after a decision has been made to conduct an intercept. The small number of launch pads available for ASAT launches imposes a further operational limitation.

The present Soviet ASAT potentially threatens low-flying U.S. space assets, including photographic reconnaissance satellites and the Transit navigation satellites. However, most important U.S. satellites, such as those used for early warning and communications, are in geosynchronous orbit (GEO) at 36,000 kilometers above the Earth—far beyond the demonstrated range of the Soviet ASAT. The threat to satellites in lower orbits will decline in coming years, as various survivability programs for them are implemented, such as the transfer of the navigation support mission to the Navstar satellites, which orbit at an altitude of 20,000 kilometers.

DURING the 1970s both countries greatly increased their reliance on space to support conventional and strategic forces on Earth. In the absence of restraint these numerous military support satellites could be an incentive to develop new and more capable ASATs in order to reduce enemy military effectiveness, with serious negative implications for both crisis and arms-race stability.

The Soviet resumption of ASAT testing in February 1976, after a pause of over five years, was the proximate impetus for the development of the new U.S. ASAT, initiated in the closing days of the Ford Administration. Major ASAT funding increases had been proposed prior to the resumption of Soviet testing, and the Carter Administration subsequently concurred in this decision as part of a multi-pronged effort that included programs to enhance the survivability of military satellites and negotiations with the Soviet Union to limit ASATs.

The ASAT configuration chosen for development is the Air-launched Miniature Homing Vehicle (ALMV), delivered by a small two-stage rocket to be carried on an F-15 fighter aircraft. The SRAM (Short-Range Attack Missile) first stage and the ALTAIR-III second stage would be launched from the F-15 guided by a programmed inertial guidance system, to intercept a satellite whose orbital parameters had been determined by ground-based sensors. Weighing about 1,200 kilograms, the F-15 launched rocket would boost a Miniature Homing Vehicle (MHV) which would maneuver to intersect the target satellite's orbit, destroying the target on impact.

The maximum altitude at which the ALMV can attack satellites may be in the range of 2,000 kilometers. Whatever the "reach," or cross-range capability, of the ASAT, the F-15 can carry it to launch points several thousand kilometers from the home air base. With the use of mid-air refueling and basing at forward facilities such as Diego Garcia or Ascension Island, the ALMV could be used to attack low-altitude satellites at almost any point in their orbit. This system will be capable of attacking a wide range of Soviet military satellites, including all their photographic and electronic intelligence satellites, the Radar Ocean Reconnaissance Satellites (RORSATs), and the *Salyut* space station. Communication and early warning satellites in highly elliptical 12-hour *Molniya* (lightning) orbits can be attacked at the low points in their orbits, which are over the Antarctic Ocean. This would require forward basing of the F-15 at Diego Garcia, Ascension Island or North West Cape, Australia, as well as aerial refueling.

The first flight test of the ALMV booster was on January 21, 1984. The first test of the system against a target in space will come at the end of 1984, and at least ten additional such tests are planned before the system becomes operational in 1987. Over 100 interceptor rockets are scheduled for procurement at a total cost of $3.6 billion, although this cost is expected to increase. About 50 F-15s will be modified to carry the ASAT, permitting the entire arsenal of interceptors to be fired within a few hours.

To the extent that the United States or the Soviet Union depends or is believed to depend on satellites for strategic deterrent capability, acquisition by either country of an ability to destroy the opponent's early-warning, communication and navigation satellites could provide an incentive to initiate an anti-satellite campaign that would greatly degrade the capabilities of the opponent's military forces. Should *both* countries achieve such a capability, each would have considerable incentive to initiate preemptively such a

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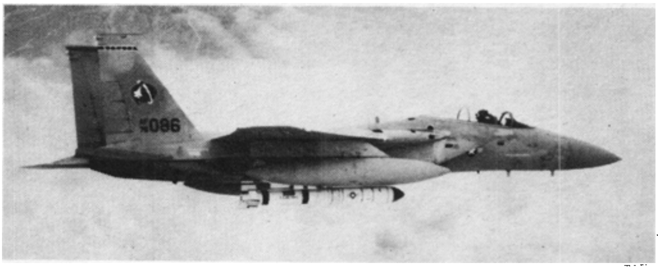
courtesy Department of Defense


An F-15 plane equipped with anti-satellite weapons (ASAT), currently being tested by the U.S. military.

campaign during a time of acute crisis. Both instances would decrease crisis stability and increase the threat of war. If a strategic defense, especially a perfect or disarming one, depends on satellites, those satellites are at particular risk. The possibility that accidental malfunctions of vulnerable satellites could exacerbate an on-going crisis also cannot be ignored.

Today we are confronted by the third generation of anti-satellite weapons. The early U.S. ASATs, flying short ballistic trajectories to deliver nuclear warheads, were soon followed by the more advanced Soviet ASAT, which orbits a conventional explosive charge that maneuvers to within range of its target. Now the United States has begun testing an even more advanced air-launched system. In the absence of mutual restraint, it can only be a matter of time before both countries field even more capable systems, thus placing arms race stability at risk.

More advanced ASATs may pose increasingly serious challenges to the 1972 ABM Treaty. U.S. (and presumably Soviet) ASATs have incorporated technologies derived from ballistic missile defense systems. In the future, systems that were nominally for anti-satellite purposes could be used to approach ballistic missile defense capabilities that are otherwise prohibited by the ABM Treaty. The more capable ASATs of one side might create such suspicions on the other, raising the specter of a gradual erosion of the Treaty regime under the guise of an ASAT competition.

President Reagan's Star Wars speech, however, has posed a more immediate challenge to the ABM Treaty. Although the Administration has proposed no immediate abandonment of the Treaty, a number of likely development and test programs may raise questions of compliance with the letter of the Treaty. More important, if the doctrinal implications of the President's initiative gain general acceptance in the United States, the demise of the Treaty will soon follow. Under these circumstances, the Soviet Union can hardly be expected to sit back and wait for the United States to choose a convenient time to announce its renunciation.

The strategic and political rationale of the ABM Treaty was developed in an era of technology that both superpowers have now surpassed. But technological innovation does not invalidate that rationale, nor lessen the Treaty's importance. No ABM system in prospect could provide a perfect defense against attack. Such systems are subject to passive and active countermeasures, including direct attack on the defensive system itself, and a ballistic missile defense system which seems promising against the existing strategic offensive force may be defeated at little cost. A ballistic missile defense system would be much more effective in defending against a small and disorganized retaliation than it would in defeating a massive and well-organized first strike. This disparity would provide incentive for preemption (by either side) that would undermine crisis stability.

Arms-race stability would also suffer, as the most straightforward countermeasures would be a simple proliferation of offensive arms. Since each country would tend to overestimate the effectiveness of the opponent's defensive system, while underestimating the effectiveness of its own defenses, conservative planning would generate ever higher requirements for offensive forces. There is no rational upper limit to this competition, save perhaps the carrying capacity of the country's economy.

These systems would require funding on an unprecedented scale. Various estimates place the cost of two layers of ground-based ABM systems at $200 billion, and the cost of the space-based component at perhaps $500 billion. To these costs should be added those of continental air defense and civil defense, which would push the cost of the total strategic defense package to over $1 trillion.

