# EIR Science & Technology

# The European Defense Initiative: a near reality?

*Carol White presents the proposal for an anti-missile defense of Western Europe as developed by Gregory Canavan of Los Alamos National Laboratory. The first of two parts.*

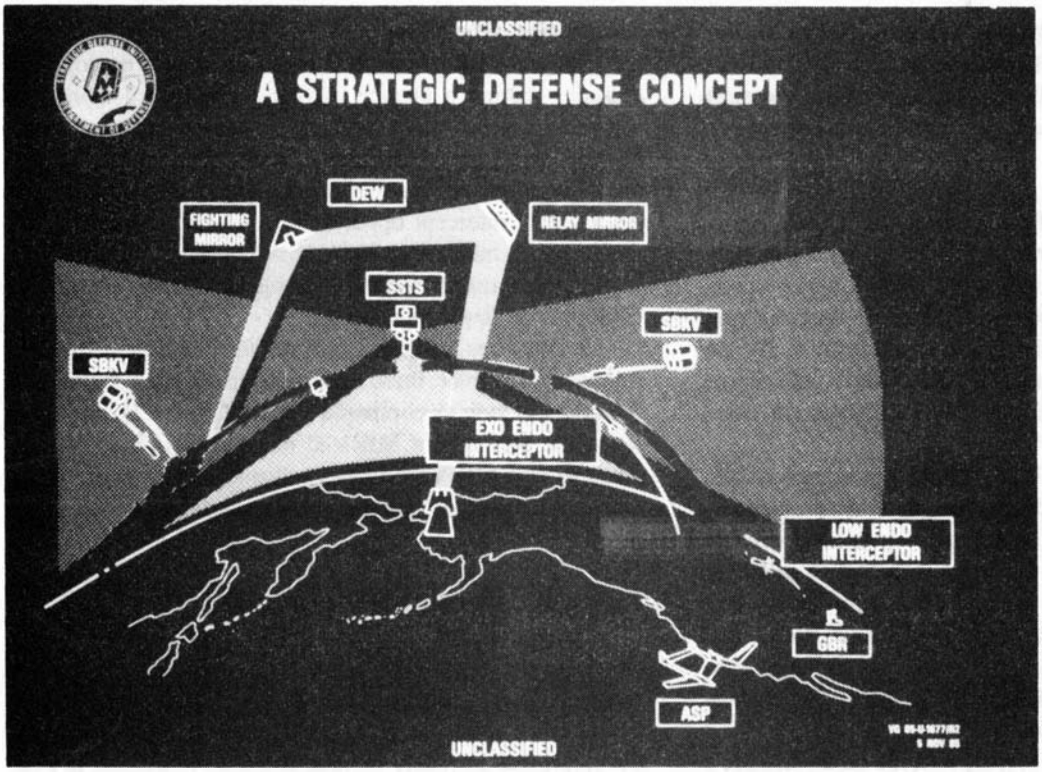
We are publishing here, excerpts from a recent study by Gregory H. Canavan, of Los Alamos National Laboratory, scheduled for publication in *Swords and Shields,* edited by Yost, Wohlstetter, and Hoffman. Canavan, who is the assistant division leader of the Physics Division at Los Alamos, concludes that, by all existing parameters, the adaptation of the Strategic Defense Initiative to Europe would be both easier and cheaper than the defense of the United States. Indeed, Canavan puts forward a proposal for the Tactical Defense Initiative to use space-based lasers for the boost phase intercept of Soviet ballistic missiles, and anti-missile rockets for mid-course and terminal intercept, that would cost only $2-3 billion, which he calculates to be one-tenth the cost of the SDI.

Over the past year, agreements for cooperation have been reached between the United States, Europe, and Japan, for research and development of the SDI. These will be critical for the rapid development of a defensive shield—for example, it is estimated that cooperation with the Japanese will push the date of possible deployment forward by two years. But the question of the SDI is not primarily a technical question. The shift in policy from Henry Kissinger's insane doctrine of Mutually Assured Destruction, to a commitment to mutually assured survival, is the key strategic issue of our time.

