# Experts Cast Doubts on X-ray Laser

## *The jewel of the "Star Wars" missile defense program fails to glitter*

At the Lawrence Livermore National Laboratory, east of San Francisco, nearly a hundred scientists are hard at work on what they hope will be the most potent and cost-effective weapon in the Strategic Defense Initiative (SDI) arsenal. This weapon, when lofted to a distant point in space, will be capable of firing laser beams to destroy tens, if not hundreds, of Soviet ballistic missiles all at once, its proponents claim. If successful, it would go a long way toward fulfilling the dream of a missile shield envisioned by President Reagan in his historic 1983 "Star Wars" speech.

Edward Teller, who touted the weapon to the President well before his speech, describes it as the "most novel and potentially the most fruitful" missile defense technology under investigation. Similarly, Lowell Wood, a physicist at Livermore and protégé of Teller's who helps direct the research effort, regards it as "the most robust means of strategic defense that has yet surfaced." Last March, Richard Wagner, an assistant to the secretary of defense for nuclear energy, told the House Appropriations Committee that the weapon "is, in fact, very much at the center of our thinking."

The object of this enthusiasm is an x-ray laser, the nearest to fruition of all the so-called third-generation of nuclear weapons. The shared goal of these weapons is to harness the energy of a nuclear detonation and focus it on a specific target instead of dispersing it in all directions. An x-ray laser, for example, is created when x-ray and gamma radiation from a nuclear detonation is directed onto rods of lasing material, causing some atoms to lose their electrons. The electrons that remain are then briefly "excited," or moved to an orbit of higher energy. As the electrons return to a normal state, additional x-rays are generated, and a "cascade" of coherent light radiation is thus created and emitted in the direction the rods are pointing.

Lasing occurs only momentarily, as the entire weapon is obliterated by the effect of the shock wave within a millionth of a second or so. Theoretically, the beams can heat the skins of enemy missiles as hot as the sun, causing violent, extremely rapid evaporation. This in turn generates a rebounding shock wave that can cause the missile to buckle and break up. The only problem is that the beam is incapable of easily penetrating the earth's atmosphere, so both the bomb's detonation and the missiles' destruction must occur at an altitude greater than 100 kilometers.

Recognizing the potential usefulness of such a weapon, the Department of Energy has given the program a high priority. Next year, it will spend roughly $100 million on x-ray laser research, more than triple the amount spent in 1982. The Defense Department is also enthusiastic. Next year it will increase its support from roughly $7 million to $20 million, and the following year it will spend $35 million. The possible value of such weapons has also not been lost on the White House, where the need to conduct underground x-ray laser tests is seen as an enduring obstacle to agreement with the Soviet Union on a comprehensive test ban.

**Curtis Hines**

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Elsewhere in the defense community, however, there is growing skepticism about the x-ray laser. In the wake of several disappointing tests, as well as a detailed study of potential countermeasures, many weapons analysts and engineers have concluded that the weapon will be incapable of attacking Soviet missiles in the boost phase, while they are easily tracked and still carrying warheads and decoys. The deployment of a defensive system with this capability is considered by many to be crucial to the success of the overall Strategic Defense Initiative (SDI) goal.

Paul Robinson, the principal associate director for national security programs at Los Alamos National Laboratory, believes that the x-ray laser is flawed because it might inadvertently wreak havoc on other SDI components in space. Similarly, Curtis Hines, a department manager for systems analysis at Sandia National Laboratory, believes that its range and power will be inadequate for boost-phase missile defense. And Edward Gerry, a former directed-energy manager for the Defense Advanced Research Projects Agency and a key member of the influential Fletcher panel on SDI (*Science*, 25 November 1983, p. 901), is skeptical about the practicality of any defensive nuclear weapon that may have to be detonated within seconds after a Soviet nuclear attack has begun.

Some of this skepticism extends, moreover, to other defensive weapons that might be used against Soviet missiles during the boost phase. "Yes, I think boost phase [defense] may be out of the question," says Hines, "which is unfortunate. There is a lot to be gained by it." The difficulty, according to Hines and others, is that the x-ray laser, like any defensive weapon intended for boost-phase attack, must either be based in space or swiftly launched upon warning of an attack, and neither choice seems practical.