These estimates, however, do not fully capture the magnitude of the problem, since such defensive systems will have to be maintained, modified and upgraded in response to the changing and inexorably expanding offensive threat. What is really under discussion is the addition of perhaps $100 billion annually to the defense budget, perhaps as soon as the mid-1990s. Given the negative impact on crisis and arms-race stability of strategic defensive systems, it is difficult to see the justification for expenditures of this magnitude.

Prospects

In most important respects the new U.S. ASAT constitutes an order of magnitude improvement over the existing Soviet ASAT. The flight time from launch to intercept is one-tenth as long. The total number of interceptors will be ten times greater. The Soviet ASAT booster is ten times the size, and 100 times the mass of the U.S. ASAT booster, and the disparity between the sizes of the actual intercept vehicles is even greater.

It is clear, however, that the new U.S. ASAT is not the last word in weapons of this sort. In the absence of negotiated restraint, both the United States and the Soviet Union are likely to develop even more capable anti-satellite weapons, which will share two disturbing characteristics: the ability to attack satellites in high orbits and an increasing resemblance to anti-ballistic missile systems. Both are good reasons for precluding the development of such weapons.

The United States has already studied several advanced ASATs that would use the Miniature Homing Vehicle and more capable boosters. A larger air-launched booster rocket could extend the range of the F-15 system so that it could attack satellites at an altitude of several thousand kilometers. Above this range, the advantage of using air-launching to match the orbital ground track of the target diminishes. Satellites at higher altitudes could be attacked by launching the MHV atop a larger rocket, such as the Minuteman or the Trident. These systems could be developed in a few years time, at a cost of several billion dollars.

A transfer from low Earth orbit (LEO) to inject into GEO with minimum additional energy requires a velocity increase of 3.6 kilometers per second— about a factor three increase in launch weight (or a factor three reduction in available payload). This does not include the plane change required if one insists on *co-orbital* trajectory; that amounts to almost another factor two if one starts with an orbital inclination of 60 degrees corresponding to Soviet launch latitudes. The flight time from launch to interception of satellites at semi-synchronous or geosynchronous orbits would be several hours, permitting evasive maneuvering by the target. Such long flight times would also result in loss of surprise, which is important for attacks on targets such as early-warning satellites.

Thus the use of directed energy weapons has attracted some attention. These weapons could be either ground-based or space-based. Published reports suggest that the United States could test a ground-based laser against targets in geosynchronous orbit by the end of this decade. Tests of a space-based laser of somewhat lesser range could begin by 1992. However, this space laser would pose serious questions concerning compliance with the 1972 ABM Treaty, and thus no decision has been made to conduct such a test.

The Soviet Union could also introduce a variety of improved ASATs. With continued testing, they will eventually perfect the thus far unsuccessful passive optical guidance for their present ASAT. Because the general trend in the Soviet ASAT program has been toward reducing the flight time from launch to interception, we might expect to see the introduction of a non-orbital "pop-up" ASAT, which would intercept its target within a few minutes after launch. The present Soviet system could be used in this mode if it were provided with a guidance system capable not only of bringing it to a specified point in space, but also at a specified time. Large ground-based radar could be used to overcome target countermeasures such as maneuvering, jamming or decoys. These radars could also be used in support of an air-launched system similar to the new U.S. ASAT, which could use planes such as the Foxbat fighter or the Blackjack bomber as launch platforms. Such systems would pose serious problems for verification of a treaty that included a ban on deployment.

For several years Defense Department officials have reported that the Soviet Union might soon launch a large laser into orbit. Given the pace and schedule of the U.S. space laser program, the state of Soviet work in this field and the Soviet tendency to move to field testing of prototypes at an earlier stage than is the case in U.S. programs, this prediction is not unreasonable. It tends to create the impression that a Soviet space laser would convey a military benefit, which is not the case. Nevertheless, testing of a space-based weapon would be regarded as development of a space-based ABM system, specifically banned by the ABM Treaty.

IN HIS MARCH 23, 1983 speech, President Reagan asked "the scientific community in our country . . . to turn their great talents now to the cause of mankind and world peace: to give us the means of rendering these nuclear weapons impotent and obsolete. . . . I am directing a comprehensive and intensive effort to define a long-term research and development program to begin to achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles." And on March 27, 1983, Secretary of Defense Caspar Weinberger said on the "Meet the Press" television program, "The defensive systems the President is talking about are not designed to be partial. What we want to try to get is a system which will develop a defense that is thoroughly reliable and total, yes. And I don't see any reason why that can't be done."

The President and the secretary are clearly talking about "assured survival," as an alternative to deterrence of nuclear war by threat of retaliation. But to eliminate the fear of nuclear weapons, even of delivery of nuclear weapons by ICBMs, in the presence of the almost 10,000 strategic reentry vehicles on either side, is more than we believe the United States or the Soviet Union can accomplish. ICBMs take about 30 minutes to fall to their targets, as do submarine-launched ballistic missiles (SLBMs) of intercontinental range. Shorter-range SLBMs and the notorious intermediate-range nuclear forces (INF) may take ten minutes. Thus to be useful against ballistic missiles a system must do its job within 30 minutes or not at all. A space-based defense which would prevent 50 percent of the reentry vehicles from landing would be doing a pretty good job; one which prevented 90 percent would be an active defense beyond experience. Yet achieving even such defenses would simply result in the elimination of some of the marginally useful targets for nuclear weapons and would focus the remainder (for

Figure 1. Destructive mechanisms

Mechanism	*Device*	*Operation*
Pulsed laser	X-ray laser Excimer laser	Deliver a high impulse or shock to a missile to break or blow a hole in it and cause structural collapse of the booster
Continuous wave laser	Free electron laser Excimer laser Hydrogen fluoride/ deuterium fluoride laser	Stay on target until a hole is burned through it, then switch to another target
Continuous particle beam	Neutral particle beam	Destroy internal weapon components
Mass accelerator	Kinetic energy rail gun	Accelerate small homing hit-to-kill vehicles (non-nuclear kill)
Self-propelled missile	Miniature homing vehicle	Infrared sensor senses spot of radiation from incoming re-entry vehicle. Homes in and destroys with hit-to-kill vehicle

Source: Department of Defense, as cited by Richard D. DeLauer, undersecretary of defense for research and engineering, in his testimony before the House Armed Services Committee, Nov. 10, 1983.

deterrence or for "compellence") on the society's centers of value—industry and population.

Recognizing the difficulty or impossibility of having any system which will provide 99.99 percent protection (to reduce the expected number of warheads striking their targets to less than one), advocates of such programs rely on arithmetic, asserting that a defense of four totally independent layers, each of which allows only 10 percent of the incoming weapons to leak through, will allow an average of only one in 10,000 weapons through all four layers. This assumes that there are no common-mode failures (that is, if a reentry vehicle leaks through one layer, it will automatically leak through another) in which case the number leaking through increases by a factor 10, 100 or 1,000. Furthermore, the *assumption* of four layers, each with 10 percent leakage, does not guarantee the existence of even *one* such layer. Finally, if four independent defenses can be found which are compatible with layering, all four must be paid for, maintained, and not allowed to interfere with one another.