Because Kissinger's policy influence has not yet been eliminated in the United States, our European allies rightly are fearful that the zero-option, almost negotiated by President Reagan at the Reykjavik pre-summit, might become a reality—thereby throwing Europe open to Soviet domination. Therefore, they are susceptible to deliberate Soviet disinformation about the SDI policy, even though that policy would, in fact, guarantee a sound strategic basis to the U.S. commitment to Europe. The Soviets lie that the SDI implies a U.S. policy of first-strike, at the cost of our NATO allies. This lie is echoed by traitors, even in the U.S. Congress, and politicians of similar pro-Soviet bias in Europe.

Clearly, the currently developing climate of trade war plays into the hands of those who would decouple Europe from the United States, and who therefore wish to show the United States as a treacherous ally, not to be trusted. From every point of view it is essential that there be a full sharing of technology among the United States, the European members of the Western alliance, and Japan. Besides the technical issues, merely from the standpoint of the economic benefits which will spin off from the technical gear-up necessary to accomplish near-term deployment of the SDI, such cooperation is essential. What the West needs most of all is an economic recovery. Any military build-up would be useful in providing a cushion against the growing unemployment in basic industry; but the SDI is of particular importance because of the level of increased productivity which it would infuse into the economy. Conversely, such a mass mobilization for a crash deployment of the SDI, would be a way of defeating the mood of pessimism among European workers, which is making them susceptible to the influence of KGB-oriented circles in the trade-union movement—as in the recent French strike wave.

Nonetheless, the argument for the SDI should not be limited to the advantages for the Europeans of a strategic defensive shield. The Fusion Energy Foundation has actively developed the case in both Europe and Japan that the "SDI"




U.S. Department of Defense

*A schema for the Strategic Defense Initiative released in 1985 by the SDI Organization*

is equally important in providing a tactical-theater-wide defensive shield. The military effectiveness of ABM systems under conditions of a threat from short-range missile deployment has raised many questions. Since the military benefit has not been as obviously to the advantage of the Europeans, this has been played upon by the Soviets to suggest that the United States wanted the SDI to raise a defensive shield around a United States, decoupled from Europe.

Superficially, it might appear that the shorter distance involved in defending against tactical missiles, would raise serious problems in mounting an ABM defensive system by decreasing the time available for countermeasures to be taken. This, however, proves not to be the case.

In this report, we will quote at length from the chapter written by Canavan for the book, *Swords and Shields,* with some additional commentary of our own to explicate points which are otherwise compressed in the text—which appears to have been written with the expectation of an audience with a fair amount of expertise in the subject. The proposal for a European Tactical Defense Initiative by Canavan is relatively conservative in the technology it suggests. For that very reason, it is especially convincing, although we might wish to see an actual defense configuration which relied more heavily on advanced technologies, such as the x-ray laser.

One assumption by Canavan, which we would certainly take issue with, is that the Soviets will wish to engage in a limited tactical nuclear war, rather than risk an all-out war. Again, this does not obviate the otherwise useful conclusions which he develops in his study. He divides the consideration of defense against missiles into the traditional four tiers of the SDI: 1) low endoatmosphere, 2) high endoatmosphere, 3) mid-course, and 4) boost phase, remarking that: "This order—the reverse of that in the missile's trajectory—is useful for describing the concepts, since it moves from the more familiar to the less familiar ones."

Continuing, he writes: "In low endoatmospheric intercepts, below about 15 km, most large decoys have been decelerated and discriminated by atmospheric drag during reentry. Any remaining fast objects are likely to be reentry vehicles (RVs) containing weapons. In high endoatmospheric intercepts, up to about 100 km, decoys are decelerated sufficiently to permit partial discrimination.

"In mid-course, the portion of flight that lies above the atmosphere, all objects follow ballistic trajectories—even the decoys deployed with the RVs to conceal them. Thus, there is little basis for distinguishing between them. Since that is true for even very light decoys, the offense has the option of deploying them in very large numbers, which makes it unattractive to attack them indiscriminately. Thus, the ability to identify the actual RVs is pivotal to the development of a successful and robust midcourse layer. In the boost phase, neither RVs nor decoys have been deployed, and there is great advantage in destroying their missiles before they are."

