DANIEL KAPLAN

Lasers for missile defense

In late March President Reagan called upon scientists "to turn their great talents to the cause of mankind and world peace: to give us the means of rendering . . . nuclear weapons impotent and obsolete." The President had in mind not the formulation of new arms control agreements with the Soviet Union, nor the invention of novel ways of verifying compliance with such agreements.He was considering instead the development of high energy laser beams and other weapons for launching the military into space. He was asking scientists to help create a new generation of strategic weapons.

The prospect of the militarization of space has met with little opposition, largely because lasers are advertised not as a mere weapon, but as an "anti-weapon weapon." Lasers, it is claimed, would protect the people of this country from a nuclear attack; they would put an end to the nuclear arms race and enable the United States to live in peace under a shield of light. The types of space lasers being discussed in the Senate and in industry, oddly enough, are only capable of shooting down a few satellites and perhaps a small fraction of attacking Soviet missiles. But, the argument goes, an anti-satellite laser would be a first step to a laser defense against missiles in 30 or 40 years.

The idea that lasers in space could defeat a nuclear attack is, however, fatally flawed. It is unlikely that any system of lasers, no matter how comprehensive, could destroy missiles with sufficient reliability to be regarded as the main component of a defense against nuclear attack. And even if it could, missiles are not the only means of delivering nuclear weapons. Moreover, putting in orbit a system of lasers big enough to begin to protect civilian targets from missile attack would require tremendous effort, most likely larger than any military project yet undertaken. Finally, the deployment of even a small laser system—despite its ineffectiveness as a defense—would create profound instabilities in the strategic balance between the United States and the Soviet Union.

A laser anti-ballistic missile (ABM) system would have several components: one or more high-energy lasers, mirrors to point and focus the laser beam, sensors to detect and locate missiles in flight, and a command system for firing the lasers. Advocates of a laser ABM system envision a number of "battle stations" orbiting the Earth and providing continuous coverage of its surface. Since it would be in space, the laser beam would not be absorbed by the Earth's atmosphere. Whenever the launch of a hostile missile was detected, the beam would be directed precisely in the direction of the missile. The shooting would occur during the "boost phase" of the missile's flight, which lasts for the first 250 seconds or so when the rocket is under power. The missile would be targeted during the boost phase for three technical reasons: During this phase, the target is relatively "soft," can be tracked by following the rocket's flame, and all of the MIRVed warheads can be destroyed at once.

The designer of a system of lasers for defense against ballistic missiles is faced with three fundamental constraints:

- Laser light, like any other light, beyond a certain distance decreases in intensity of power as the square of the distance from the source. Even in the vacuum of space, the range of any laser weapon is limited by this basic physical principle.
- The lower the orbit and range of a laser, the smaller the area of the laser's coverage. While three satellites in geosynchronous orbit of 30,000 kilometers could cover the Earth's whole surface, more than 200 would be needed if the lasers had a range of 1,000 kilometers. Because satellites in low orbit cannot hover over one spot, in order to cover all of the Soviet Union it is necessary to cover virtually the whole of the Earth's surface.
- For an effective defense, the laser system would have to be designed to deal with the worst case situation—the Soviets launching all of their approximately 2,000 missiles in a short time. A sufficient number of lasers would need to be in position over the Soviet Union at all times to be capable of shooting down the missile force. Thus, the number of lasers needed for an effective ABM becomes very large.

Contrary to popular notions, laser weapons do not vaporize the target. Instead, the energy in a laser beam weakens the skin of the missile, causing it to destroy itself by its own internal stresses. Missiles have a certain "hardness," which corresponds to the amount of energy per square centimeter which the laser must deliver to destroy the missile.

Although the details of laser systems now under consideration by the military are classified, it is possible, using the principles outlined above, to determine the size of a laser system needed to defend against a barrage launching of all Soviet missiles. We have done so for the two types of lasers most discussed in the Senate as candidates for a laser ABM. The "small" laser is a five-megawatt hydrogen fluoride laser with optics four meters in diameter. The "large" laser is a 10-megawatt hydrogen fluo-

Daniel Kaplan is a scientist with Battelle Pacific Northwest Laboratories in Washington, D.C. (20036). He was formerly associated with the Federation of American Scientists.

ride laser with 10-meter optics. Both are huge compared with present high-energy lasers, and the optics are not comparable in size and precision to any high-power mirror that has yet been built. (See accompanying table for a range of missile hardness.)