For 20 years the fact that one can "hit a bullet with a bullet" has not solved the ballistic missile defense problem. That solution requires not only the application of science and technology but also the assurance that the scientists, technologists and investors of the other side will not be able to *counter* the defenses. The fact that one nuclear warhead can kill a million people and do at least $100 billion worth of property damage makes it very important to prevent access by even one reentry vehicle. Obviously it is essential to know whether such a perfect defense is possible. A nation possessing such a defense need not be deterred from destroying its adversary, since it could protect totally against retaliation in case it launched a nuclear attack. Of course, not only the feasibility but also the *counterability* of such a defense is important, and neither side need promise to lie down and play dead if the other side develops and deploys a defense which promises to be effective against the "unadapted" force.

We went through this in the 1960s, when U.S. perceptions of the emergence of a ballistic missile defense by the Soviet Union led Secretary of Defense Robert McNamara to authorize the development of MIRVed Minuteman missiles, thereby countering the nascent Soviet ballistic missile defense and increasing greatly the flexibility of the U.S. strategic offensive force and the threat to the Soviet Union.

What is new? Not the desire to feel free from the threat of destruction! That is as old as human beings, and many have availed themselves of that desire by retreating to a world of unreality. New are the existence of high-speed flexible computation in small packages; optical lasers for viewing and for concentrating potentially damaging radiation at a distance; complex focal-plane arrays for viewing large areas with reasonable resolution; and the prospect of the soft X-ray laser pumped by a nuclear explosion which can hope to focus one one-thousandth or one ten-thousandth of the energy of a nuclear weapon into one-millionth or one-billionth of the sphere, corresponding to an increase of X-ray intensity over that provided by the same nuclear explosion by a factor 100 or 1,000 (or 100,000 or one million).

Furthermore, a ten-fold larger nuclear weapon exploded at 1 percent of the distance would correspond to a 100,000-fold increase in intensity over the reference weapon, so that there is a tradeoff (assuming operationally and technically feasible X-ray lasers) between their use and the pre-deployment of X-ray defenses. In fact, the X rays from a nuclear explosion may be much more effective than those from an X-ray laser, for the same energy delivered to the target.

ANY SUCCESSFUL manager or leader strives to eliminate potentially unsuccessful candidates as quickly as possible, and if defensive systems can be shown to be vulnerable, that is as good a way to eliminate them as showing them to be technically infeasible. Because defensive systems are far more complicated than offensive systems, the offense has time to adapt to a defense of potentially great effectiveness.

Thus the United States has long done major research and field testing on penetration aids against terminal and midcourse ballistic missile defense. It may not carry those "pen-aids" on its ICBMs and SLBMs since it is confident that no such defenses exist. Nevertheless, if the Soviet Union initiated a multi-year deployment of ballistic missile defenses the United States certainly would have pen-aids ready in time. At the cost of a small fraction of the warheads now carried on the strategic offensive force, the remaining warheads would have a high probability of penetration to their targets. An estimate of the penetration probability of the *unadapted* force might yield a totally different result, but it would not be relevant.[2]

Midcourse intercept of reentry vehicles continues to be frustrated by the feasibility of balloon decoys to fool radar and infrared and optical sensors.

The boost phase of an adapted offensive force lasts a short time (40–100 seconds), and defensive systems stationary with respect to the likely launch areas are either based on the Earth, in its atmosphere or in GEO (in any case 10,000 or 40,000 kilometers from the launch). It is thus not possible to attack with rocket-propelled defenses, unless the rockets can be fired *before* ICBM or SLBM launch, in confidence that the offensive weapons will be launched only to be destroyed! Considering systems based in orbit, cross-track capability out to 250 kilometers could be obtained from vast numbers of small interceptors which burn 90 percent of their initial mass as rocket fuel, but some 3,000 would be required in orbit to have one close enough to destroy a single ICBM. If no more than 100 silos are located within a circle 500 kilometers in diameter, 300,000 of these orbital rockets would be required even if they were 100 percent effective and reliable. (Of course, a mere 3,000 "space trucks" each carrying 100 interceptors could do the job, but they would be vulnerable to space mines.)

As for beam weapons, a simple calculation shows that a fluence (energy per unit area) exceeding ten kilojoules per square centimeter is required to damage a rocket booster which has been modified to survive against optical or X-ray lasers. For optical lasers, we have the usual tension between basing in synchronous orbit (at some 40,000 kilometers from their targets and viewing the ICBM or SLBM launch sites all the time), and basing them in LEO, where they could use effective ranges as short as 1,000 kilometers. But in LEO they would have to reckon with the facts that the Earth's surface area is 500 million square kilometers and that the area coverable by a weapon at 1,000 kilometers is only 3 million square kilometers. If the effective range of a laser were to be taken as 1,000 kilometers instead of 40,000 kilometers, its power need be only one sixteen-hundredth as great (or its mirror diameter one-fortieth as large), but it would have to slew over a much wider angle to catch all the boosters within its purview, and 170 lasers in LEO would put only one within range of a particular launch. Furthermore, any laser would have to be able to destroy as many as several hundred boosters during the couple of minutes of boost phase.

Assuming the existence of one-megawatt lasers in the midwavelength range (perhaps three microns) and a boost phase for an adapted strategic offensive missile of 120 seconds, a laser could destroy *one* ICBM if it illuminated it for 100 seconds at a power of 100 watts per square centimeter to meet the assumed kill criterion of 10 kilojoules per square centimeter. At this wavelength, however, a mirror three meters in diameter would provide a spot 100 meters in diameter and the intensity from a 100-megawatt laser would be only *one* watt per square centimeter instead of the required 100. Therefore to destroy even a single ICBM in boost phase from GEO would require an optically perfect mirror 30 meters in diameter and a laser of 100 megawatts. One can *assume* that the problem of mirror accuracy can be solved by segmenting the mirror and controlling it adaptively, and that the problem of increasing laser power will yield to development. Nevertheless, these are only assumptions, and the problems of transporting the laser and its fuel to GEO and paying for it will remain. At a laser yield of about 500 joules per gram of fuel, the fuel for a single such intercept (using 100 megawatts of light for 100 seconds) weighs 20 tons and would take some 3 shuttle launches at $90 million each, to place the fuel for a single intercept into GEO ($300 million).

If one could have a laser of 0.3 micron wavelength (ultraviolet) instead of 3 micron and a mirror 30 meters in diameter with adequate reflectivity at this wavelength, and with the required ten times better perfection of its figure, the fuel requirement would fall by a factor 100. Nevertheless, such vastly expensive systems on satellites are easily countered by space mines or other ASAT means. No less a defense proponent than Edward Teller has testified and indicated in many interviews that no defensive system can depend upon satellites because they are "costly to put up and cheap to shoot down."

Furthermore, the vulnerability of the booster itself can be greatly reduced by various means: by rotating it, thereby spreading the heat over a larger region; by concealing it in smoke; by interposing reflecting foils so as to hide the booster itself; by deceiving the laser as to its position; and even by launching dummy boosters without warheads or silos, to provoke the defense to attack substantially more "ICBMs" than really exist, thus driving up the cost of defense. The ultimate problem for satellite-based lasers, or any orbital defensive system, is vulnerability to space mines —small satellites based in orbit in peacetime, remaining always in lethal range of their quarry satellites and ready to explode on command.