In the discussion of the 1960s on the feasibility of deploying an ABM defense, the problem of decoys was a talking point against an ABM program; however, decoys can be spotted in any of the four above-cited stages either passively, by means of their infrared signature, or actively, by their response to laser or particle-beam bombardment. It is easiest to pick out decoys as they travel through the atmosphere.

## Time is not a problem

When missiles are fired from a closer range, their trajectory is lower. Thus, short-range theater missiles can only support undecoyed operations, since decoys which travel through the atmosphere respond differently to drag, making it relatively easy to discriminate and avoid decoys. By the same token, the speed of the missiles is reduced by the degree to which they are fired at shorter range. Canavan discusses this as follows:

"The range to the missile's target is an important variable, although its impact on the defense is sometimes misunderstood. The velocity required on optimal trajectories increases from 1 to 4.4 km/second as the range increases from 100 to 2,000 km. Even the highest are only about half the 7-8 km/second of intercontinental ballistic missiles (ICBMs), and the rest are well below the 4-5 km/second typical of submarine-launched ballistic missiles (SLBMs), which makes theater intercepts kinematically simpler.

"Moreover, apogee, the highest altitude on the missile's trajectory, decreases linearly from 500 to 25 km as the range decreases from 2,000 to 100 km. Apogee determines the total amount of atmospheric drag the object experiences in transit. Even RVs experience significant drag at 80-100 km altitudes, and light decoys are slowed enough by 120-130 km for discrimination. That means that short-range missiles such as the SS-21 and SS-23 whose apogees lie at 125 km or lower, cannot use decoys effectively, since they would be slowed perceptibly by drag, revealing the RVs for interception.

"Their trajectories could be lofted to a higher altitude to reduce drag and restore the efficacy of the decoys, but that would negate the advantage of the missiles' short range. The RV's flight time is uniquely determined by its apogee. Thus, increasing its apogee would also increase its flight time, giving the defense a time for warning and interception about as long as that for more survivable long range missiles."

Canavan makes an additional point which is of relevance to those critics of the SDI who suggested that the Soviets would develop a fast-burn booster rocket to prevent boost-phase missile kills. He points out: "Atmospheric deceleration and discrimination also affect long range missiles [e.g., SS-20s] by extending the interval during which they are most vulnerable. The bus, the final stage of the missile, which aims the RVs and deploys the decoys, cannot release either until it is above most of the atmosphere's drag, i.e., about 120-130 km. That extends the effective engagement times from the tens of seconds that fast burn boosters would require to accelerate the buses to the 100 seconds or more the buses would require to traverse the atmosphere—a dilation of the engagement time that is relatively insensitive to the missile's acceleration or burn time.

"The bus could then either try to coast to its deployment altitude—taking a chance of being intercepted along the way—or it could deploy its decoys at a lower altitude, which helps to evade the defense but unmasks the decoys to any onlooking sensors. The former provides boost phase defenders a useful intercept opportunity; the latter eliminates decoys, giving midcourse and endoatmospheric defenders an identifiable threat they should be able to intercept efficiently. Both options favor the defense."

He discusses the question of missile launchers which are reloaded. However, these can be dismissed since the time of reloading is long as compared to missile boost times. Similarly, the question of MIRVed missiles can be dismissed, since in fact MIRVing is a disadvantage with boost phase anti-missile defense. He then reviews defensive concepts in detail.

## Low endoatmospheric intercepts

Canavan writes: "In the past the major barriers to the development of viable concepts for terminal intercepts were radar blackout, saturation at high threat rates, and vulnerability, all of which could arguably now be overcome. New developments in radars include antennas imbedded in concrete slabs, replaceable radars, and mobility. If the radars only have to control low altitude intercepts, their size could be reduced enough for them to be truck mounted. Then the straight approach to survivability could be the use of mobile sensors and interceptors, which on off-road vehicles could be no less survivable than the targets they defend."

Canavan also raises the question of nuclear ABM missiles deployed in the low endoatmosphere, creating conditions in which the defending side is unable to deploy its own radar. This was the case with the Sprint missile in the Safeguard and Sentry systems of the 1960s. He points to the present development of non-nuclear, kinetic energy weapons as one direction of solution.