Number of Lasers Needed for Defense[a]

Laser type	*Missile hardness (joules per square centimers)*	*Number of lasers required*
small	soft (300)	700
	medium (2,000)	4,700
	hard (20,000)	Hard missiles cannot be destroyed by small lasers.
large	soft (300)	55
	medium (2,000)	400
	hard (20,000)	4,000

[a]Theoretical minimum number of lasers needed to defend against a concerted launching of 2,000 Soviet missiles.[1]

It has been estimated that each laser weapon would weigh 100 tons. If this is true, as many as 14,000 launches of the space shuttle would be required to place the lasers in orbit, and more launches would be needed to maintain them. Currently, fewer than 400 launches of the space shuttle are planned through 1992. The National Aeronautics and Space Administration (NASA) estimates that a substantial increase in the number of launches would cause considerable harm to the ozone layer.

This is not the whole story, however. Only about four percent of the laser satellites would be over the Soviet Union at any one time. It is these four percent that would shoot at Soviet missiles in the event of an attack; the other 96 percent would be out of range. Advanced military equipment is in service typically around 60 percent of the time. Assuming that the lasers would be 80 percent reliable—even though they would be more complicated than any of today's military equipment—there is still a good chance that some of those few satellites over the Soviet Union would not be working. In order to protect against a hole in the defense, it would be necessary at least to double the number of satellites in orbit.

Such a huge system of lasers is certainly not practicable. And in any case, even a system of this magnitude probably could not prevent tens or hundreds of MIRVed missiles from getting through, allowing hundreds or thousands of warheads to reach U.S. cities. To see why this is so, assume that a "perfect" defense system could be deployed—perhaps a laser system with a backup "conventional" ABM. In order to determine with any certainty that the system is, say, 98 percent effective, hundreds of missiles would have to be tested against it, an expensive and perhaps dangerous operation. And even if testing of this magnitude took place, it would not be under the full range of war conditions. Nor could tests take into consideration unknown Soviet advances in hardening missiles or disabling the laser system. Thus, however perfect the system appears on the drawing board, it is unlikely to be considered more than 98 percent effective. If the Soviets deployed no more missiles than allowed by SALT II, more than 400 warheads could still get through such a defense, enough to inflict huge damage.

Despite speculation that lasers could shift the emphasis of nuclear strategy from deterrence to defense, it is unlikely that a laser ABM could do more than supplement a deterrent force. A laser defense probably would be little more than another element in the sort of nuclear balance of terror that exists today. Not only is it likely that missiles can penetrate a laser defense; a defense against nuclear attack would also be incomplete without some means of protecting against low-flying bombers, cruise missiles and other low-altitude delivery systems. The atmosphere absorbs, scatters and defocuses laser light, affording a natural protection against lasers to weapons operating at low altitudes. Unless a means of countering these effects is developed, a laser ABM would be only a partial defense, even if it were completely effective against missiles.

In addition to using cruise missiles and bombers, it is possible to counter laser weapons directly. For instance, a laser could be destroyed—before or after it became operational—by exploding a nuclear bomb nearby in space. Or, space mines could be used, with satellites carrying explosive charges stationed nearby to destroy the lasers before they were functional. Some have claimed that by a combination of armoring the laser and using it to shoot down anything that threatens it, a laser could be protected against attack. However, this does not seem to be practicable. One reason is that a laser weapon must have large optics, which are necessarily susceptible to damage. An effective way of disabling a laser, therefore, would be to shoot at its optics with a wire mesh, sand, or ball bearings travelling at high speed. Because the projectiles would be small, and not contain sensitive explosives or guidance equipment, the laser would have to vaporize them—a very difficult task at the intensities usually discussed. Creating even a small chip in the mirror would cause the laser to destroy itself in a short time, since it would absorb its own energy. Thus, it would probably not be possible to defend against such anti-laser weapons except by denying entry into space to all suspicious satellites.