Some (notably George Keyworth, Jr., the President's science advisor) have advocated reducing the cost of such a system by placing the lasers and their fuel supply on the ground, directing the beam upward through the atmosphere by adaptive optics to compensate not only for imperfections of the mirror but also for the turbulent optical properties of the atmosphere. Such a ground-based laser would illuminate a relay mirror in orbit, which would then send the beam to other "fighting mirrors" which would direct the beam first at one booster and then at another. These mirrors also would be of very substantial size and cost and also vulnerable to space mines. As an additional element of vulnerability, the ground-based lasers could be put out of action by cloud, dust or sabotage.

> "The President's defensive technologies initiative is a spectacularly ambitious one. Quite simply, it will require a scientific, technical, military, and organizational undertaking that will dwarf anything ever before mounted by the human race. . . .
>
> I believe that mutual assured destruction is a morally bankrupt philosophy that places Government in the untenable position of refusing to defend its citizenry. What the President has proposed is no less than a moral recovery in American strategic policy which would take us from the horror of MAD to the promise of mutual assured protection. It is a goal which deserves the fervent support of all who yearn for a world safe from nuclear weapons. Unless we are willing to accept the prospect of a nuclear Pearl Harbor from space, we must now join the President in a new national commitment to mutual assured protection."
>
> —*Ken Kramer (R-Colorado)*
>
> Statement before the Subcommittee on Research and Development, House Armed Services Committee, Nov. 10, 1983, advocating the People's Protection Act. The Act was co-sponsored by Representatives Montgomery (D-Mississippi), Whitehurst (R-Virginia), Badham (R-California), Skelton (D-Missouri), Corcoran (R-Illinois), Davis (R-Michigan), Daniel Crane (R-Illinois), Hunter (R-California), Dyson (D-Missouri), Hartnett (R-South Carolina) and Skeen (R-New Mexico).

The other type of damaging energy that can be projected at nearly the speed of light consists of particles given their energy by particle accelerators in space. Although charged particles can be accelerated with efficiencies above 50 percent, they are bent by the Earth's magnetic field. Conversion of the charged particles to neutral particles can also be done with reasonable efficiency, but the quality of the beam is spoiled, and the angular spread introduced dilutes the fluence at the target. The negative hydrogen atom, however, is unique among charged particles and would present a considerably smaller angular spread. The problems of developing and deploying a particle-beam defense even against a non-reactive adversary are enormous, but the system is ultimately vulnerable to space mines or to other ASAT weapons.

NEW SINCE Garwin's article in the May 1981 *Bulletin* is the X-ray laser driven by a nuclear explosive.[3] This "recombination-pumped" laser produces a low-density plasma by absorbing the energy from a nuclear explosion in space, at some 100 centimeters from a set of metal wires pointing at a distant target. Almost all the energy from the fission or fusion process in a space explosion resides initially in the thermal energy of the bomb materials or in the radiation energy of its volume; this energy can be radiated as thermal X rays before the materials of the weapon can expand far enough to acquire a substantial fraction of the bomb energy as kinetic energy. The relatively "hard" X-ray photons from the bomb are to be absorbed in copper or zinc, expanding the wires which continue to absorb photons and lose electrons, which then recombine selectively to populate the upper levels of the ions. Since no mirrors are available at these X-ray wavelengths and fluences, the angular aperture of the X-ray beam is at least as big as the angular aperture of one of the lasing rods—roughly the ratio of width to length—which in the example is about 1,000 microradians.

There are many problems in making a laser and many further problems in making an effective weapon from that laser. One might hope to achieve a transformation of 0.1 percent of the bomb energy into directed X rays, and if one uses the one milliradian angular aperture, this corresponds to a fluence from GEO of 0.1 percent of the bomb energy (which might be 20 kilotons) over a diameter on the order of 40 kilometers, or 0.01 joules per square centimeter which would not damage missiles or even satellites. The mechanism of damage by a short pulse of soft X rays consists of the blowoff of the thin surface layer absorbing the X rays, creating a shockwave going through the skin of the missile and an impulse communicated to the skin.[4] Because the laser X rays in the example are so soft, they are absorbed in a very thin layer of the order of 0.1 milligram per square centimeter and the resulting impulse is substantially less than that communicated by a similar fluence of hard X rays.

The particle beams and soft X-ray lasers can be negated by the same hardened, fast-burn boosters which cause so much trouble for a chemical laser system. Burning out below 80 kilometers, the booster is shielded by sufficient air to absorb the X-ray laser beam kilometers from the booster and to strip any hydrogen atom beam, allowing the resulting protons to be swept off target by the Earth's magnetic field.

Options

The preceding technical sketch suggests the vast range of choices available for attack on fragile satellites and the much greater difficulty associated with a defense which would "render nuclear weapons impotent." But as ASAT weapons, lasers and particle beams seem to offer only increased delay and higher cost, in comparison with space mines for which present technology would suffice.

The 1972 ABM Treaty already bans the development or testing (and even more the deployment) of ABM systems that are mobile, space-based or air-based, and President Reagan has stated that the United States would explore defensive possibilities within the constraints of that Treaty. Furthermore, many of the capabilities conferred by the adversary's satellites can be negated by means other than ASAT weapons—jamming, attack on ground stations, concealment and the like. Calamitous effects of attack on one's own satellites can be avoided by prudent planning, replacement capabilities, backup systems, and so forth.

Can one prove with certainty that space weapons will lead to disaster rather than to improved security or that global defense against ballistic missiles is *impossible*? If not, how do we dare deny ourselves these options? Are we joining the ranks of those who denied the possibility of airplane flight or of an ICBM bearing a nuclear warhead?

Over the years we have considered three possibilities concerning space weapons:

- no additional arms control measures in space;
- banning all military activities in space; and
- banning weapons in space.

In our opinion, the combination of a program for nullifying nuclear weapons by space means and the necessity for satellite components of any such system is a most severe threat to U.S. national security. That combination can convert the present world (with the universally acknowledged ability to destroy the Soviet Union, the United States, their allies and perhaps much of human life in the Northern Hemisphere) from a stable confrontation to an inherently unstable one, needing only the smallest spark to bring on a nuclear conflagration. This instability can arise from appearances—it does not need real capability. Pointing a toy handgun at a police officer is as good a way to be shot by the officer's partner as pointing a real gun. A supposedly effective ABM system depending on space elements could be countered by space mines within lethal range of the satellites. An attempt to prevent such vulnerability could be enforced in the early stages of deployment only by the destruction of the other side's missiles while it was launching space mines.

Banning all *military* activity from space seems neither necessary or desirable, since "military" applies to communication, navigation, administration, supply and other normal functions when performed for military personnel. The matter has also been discussed in the U.N. Committee on Disarmament, and even to that body a total ban on military activities seems neither practical nor desirable. Uninhibited ASAT development, in a protracted drive for space-supported defense (ICBM-killers), appears likely to lead to instability and attack even in peacetime.