He goes on, "Today, infrared (IR) terminal homing could apparently eliminate the need for command guidance and still achieve the miss distances required for nonnuclear kill (NNK). The ability to intercept reentering ballistic objects with NNK interceptors was demonstrated in the 1984 Homing Overlay Experiment (HOE), based on which there are systems in development, which have already passed significant testing, that have the propulsion and maneuvering systems aimed at low cost needed to make NNK intercepts economically attractive. Both the missiles and their sensors could be scaled down directly, aiding their transfer to the theater.

"More sophisticated threats such as maneuvering reentry vehicles (MaRVs), which generate lift and change course during terminal approach, complicate the evaluation of terminal defenses. At present, maneuver is used primarily for accuracy, but in the future MaRVs could be used to evade interceptors with a limited pursuit capability. But a MaRV's evasive acceleration scales roughly as the square of its velocity. At the lower terminal velocities of the theater their ability to evade is reduced by a factor of 10-100, which should permit even modest interceptors to engage them.

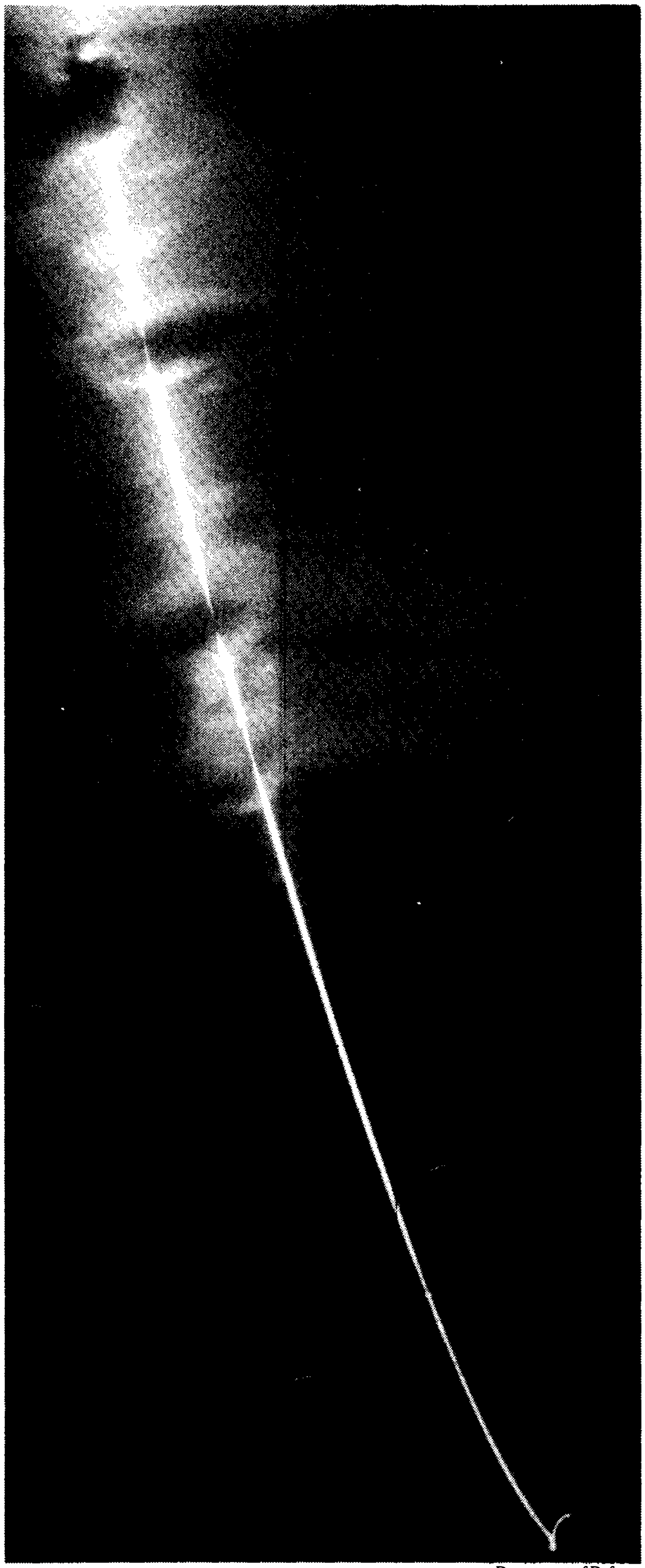
"A second complicating factor," he writes, "is salvage fusing." Here the enemy booby traps his warhead so that it explodes when it is hit by a non-nuclear kinetic energy weapon; whereas, ironically, a nuclear tipped defensive missile will kill the incoming missile before the salvage fusing has time to detonate. Therefore, he continues: "At low altitudes such salvage detonations could produce a significant fraction of the desired damage to the target, as well as degrading its defenses." Canavan rejects arguments for lasers, railguns, etc. at this stage of the defense, in favor of chemical rockets.