So far, these pessimistic judgments by weapons designers have escaped wide public notice, partly because of the intense secrecy that enshrouds the x-ray laser program. Perfunctory documents explaining the program to Congress this year received an extremely high classification, and the Federal Bureau of Investigation was called in to investigate the source of a brief news account of the program last June. But stirrings of unrest are nonetheless evident in Congress, where this spring an attempt was made to end the research effort on the grounds that the government has no business preparing for the deployment of nuclear bombs in space. "The Administration talks about all this as a non-nuclear defense, a program to rid the world of nuclear weapons," says an aide to Representative Thomas Foglietta (D–Pa.), who sponsored the attempt. "The question is what are they selling?"

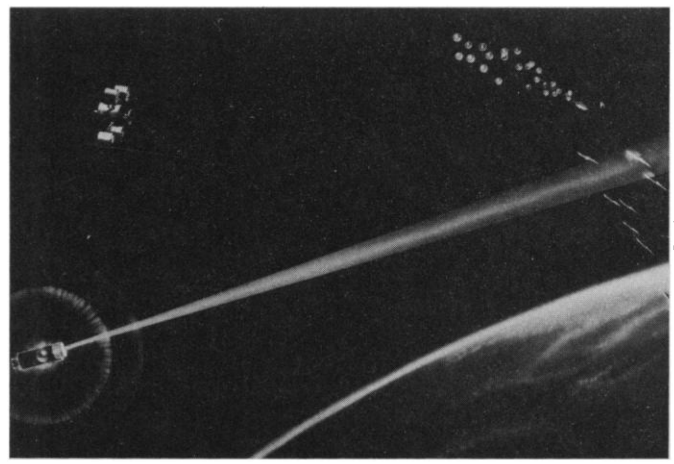
Foglietta's amendment would have blocked all "development, demonstration, test or evaluation of . . . weapons powered by nuclear explosions in space," and as a result it created considerable anxiety in the office of William Hoover, then the assistant secretary of energy for defense programs. But Hoover was able to hammer out an agreement about the importance of x-ray laser research with his counterparts at the Defense Department, and release it on the day before the amendment was considered on the House floor. Foglietta then agreed to alter the provision so that it merely barred "advanced development" that is inconsistent with existing arms treaties, effectively allowing the research to proceed without constraint.

Since the program formally got under way in 1980; there have been only a handful of underground tests, the most recent of which is said to have cost roughly $30 million. At least three are known to have been either unsuccessful or indeterminate because monitoring equipment malfunctioned. The most recent test, held on the second anniversary of Reagan's 23 March speech, was reported in the *New York Times* to have demonstrated a dramatic increase in laser beam brightness. Subsequently, however, lab researchers discovered that key monitoring equipment had been improperly calibrated, rendering this judgment uncertain. In addition, a new defect in beam collimation cropped up, apparently caused by an acoustic disturbance of the lasing medium. A vigorous search for alternative lasing rod materials is under way, and plans have been set to reduce the laser's considerable mechanical complexity, as well as to boost its relatively low efficiency and power, according to several scientists familiar with the program.

Despite these rumored difficulties, Lowell Wood, for one, remains unfailingly upbeat. "Obviously, we aren't satisfied with where things stand, or we would have pushed the weapon out the door and we wouldn't be doing a lot of work that we are manifestly doing," he says. "Where we stand between inception and production I can't tell you . . . [but] I am much more optimistic now about the utility of x-ray lasers in strategic defense than when we started." In particular, he adds, there has been "very substantial improvement, relative to where we started" in laser beam fractionation and brilliance.

George Miller, the deputy associate director for nuclear design at Livermore, is more cautious, however. The scientific goal of bomb-pumped x-ray lasing has indeed been achieved, he says. "But what we have not proven is whether you can make a militarily useful x-ray laser. It's a research program where a lot of physics and engineering issues are still being examined. . . . There's a lot of work to do, not the least of which is actually designing the system, not just the laser itself."

Indeed, it is precisely this challenge that worries the experts most. Under one approach, the United States would use the x-ray laser to attack Soviet boosters from permanent battle stations in space. Steven Rockwood, the director of SDI research at Los Alamos, spells out the immmediate political drawbacks. "What would you think if this satellite is passing over Washington 5 times a day and you know it's carrying a nuclear weapon? Will you trust me that it's only a defensive weapon, and not something that can be dropped on your head without any notice or warning? I don't think the Soviets in their paranoid attitude will ever believe what we tell them."