During the U.S.-Soviet ASAT negotiations of 1978–1979, many options were considered, including the possession by each side of a single type of ASAT system, the provision of sanctuary to satellites above a certain altitude, a total ban on damage to or destruction of satellites and the like. The negotiations were not resumed after the Soviet invasion of Afghanistan, but in 1981 the Soviet Union introduced into the United Nations a draft "treaty on the prohibition of the stationing of weapons of any kind in outer space." Unfortunately, that treaty appeared to convey protection only to those "space objects . . . placed in orbit in strict accordance with . . . this treaty" and to sanction the use of force against other satellites. Furthermore, the 1981 Soviet draft covered only space-based systems, thus permitting current Soviet and U.S. ASATs.

In September 1982, at a Senate Foreign Relations Committee hearing on the militarization of space, Richard Garwin testified that the 1981 Soviet draft should not be ignored and that if the U.S. government did not reply with a draft which would serve U.S. purposes, then even a private group might forward the cause of U.S. security by doing so. In May 1983 Admiral Noel Gayler, Kurt Gottfried and Garwin testified to the same committee in support of "A Treaty Limiting Antisatellite Weapons," which we had helped prepare, with the support of the Union of Concerned Scientists (see page 10S). The Soviet Union followed in August by introducing into the United Nations a new draft treaty "On the Prohibition of the Use of Force in Outer Space and from Outer Space with Regard to Earth" (see page 11S). Aside from what seems to be a totally unnecessary and unacceptable provision "not to test, nor use, for military, including counter-satellite ends, any manned spaceships," this 1983 Soviet draft provides a very suitable basis for early agreement.

Recommendations

The greatest urgency is to negotiate quickly a ban on weapons in space, starting with the Soviet draft of 1983, because it is presumably largely acceptable to the Soviet Union. Although it might be argued that in principle a better agreement could be obtained by going into more detail and taking longer to analyze and to negotiate, the situation is not static and the benefits of an early, all-encompassing agreement far outweigh any advantages which might follow from more detailed consideration.

The United States of course should take unilateral steps to make its military capabilities effective and robust against violation of such an agreement. This means, for example, backup communication and navigation systems for theater war. The United States should also (and the Soviet Union probably will) develop means for reducing the effectiveness of opposing satellite-based systems for support of conventional or nuclear military operations, short of putting weapons into space or damaging or destroying satellites. These measures could include jamming of communication links, decoys to deceive radar satellites and preparations for attack on ground stations not as safeguards necessitated by an ASAT ban, but as prudent self-interest.

An ASAT ban like that of our May 1983 draft or the Soviet draft of August 1983 cannot be expected to protect satellites in an all-out nuclear war. Nor can one realistically (or verifiably) eliminate residual threats to satellites, such as the nuclear-armed Soviet ABM system deployed at Moscow since before 1972 and permitted by the 1972 ABM Treaty. It would not eliminate the possibility of satellite destruction by a nuclear-armed ICBM launched to attack a "point-in-space" rather than a ground target. On the other hand, all the United States would renounce under an ASAT ban would be attack on Soviet satellites (and those of other countries) and some other roles for space weapons in war, (for example, attack on high-flying aircraft) which could better be performed by sensors in space and weapons launched from air or ground.

Regarding the denial of space for emplacing weapons for global defense, the proposed agreement would simply reinforce the constraints of the ABM Treaty, which President Reagan said the United States would observe in any case. We could and should continue to do theoretical and laboratory research on potential defensive systems, and a five-year review provision of a treaty of indefinite duration (as in the case of the ABM Treaty) would provide the opportunity to adapt the Treaty to technical and political realities and opportunities as they arise. □

Glossary of technical terms

geosynchronous orbit (GEO)—orbit in which a satellite remains stationary over a given area on Earth
hard X ray—one having short wavelength and high penetrating power
joule—unit of work or energy equivalent to 10^7 ergs or about 0.7375 foot-pounds or 0.2390 gram calories
kilo- —1,000
low-earth orbit (LEO)—orbit 100 to 500 kilometers in height
micro- —one-millionth
micron—one-millionth of a meter or one-thousandth of a millimeter
optical guidance system—active: emits energy which is reflected from an object; this reflected energy is then used for targeting; passive: senses energy from an object for targeting
plasma—ionized gas containing about equal numbers of positive ions and negative electrons. Differs from ordinary gas in being a good conductor of electricity and being affected by a magnetic field
radian—angular measurement equal to the angle at the center of a circle subtended by an arc equal in length to the radius of the circle; about 57.29 degrees
soft X ray—one having comparatively long wavelength and poor penetrating power
watt—power which produces energy at the rate of one joule per second; 1/746 horsepower

1. Richard L. Garwin, "Are We on the Verge of an Arms Race in Space?" *Bulletin* (May 1981), pp. 48–53.
2. A.B. Carter and D.N. Schwartz, eds., *Ballistic Missile Defense* (Washington, D.C.: The Brookings Institution, 1984).
3. Since there appear to be no recent unclassified technical articles by U.S. workers in this field available, we use results of Soviet research. F.V. Bunkin, V.I. Derzhiev and S.I. Yakovlenko, "Specification for Pumping X-Ray Laser with Ionizing Radiation," *Soviet Journal of Quantum Electronics* (July 1981), pp. 971–72.
4. Hans A. Bethe and Richard L. Garwin, "Anti-Ballistic Missile Systems," *Scientific American*, 218 (March 1968), pp. 21–31.

A treaty limiting anti-satellite weapons

Draft treaty presented to the U.S. Senate Foreign Relations Committee in May 1983 by the Union of Concerned Scientists et al.

Article I

Each Party undertakes not to destroy, damage, render inoperable or change the flight trajectory of space objects of other States.

Article II

1. Each Party undertakes not to place in orbit around the Earth weapons for destroying, damaging, rendering inoperable, or changing the flight trajectory of space objects, or for damaging objects in the atmosphere or on the ground.
2. Each Party undertakes not to install such weapons on celestial bodies, or station such weapons in outer space in any other manner.
3. Each Party undertakes not to test such weapons in space or against space objects.

Article III

1. For the purpose of providing assurance of compliance with the provisions of this treaty, each Party shall use national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law.
2. Verification by national technical means shall be supplemented, as appropriate, by such cooperative measures for contributing to the effectiveness of verification by national technical means as the Parties shall agree upon in the Standing Consultative Commission.
3. Each Party undertakes not to interfere with the national technical means of verification of the other Party operating in accordance with paragraph 1 of this Article.
4. Each Party undertakes not to use deliberate concealment measures which impede verification by national technical means of compliance with this treaty.