Because a laser defense would be a system, rather than a collection of independent parts, one means of attack would be to interfere with the links among the components. In any laser system, there would probably have to be a command communication link between Earth and the laser satellites. This link might be disrupted by many things, among them the electromagnetic pulse produced by nuclear explosions in the atmosphere. And even if the connection between ground and satellite were secure, it would still be possible to diminish the system's effectiveness by disrupting the coordination between laser satellites, since each laser would have to know what targets other lasers were shooting at, so as not to waste its own fire or let missiles through.

To aim at a target, a laser weapon would need detectors with their own large optics. Because the detectors would have to be highly sensitive in order to pick up the feeble signs of an ICBM in flight hundreds of kilometers away, they would be easy to interfere with. This could be done by blinding the detectors with a ground-based laser, by lighting flares to confuse the detectors, or by launching decoys. Since it is practically impossible to distinguish decoys from warhead-carrying missiles, lasers would have to spend valuable time shooting at decoys. Decoys might also induce aiming or tracking errors. Another possibility might be to build "stealth" missiles (just as Stealth bombers are being considered), or to hide the missile itself behind a screen, so that although it would be detectable it would not be targetable.[2]

As already mentioned, missiles can be hardened against laser light. Current Soviet liquid-fueled missiles might be vulnerable to as little as 300 joules per square centimeter of laser energy incident upon their surface, because the stress produced by the laser would combine with the stresses produced in the missile during launch. However, present-day re-entry vehicles (that is, the warheads themselves) are hardened to about 7,000 joules per square centimeter. This is a by-product of their being made to withstand both re-entry into the atmosphere and X-rays produced by nuclear explosions. One estimate is that the limit of ablative coatings—in which the protective shield flakes off as it heats up—is as much as 20,000 joules per square centimeter.[3] And there is no predicting what the limits of other missile hardening technologies may be. By rotating the missile in flight, the laser's energy could be more widely distributed over the missile surface, effectively increasing its hardness more than three times. Because techniques of missile hardening can be developed relatively quickly a laser defense would be subject to sudden obsolescence.

Whatever countermeasures have already been discovered, it is likely that efforts to find still better ones will be spurred on by continuing development of laser weapons. And the potential for development of countermeasures forces the designer of a laser system to find a way to obviate them, or to build another weapon which will fill in the gaps left by the laser.

Advocates of space lasers see them as essentially defensive, and claim that it is unlikely that deploying such a system would adversely affect the arms race or America's relation in general with the Soviet Union. But considering the structure of the nuclear balance, in which offensive weapons are designated as a deterrent to attack, the classification of a weapon as defensive is practically meaningless. The Soviets would probably view a U.S. laser system as offensive, in much the same way that Soviet civil defense plans are interpreted in the United States as a sign of Soviet aggressiveness.

For Moscow to look upon U.S. deployment of even a small system of lasers as a preparation for attack on the Soviet Union is not unreasonable. One mission well suited to a system of only a few laser weapons would be to cover a counterforce first strike—against strategic military forces, not civilian targets. The position of the military today is that the danger of a counterforce surprise attack can be greatly reduced by planning to launch the targeted missiles before the incoming missiles arrive: the tactic of "launch on warning." However, if four or five lasers were orbited—not nearly enough to *defend* against a surprise missile attack—their orbits could be coordinated so that they could cover all necessary targets within a certain time window.

These few lasers could be used to prevent missiles from being launched on warning during the half-hour interval of a counterforce attack; or, at least, so some military planners claim. And because of this capability to back up a counterforce strike, even a few lasers put into orbit could stimulate the arms race, just as the claimed development of accurate "silo-killing" missiles has done.

Another problem with space laser weapons is that they would have to be on hair triggers. To be effective, a laser would have to fire at a missile during the missile's boost phase. In a mass attack, the very size of the missile launch would be a clear indication of hostile intent. But if just one or two

Excerpted from President Reagan's March 23 speech:

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. This could pave the way for arms control measures to eliminate the weapons themselves.

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launches were seen, there would be a serious question as to whether they were for aggressive purposes or not. Because of the short time available to make a decision, unless there were a policy against using lasers except during mass launches, a peaceful satellite might be shot down by mistake.

This problem is deepened by the likelihood that space lasers would be mined. In order to counteract a U.S. laser, for instance, the Soviets might orbit an explosive device nearby, designed to destroy the laser when commanded to do so. Equally, the mines might be countermined. In any crisis, there would be a temptation to use one's mines before the other side did. The existence of space lasers might tend to escalate a crisis.