LLNL painting by George P. Dooley

*Pictured is an artist's conception of a nuclear-pumped x-ray laser (lower left) and chemical rocket platform (upper left) attacking enemy missiles during the boost phase of their flight. At least one missile, however, has survived its boost phase and is shown releasing its warheads and numerous decoys, chaff, and other materials aimed at confusing sensors.*

Curtis Hines of Sandia explains the principal military drawback. "Every time we look at it, it seems very difficult to ensure the survivability of space-based assets," he says. One important threat is the x-ray laser itself. Although the Soviets are thought to be behind the United States in x-ray laser development, there is a widespread presumption that if the United States builds one, they will too. The Soviets could then use their lasers to attack those based in space, even while they remain protected by the earth's atmosphere.* Such an attack "could present a serious threat to space-based assets and seriously disrupt our plans for defense," says Cory Coll, the director of SDI systems analysis at Livermore. Miller and Robinson both agree.

The alternative is to deploy the x-ray laser atop numerous land and sea-based missiles, ready for instantaneous launch on warning of a Soviet attack. In one sense, the laser is ideally suited for this mission, being substantially lighter and more powerful than virtually any other type of defensive weapon. "I don't know of anything that has that combination of lightweight power supply and speed of light kill," says Gerald Yonas, SDI's chief scientist. "What else is there?"

But here, too, there are serious drawbacks. Due to the laser's inability to penetrate the atmosphere, the missile carrying the x-ray laser must outrace that carrying nuclear warheads and fire when both are in space. This requires at a minimum an elaborate, virtually perfect warning system. Even then, ordinary procedures for presidential consultation would have to be short-circuited, a circumstance that may prove politically unpalatable. "Personally, I have trouble with any system that requires hair-trigger launch of a nuclear weapon," says Edward Gerry. Rockwood agrees. "I have not seen a scenario that uses nuclear directed-energy weapons that is politically acceptable and gets into the early part of a war," he says.

If the political obstacles can somehow be overcome, the Soviets could sharpen the technical difficulties by developing and deploying rockets substantially faster than those they have at present. This would require that the lasers be stationed at sites close to Soviet territory, in order to gain time and obtain the most direct line of sight. "Turkey, Japan, Western Europe, Norway, maybe even China: All of these are places that have a legitimate interest in being defended from Soviet attack," Wood says. But other experts, including Donald Kerr, who recently retired as Los Alamos director, are incred-

*Because beam intensity diminishes with increasing distance from the power source, a laser still within the atmosphere has an inherent advantage over one based in space. The former will be able to penetrate or "bleach" through the atmosphere long before it can be attacked by the latter.

ulous that these countries would ever agree to such a step.

Wood counters that in any event the demand for quick launch might eventually be eased because x-ray lasers will be powerful enough to reach far into the upper atmosphere—to an altitude of roughly 60 to 80 kilometers—through a process known as bleaching. Bleaching occurs when the beam exhausts the absorption capabilities of molecules in its path, and a column of air becomes momentarily transparent. But some experts say that this can be accomplished only if the brightness of present x-ray laser beams is increased by more than ten orders of magnitude—an extremely daunting scientific challenge.

One approach might be to increase the yield of the bomb that pumps the laser. Already, according to various officials, yields of at least 100 kilotons are required; thus, the bomb in each superlaser might be well over a megaton. Even at the lower yield, according to Robinson and Ashton Carter, a physicist at Harvard who wrote a 1984 study of SDI for the congressional Office of Technology Assessment, the detonation in space of x-ray lasers might spill enough radiation to disrupt the operation of some key U.S. satellites. Those within a direct line of sight or a distance of 100 kilometers or so might perish immediately from x-ray and gamma radiation; others might fail when floating clouds of radioactive plasma "charge up various parts of their circuits, accelerating the current and overheating solid-state elements," as Robinson describes it, much like a powerful sunstorm. Particularly vulnernable are satellites in equatorial orbits at low altitudes, the optimum spot for the infrared sensors on which a boost-phase defense may depend. The only effective safeguard might be to limit the satellites' power while the plasma is nearby, rendering them virtually useless in combat.