Article IV

1. To promote the objectives and implementation of the provisions of this treaty, the Parties shall use the Standing Consultative Commission, established by the Memorandum of Understanding Between the Government of the United States of America and the Government of the Union of Soviet Socialist Republics regarding the Establishment of a Standing Consultative Commission of December 21, 1972.
2. Within the framework of the Standing Consultative Commission, with respect to this treaty, the Parties will:

a) consider questions concerning compliance with the obligations assumed and related situations which may be considered ambiguous;

b) provide on a voluntary basis such information as either Party considers necessary to assure confidence in compliance with the obligations assumed;

c) consider questions involving unintended interference with national technical means of verification, and questions involving unintended impeding of verification by national technical means of compliance with the provisions of this treaty;

d) consider, as appropriate, cooperative measures contributing to the effectiveness of verification by national technical means;

e) consider possible changes in the strategic situation which have a bearing on the provisions of this treaty, including the activities of other States;

f) consider, as appropriate, possible proposals for further increasing the viability of this treaty, including proposals for amendments in accordance with the provisions of this treaty.

Article V

The Parties undertake to begin, promptly after the entry into force of this treaty, active negotiations with the objective of achieving, as soon as possible, agreement on further measures for the limitation and reduction of weapons subject to limitation in Article II of this treaty.

Article VI

In order to ensure the viability and effectiveness of this treaty, each Party undertakes not to circumvent the provisions of this treaty, through any other State or States, in any other manner.

Article VII

Each party undertakes not to assume any international obligation which would conflict with this treaty.

Article VIII

1. Each Party may propose amendments to this treaty.
2. Agreed amendments shall enter into force in accordance with the procedures governing the entry into force of this treaty.

Article IX

This treaty shall be of unlimited duration.

Article X

Each Party shall, in exercising its national sovereignty, have the right to withdraw from this treaty if it decides that extraordinary events related to the subject matter of this treaty have jeopardized its supreme interests. It shall give notice of its decisions to the other Party six months prior to withdrawal from the treaty. Such notice shall include a statement of the extraordinary events the notifying Party regards as having jeopardized its supreme interests.

Article XI

1. This treaty shall be subject to ratification in accordance with the constitutional procedures of each Party.
2. This treaty shall enter into force on the day of the exchange of instruments of ratification.

Article XII

1. Done in two copies, each in the English and Russian languages, both texts being equally authentic.
2. This treaty shall be registered pursuant to Article 102 of the Charter of the United Nations.

Treaty on the prohibition of the use of force in outer space and from space against the Earth

Presented by the Soviet Union to the General Assembly of the United Nations in August 1983

Article 1

It is prohibited to resort to the use or threat of force in outer space and the atmosphere and on the Earth through the utilization, as instruments of destruction, of space objects in orbit around the Earth, on celestial bodies or stationed in space in any other manner.

It is further prohibited to resort to the use or threat of force against space objects in orbit around the Earth, on celestial bodies or stationed in outer space in any other manner.

Article 2

In accordance with the provisions of article 1, States Parties to this treaty undertake:

1. Not to test or deploy by placing in orbit around the Earth or stationing on celestial bodies or in any other manner any space-based weapons for the destruction of objects on the Earth, in the atmosphere or in outer space.
2. Not to utilize space objects in orbit around the Earth, on celestial bodies or stationed in outer space in any other manner as means to destroy any targets on the Earth, in the atmosphere or in outer space.
3. Not to destroy, damage, disturb the normal functioning or change the flight trajectory of space objects of other States.
4. Not to test or create new anti-satellite systems and to destroy any anti-satellite systems that they may already have.
5. Not to test or use manned spacecraft for military, including anti-satellite, purposes.

Article 3

The States Parties to this treaty agree not to assist, encourage or induce any State, group of States, international organization or natural or legal person to engage in activities prohibited by this treaty.

Article 4

1. For the purpose of providing assurance of compliance with the provisions of this treaty, each State Party shall use the national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law.
2. Each State Party undertakes not to interfere with the national technical means of verification of other States Parties operating in accordance with paragraph 1 of this article.

Article 5

1. The States Parties to this treaty undertake to consult and co-operate with each other in solving any problems that may arise in connection with the objectives of the treaty or its implementation.
2. Consultations and co-operation as provided in paragraph 1 of this article may also be undertaken by having recourse to appropriate international procedures within the United Nations and in accordance with its Charter. Such recourse may include utilization of the services of the Consultative Committee of States Parties to the treaty.
3. The Consultative Committee of States Parties to the treaty shall be convened by the depositary within one month after the receipt of a request from any State Party to this treaty. Any State may nominate a representative to serve on the Committee.

Article 6

Each State Party to this treaty undertakes to adopt such internal measures as it may deem necessary to fulfill its constitutional requirements in order to prohibit or prevent the carrying out of any activity contrary to the provisions of this treaty in any place whatever under its jurisdiction or control.

Article 7

Nothing in this treaty shall affect the rights and obligations of States under the Charter of the United Nations.

Article 8

Any dispute which may arise in connection with the implementation of this treaty shall be settled exclusively by peaceful means through recourse to the procedures provided for in the Charter of the United Nations.

Article 9

This treaty shall be of unlimited duration.

Article 10

1. This treaty shall be open to all States for signature at United Nations Headquarters in New York. Any State which does not sign this treaty before its entry into force in accordance with paragraph 3 of this article may accede to it at any time.
2. This treaty shall be subject to ratification by signatory States. Instruments of ratification and accession shall be deposited with the Secretary-General of the United Nations.
3. This treaty shall enter into force between the States which have deposited instruments of ratification upon the deposit with the Secretary-General of the United Nations of the fifth instrument of ratification, provided that such instruments have been deposited by the Union of Soviet Socialist Republics and the United States of America.
4. For States whose instruments of ratification or accession are deposited after the entry into force of this treaty, it shall enter into force on the date of the deposit of their instruments of ratification or accession.
5. The Secretary-General of the United Nations shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification or accession, the date of entry into force of this treaty as well as other notices.

Article 11

This treaty, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations, who shall send duly certified copies thereof to the Governments of the signatory and acceding States.

Effect on strategic stability

by Yevgeny P. Velikhov

TWO DISTINCT DIRECTIONS in space militarization have recently emerged—the creation of anti-satellite weapons (ASAT) and the development of space-based anti-missile systems (SBAMS). These two directions, I believe, are closely meshed with the problems of strategic balance and stability, and with prospects for substantial nuclear arms reductions.

With regard to anti-satellite weapons my impression is that their proponents in the United States have not adequately considered the real functions such weapons could have in the overall strategic context.

American scientists have explained to my colleagues and me that the advocates of U.S. anti-satellite systems push their plans through only because the Soviet Union is rapidly developing such systems. But the Soviet leadership has authoritatively and concretely declared that it unilaterally assumes the obligation not to test and deploy anti-satellite systems, and that it proposes to reach an agreement with all countries not to acquire new anti-satellite systems and to eliminate all the existing systems. Thus, the argument used by supporters of the U.S. ASAT system becomes completely groundless and unpersuasive.

As for the strategic consequences of the deployment of these weapons, if they were used, the side attacked would have to consider the hypothetical massive use of offensive nuclear weapons that could follow.

An attempt to destroy the opponent's satellites or even to "blind" them for some period of time can be justifiably regarded as the first step in initiating unlimited nuclear war. Destruction of the satellites would give every reason to the attacked side to retaliate immediately, destroying all possible enemy targets, without waiting for a nuclear attack on their own, launching complexes and other military and civil targets.