The most likely Soviet response to a U.S. laser system would be an increase in Soviet spending on cruise missiles and low-altitude bombers, weapons which are virtually immune to space lasers. But even though lasers are meant specifically to shoot down ballistic missiles, it may be that the most effective response to the deployment of a laser system would be to increase the numbers of ballistic missiles, or to take even drastic measures to harden missiles. For any of the laser systems considered above to compensate for an increase of, say, 25 percent in the size of the Soviet missile force, the number of lasers in orbit would have to be raised by 25 percent.[4] Similarly, doubling the hardness of missiles would require doubling the number of lasers.

It is a mistake to consider the cost of a laser system as a one-time expense which can be borne without regard to the economies involved. If it costs more to shoot down a missile than to add one to the missile force, then the United States would probably lose a laser *versus* missile race. Of course, the Soviets might find it less expensive to harden old missiles, or to build cruise missiles or bombers, than to add new ballistic missiles.

Supporters of space lasers tend to view them as a kind of ultimate weapon. They feel that whichever nation first deploys them will not only be able to protect itself against nuclear attack, but control space as well. Senator Malcolm Wallop of Wyoming, a prime supporter of laser weapons, expresses the fear that "as the Soviet Union perfects the kind of space-based laser system that can deny one or two missiles entry into space, we will have to tell them in detail the payload of everything we send up from there on, or they will shoot it down, treaty or no treaty, and we may never get to deploy [our own lasers]."[5] Wallop urges the military to increase its research efforts so that a laser system can be deployed in five or 10 years. This, he says, would enable the United States to prevent the Soviet Union from orbiting its own lasers. Wallop succeeded in getting a bill passed which adds $50 million to the 1982 budget for space laser research, and this was a compromise. His original intention was to add $250 million to the research budget and stipulate that a prototype weapon be built by 1985. Yet most experts think that it will be at least 20 years before working space laser weapons can be built, and some believe it simply cannot be done.

Official Pentagon policy is to proceed with the development of lasers, large-scale optics and other equipment associated with a space-based laser weapon, but not to direct effort toward construction of prototype weapons. This policy allows the United States to maintain its position technologically with respect to the Soviets, helps determine what sorts of laser missions are and are not practicable, provides a basis for assessing Soviet technology, and gives the potential for warning of a Soviet breakthrough in laser technology. The budgets for laser research in the Air Force and the Defense Advanced Research Projects Agency have increased steadily to a total in 1983 of about $470 million, and they are expected to increase more rapidly in the future. Contracts have already been let to assess the vulnerability of missiles to laser light, to design pointing and tracking devices for lasers, and to develop large-scale optics.

While the Pentagon has given no indication of intending to build a prototype weapon, defense contractors are more ambitious. Lockheed Missiles has already unveiled a model of a space-based laser weapon, though it seems to have more publicity than technical value.

In the past, military projects have often proceeded despite a lack of strategic or technological justification. Sometimes, as with the nuclear-powered airplane, the only result was wasted money. Other times the price has not been so cheap: The ABM missile project has come and gone but MIRV—which was justified as a means of countering ABM—is a permanent legacy of escalation. Space lasers also have the potential to escalate the arms race and expand it into space. This potential completely dwarfs the benefits lasers might bring as a defense against missiles. □

1. These figures were arrived at through a calculation involving the power of the laser, its distance from the target missile, the hardness of the target, and the need, in theory, to be able to destroy 2,000 missiles that might be launched in an all-out enemy attack. The optimal altitude for a 10-megawatt, 10-meter diameter laser turns out to be 150 kilometers; however, this altitude leads to an unstable orbit. The given figures are based on an altitude of no less than 250 miles. For details on how the calculation was done, please contact the author.

2. See, for example, Richard Garwin, "Are We on the Verge of an Arms Race in Space?," *Bulletin* (May 1981), pp. 48-53.

3. *Aviation Week and Space Technology* (Feb. 16, 1981), p. 17.

4. This is because lasers, in most cases, could not be stationed at their theoretically optimal altitudes. See note 1.

5. Congressional Record (July 1, 1980), at S9075.