This might be academic, of course. Hines believes that the development of such a superlaser is not likely "in the foreseeable future," and Coll is also pessimistic. "In the end, the pop-up x-ray laser is simply not feasible against a fast-burn booster," he says. "Fast-burn boosters rule out pop-up anything." This judgment is also expressed in a little-noticed letter to the House Appropriations Committee from the Defense Department last year. "Should switching to faster burning boosters prove to be a feasible and effective countermeasure," the Pentagon acknowledged, "it would cast doubts upon some proposed concepts for boost-phase intercept. In particular, standard chemical rockets, x-ray lasers, and particle beams might not be viable options for boost-phase intercept against faster burning boosters."

What, then, is the x-ray laser likely to be good for? One argument, frequently raised by Teller and Wood, is that the threat of its deployment may induce the Soviets to produce hundreds of fast-burn boosters at an enormous cost. "If we can force the Soviets to use fast-burn boosters, we will make them very busy for quite a time," says Teller. "They will have to run hard just to stay in place." But whether the Soviets would be willing to do this without the actual deployment of a credible U.S. x-ray laser network, also at considerable expense, remains uncertain.

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Second, Robinson and others note that an efficient, powerful x-ray laser could provide exceptionally clear three-dimensional portraits of human tissue and crystalline molecules, making its successful development important for nonmilitary applications. "I'm very sanguine about the medical research aspects," Robinson says. "I'm more pessimistic about the defensive application." But such a laser might also be generated without a nuclear detonation as its power source.

Third, Yonas and Wood suggest that the x-ray laser might be used to attack the so-called "post-boost vehicle," a device released by the booster that briefly carries all the warheads and decoys. But such a device can be hardened, or split into many separate pieces, or perhaps dispensed with entirely, all of which could enormously complicate the attack. X-ray laser brightness, basing, and collateral nuclear effects would still pose serious problems. As Coll says, "the timeline will still be extremely stressing, but I don't rule it out."

Fourth, some experts are hopeful that x-ray lasers can be used to discriminate between warheads and decoys during the so-called "mid-course" period of an enemy attack, which lasts roughly 25 minutes or so. With a leeway of minutes instead of seconds, the lasers could be "popped up" from sites much closer to the United States, there would be less chance of deploying or firing them by mistake, and it might be possible to obtain political authorization. The rationale is that even a fairly weak beam might be capable of destroying the balloon-like sheaths erected around warhead and decoy alike. Critics such as Richard Garwin, a physicist and weapons consultant at IBM, suggest that in response, the Soviets might deploy balloons within balloons, but the feasibility of such counter-countermeasures is uncertain. Whether other weapons, such as neutral particle beams, can perform this job more efficiently also remains uncertain.

Finally, there is widespread recognition that the bomb-pumped x-ray laser will be a superb antisatellite weapon (ASAT). "If the laser works as predicted, it could be overwhelming as an offensive weapon," says Paul Brown, Livermore's associate director for arms control. "It could wipe out all the other guy's lasers and satellites." Hines agrees. "An x-ray laser surely looks as if it is a better ASAT than SDI weapon. . . . In fact, incorporated as a popup or a space mine, it would be just devastating to a constellation of satellites, be they weapons or sensors," he says.

Several analysts, who ask to remain anonymous, insist that this unsettling situation is not well appreciated or even widely understood in Washington. Two who participated in the Pentagon's recent study of SDI architectures by ten contractors and a special team of nuclear weapons designers say that hardly any attention was paid to the inevitable Soviet x-ray laser threat by the industrial groups. "They primarily focused on the near-term, and ignored the x-ray laser threat," says a scientist who reviewed the studies. As a result, he suggests, a considerable danger exists that "we could follow their advice and deploy a missile defense in the near-term that will ultimately be incapable of dealing with this threat."

In the end, the x-ray laser program thus serves as a powerful reminder that weapons created for defensive applications might ultimately be twisted and used for offensive purposes. In addition, it is noteworthy that to a certain extent, x-ray lasers may indeed be the *best* technology for destroying Soviet missiles during the boost phase; they are light, compact, quick, and powerful. But now even the insiders doubt that they will work. This does not mean that any missile defense is impossible, or that none should be constructed. It merely means that the defense may not be highly effective, because the leverage to be gained from attacking boosters will be unavailable.—**R. Jeffrey Smith**