The creation of a constant threat to satellites through the deployment of an anti-satellite system will impair the prospects of reaching agreements on a freeze of nuclear weapons, deep reductions, and confidence in their verification. Even without this threat the verification problem is used in the United States as an argument to frustrate existing agreements.

Research by the Committee of Soviet Scientists on the problem of a freeze is nearing completion. But preliminary results show that existing national technical means of verification, based on the use of appropriate equipment on satellites, are good enough to verify agreements on the freeze of a wide range of weapon systems at various stages of development. In this connection I should emphasize that we must strengthen and not undermine confidence in national technical means. Invulnerability of satellites used for verification purposes is an important stabilizing politico-psychological factor and an indispensable technical part of a freeze agreement as well as of START and other negotiations.

In light of the decision by the U.S. side to reject a ban on ASAT weapons, we have the full right to doubt the seriousness of U.S. intentions to reach an agreement at the START talks.

It should be added that any hope of getting significant unilateral advantage from a strategic or political-military point of view is absolutely groundless. There are those who have great expectations for the technical sophistication of the U.S. anti-satellite system. In my view, however, judging by the record of the postwar decades, the United States has no chance of creating a tangible breakthrough in qualitative weapon-systems characteristics which would leave the Soviet Union far behind. And even if one side achieves short-term qualitative advantages, the other side can compensate by greater quantity.

RESEARCH AND development of space-based anti-missile systems as basic elements of widescale strategic "defense" have had a very powerful political and monetary impetus. But to my mind, those who insist on this kind of system with its attendant huge expenditures—claiming that it is the way to eliminate the threat of nuclear war to the United States and the whole world—do not see the whole complex of scientific and technological problems and possible consequences affecting strategic stability and international security.

A special research project on this problem was recently completed by the Committee of Soviet Scientists' Working Group headed by R. Sagdeev and A. Kokoshin.* The study gave particular attention to the potential weapon systems that could be created on the principle of directed energy transfer—weapon systems which are the subject of active debate in the United States today. Several types of energy sources at different stages of technical development were considered as possible components for a directed energy weapons system—lasers working in infrared, visible or ultraviolet range; X-ray lasers pumped by nuclear explosion; high-energy particle accelerators; UHF (ultra-high frequency) or microwave generators.

According to published information the hydrogen-fluoride infrared lasers seem to be at the most advanced stages of technical development in the United States. It is assumed that the prototype space-based anti-missile systems would include a five-megawatt laser and four-meter diameter mirror. Such a system could presumably be developed within

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eight to ten years. According to the estimates by the Sagdeev-Kokoshin group, a space-based anti-missile system having approximately 18 orbital stations would be capable of destroying only about 15 ICBMs in 100 seconds (assuming massive launch), or up to 100 ICBMs in 15 minutes (assuming time-scattered launch). It is assumed that the launch sites would be within the range of two orbital stations simultaneously. A technically feasible improvement—some 10 to 20 kilojoules per square centimeter—of resistance to laser energy would make such a system incapable of destroying ICBMs.

The Working Group's estimates indicate further that development of a SBAMS effective enough to destroy 1,000 ICBMs in 100 seconds would require an increase in mirror diameter from four to 15 meters; in laser power capacity from five to 60 megawatts; and in fuel capacity from 45 to about 700 or 800 metric tons. Obviously, development of systems with these capabilities is currently beyond existing technical possibilities; considerably more intense research and development, on a wider scale, would be needed.

Still another requirement would be the development of a new heavy space launcher, much larger than the current space shuttle. Three to four times greater laser power capacity and two to three times larger mirror diameter would also be required if ICBM resistance to laser beams were further improved.

According to Western sources the development of neutral particle-beam accelerators which could be used in space-based anti-missile systems is not as advanced as the development of high-power lasers, and their construction would take considerable technical effort. The same situation obtains for the UHF generator-based system. Serious technical criticism could also apply to the possible uses of X-ray lasers.

The estimates mentioned above for large-scale space-based anti-missile systems using chemical lasers—up to 60 megawatts in power and with 15-meter mirror diameter—are related to a hypothetical "ideal" full-scale system, supposedly 100 percent reliable both technically and operationally. Obviously real SBAMS would not be absolutely reliable and would need backup duplicating components. The orbital stations themselves might have to be duplicated to compensate for technical unreliability. Operational unreliability would require the development of multi-layer SBAMS (having, in particular, traditional anti-missiles based on land or in space as an additional component). This has been under active consideration in the United States in recent years.

Even high operational reliability cannot guarantee absolute protection. For instance, a three-layer system, with 90 percent operational reliability for every layer, if used against 1,000 ICBMs with, say, 10 warheads each, would be expected to let through some 10 warheads. These could inflict tremendous damage.

Construction of effective SBAMS might require deployment of about 50 such platforms into polar orbits. Deploying fewer systems, in geosynchronous orbit, would take a bigger investment because of higher costs associated with such orbits, additional requirements in laser power, focusing, accuracy and so on.

The total cost of such systems, according to the Sagdeev-Kokoshin Working Group, would roughly amount to $400 billion. But that would be just one layer, which, as we have seen, would not be sufficient due to the need for redundancy.

THERE ARE SOUND reasons to believe that effective countermeasures could be taken more easily. According to the Group, such countermeasures would also be considerably cheaper—their cost amounting only to one or two percent of the total investment required for building a full-scale space-based anti-missile system. This cost ratio would probably also be preserved for the higher power capacity levels of the system and a consequent anti-system.

At a particular time, the side preparing a first strike can easily create a wide "window" among the battle platforms orbiting the Earth and use it for massive ICBM or SLBM attack. Thus the vulnerability of the system to countermeasures is the main factor leading to the view that such a system is intended for assuring a successful first strike. A strike could be launched against both offensive forces and anti-space ballistic missile defense systems of the other side, with the hope of reducing their ability to retaliate, while protecting itself with the space-based systems from such retaliation.

> "All attempts at gaining military superiority over the U.S.S.R. are futile. The Soviet Union will never allow them to succeed. It will never be caught defenseless by any threat.
>
> Let there be no mistake about this in Washington. It is time they stopped devising one option after another in search of the best ways of unleashing nuclear war in the hope of winning it. Engaging in this is not just irresponsible, it is insane."
>
> —*Yury Andropov*
>
> Replying to President Reagan's Star Wars speech in an interview in Pravda, March 27, 1983.

All this allows the conclusion that the deployment of even "ideal" systems would not assume (its proponents claim) a shift from the MAD (mutual assured destruction) posture—from the "strategy of deterrence based upon the threat of retaliation" to the defense-oriented strategy based on the ability to assure protection from a full-scale ICBM attack. On the contrary, the deployment of such a system would significantly complicate the maintenance of deterrence, making it highly unstable, for it would stimulate the illusion of advantages (damage limitation and even a chance for surviving nuclear war) associated with a first strike.

There are good reasons to believe that if both sides possessed space-based systems the destabilizing effect would be much greater than if such systems were available to only one side. In the context of strategic logic (without consider-

Figure 2. U.S. and Soviet satellites in orbit

Orbit	Mission	United States 1983	United States 1989	Soviet Union 1983	Soviet Union 1989
Low					
100–500 kilometers	Photo reconnaissance	4	2	2	2
	Radar surveillance	—	—	2	2
	Electronic intelligence	6	—	—	—
	Manned	1	1	1	2
	Subtotal	*11*	*3*	*5*	*6*
Medium					
500–3,000 kilometers	Communication military	—	—	29	2
	Navigation	5	—	10	—
	Electronic intelligence	6	14	10	8
	Weather military	2	2	3	3
	Weather civil	2	2	1	1
	Remote sensing civil	1	1	1	2
	Subtotal	*16*	*19*	*54*	*16*
Semi-synchronous					
400 x 40,000 kilometers	Early warning	—	—	9	—
	Communication military	2	2	4	4
	Communication civil	—	—	8	—
	Subtotal	*2*	*2*	*21*	*4*
Semi-synchronous					
20,000 x 20,000 kilometers	Navigation	6	21	2	12
Synchronous					
36,000 x 36,000 kilometers	Early warning	3	3	—	3
	Electronic intelligence	4	4	—	—
	Communication military	20*	22*	—	12
	Communication civil	30**	65**	10	13
	Weather	2	2	—	1
	Subtotal	*59*	*96*	*10*	*29*
Total		**94**	**141**	**90**	**67**

*Includes NATO satellites
**Includes INTELSAT satellites

Source: John Pike, "Anti-satellite weapons," *Federation of American Scientists Public Interest Report* (Nov. 1983), p. 3. Reprinted with permission of the author.

ing psychological and political aspects) this thinking arises from the fact that if both sides had these systems their impetus for a preemptive first strike would be greater, since each side could hope to secure an advantage by striking first.

As the Committee of Soviet Scientists noted, the U.S. refusal to undertake a no-first-use obligation and U.S. strategic programs aimed at acquiring a first-strike potential are additional reasons for considering prospective U.S. space-based systems as part of a first-strike strategy. An important element in implementing this policy is the deployment of U.S. medium-range missiles (particularly Pershing II) in Western Europe, aimed at "decapitation."

In contrast, the Soviet side, bearing in mind the tremendous importance of strengthening strategic stability in the atmosphere of growing political-military tensions, in June 1982 undertook the unilateral obligation not to use nuclear weapons first. This position was afterwards confirmed more than once by the highest Soviet government and military leaders. This obligation is not only political and diplomatic in character; it has become an integral part of Soviet military training and entails additional scientific and technological decisions.

In line with this commitment much more attention is paid to the goal of preventing non-nuclear conflict from growing into nuclear. Thus, more rigid limits have been set for troop training and command, and stricter controls organized to make unauthorized launch of tactical or strategic nuclear weapons impossible.

Besides the likelihood of countermeasures to space-based anti-missile systems—for example, hardening of ICBM boosters—the Sagdeev-Kokoshin Working Group thinks it highly probable that there will emerge a weapon intended to neutralize these systems (counter- "anti-SBAMS"). I agree with those specialists who have concluded that during the development and deployment stages of SBAMS, penetration capabilities of strategic offensive forces, including their qualitative improvement, will be modernized more rapidly.

The development of SBAMS could stimulate an increase in the arsenals of strategic delivery vehicles and nuclear warheads, for example, strategic cruise missiles, including sea- and ground-launched cruise missiles. Cruise missile deployment is extremely difficult if not impossible to verify by national technical means, and U.S. experts who suppose that the United States can retain a monopoly on strategic cruise missiles are badly misled.

If tests of the space-based systems were to begin, to say nothing of their actual deployment, the permanent ABM Treaty signed on May 26, 1972, would be threatened. Item 1, Article V of this Treaty postulates: "Each Party undertakes not to develop, test or deploy ABM systems or components which are sea-based, air-based, space-based or mobile land-based."

It is hard to overestimate the importance of this U.S.-Soviet Treaty today for it remains the only ratified and acting agreement in the area of strategic arms limitation.

THE PRESENCE of tested and deployed elements of space-based systems, even of limited scope, could considerably hinder the progress of negotiations on strategic arms limitations and limitations of nuclear weapons in general.

Such an unfortunate result would be inevitable. The introduction of a qualitatively new component in the strategic arsenal of one or both sides would confuse the existing assessments of strategic balances and bring up additional complications in the comparison of forces. The development of space-based anti-missile systems is likely to go in different ways in the two countries as has been true of the strategic arms race. Such differences would increase the asymmetries in the strategic potentials of our two countries —thus making comparisons even more difficult. These asymmetries could become increasingly significant in the face of deployment of potential anti-SBAMS systems and countersystems.

After these systems were deployed, U.S.-Soviet strategic arms limitation and reduction agreements would be more complex and correspondingly more difficult to understand on the part of the public, which plays an increasingly important role in solving the problems of war and peace.

With regard to international political consequences the deployment of space-based systems cannot be ignored. They would inevitably become a serious obstacle for U.S.-Soviet cooperation in the peaceful uses of space. Yet the potential value of such cooperation is important from economic, scientific and technological points of view, because of the many mutually complementary characteristics of the Soviet and U.S. space programs. Cooperation in this area could be a very positive factor, politically and psychologically, in improving U.S.-Soviet relations in general, and in strengthening the confidence between the peoples and the leaders of the two great powers.

THE POTENTIAL impact of a large-scale space-based anti-missile program on the strategic balance would be to substantially increase both the risk of a preemptive strike and the likelihood of wrong and fatal decisions in crises. Hence even if rough parity in strategic forces were preserved, strategic stability would be seriously undermined.

Deployment of strategic "defensive systems" would definitely trigger a chain reaction in the development of new weapon systems. That would confuse the strategic balance to an unprecedented degree and increase the uncertainty in political-military decision-making.

In view of the existing dialectical relationship between strategic offensive and defensive systems, even the possibility of building SBAMS would seriously undermine the possibility of future U.S.-Soviet (and perhaps multilateral) agreements on strategic arms limitation and reduction talks, and thus the prospects for strengthening strategic stability.

Abrogation of the ABM Treaty would in turn undoubtedly lessen chances for reaching mutually beneficial strategic arms limitation and reduction agreements in the near future. The stabilizing regime created by the 1972 ABM Treaty could be strengthened significantly by agreements on the non-deployment in space of any weapons and the non-use of force in space. These would include a ban on the use of force from space against the Earth, as well as a ban on anti-satellite weapons.

Vast resources would be required for construction of a space-based anti-missile system, to say nothing of the scientific and technological capital already devoted to this enterprise. These funds and efforts could be effectively diverted to large-scale international bilateral and national programs of a peaceful nature. If this were to happen, that part of U.S. industry which would have been employed to develop the space system could effectively be engaged in such peaceful projects.

It was the unanimous view of the Committee of Soviet Scientists that programs of cooperation in this field could substantially contribute to and expedite the solution of increasingly acute global problems such as economic development, energy, resources and ecology. They could also create a basis for successful space exploration by future generations of the Earth's inhabitants. □

**Political-Military Implications of Prospective American Space-Based Anti-Missile System*, report issued by the Committee of Soviet Scientists for Peace Against the Nuclear Threat (Moscow: 1983).

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