## High endoatmospheric intercepts

The issues in this regime are closely related to those in the low endoatmosphere—as are the systems concepts that result. There are, however, significant differences. Nuclear detonations in this regime do not produce catastrophic damage to targets or sensors far below, so salvage fusing is less critical. And since a MaRV's acceleration is proportional to the local air density, its evasive capability is reduced by an order of magnitude at high altitude. Offsetting those benefits is the fact that decoys are only partially decelerated, which makes them hard to identify. The key developments in this regime are infrared sensors that can avoid the background and survivability problems of previous systems, and improved discriminants that could take full advantage of the simple interceptors there.

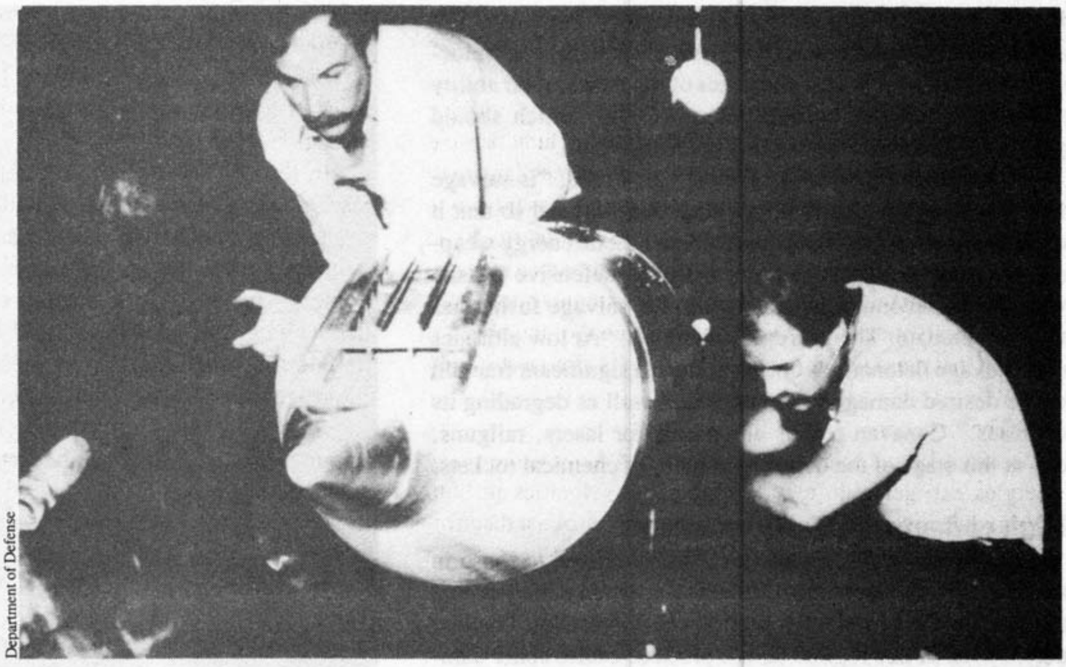
"Radars for high altitude systems are more susceptible to nuclear effects, jamming, and saturation than are those for low altitudes. That again makes IR sensors attractive, since they largely bypass those problems as well as relieving the mobility of problems of long range radars. Earlier radar-based systems were suceptible to nuclear detonations and decoys, which set an upper limit on the discrimination altitude of about 100 km, with which even high performance missiles could only achieve intercepts at 10-30 km." It is obviously desirable that ABM missiles be cheaper than the offensive missiles which they are attacking. This depends upon the height at which they can achieve their goal of intercepting the opposing missile.

He continues, "The leading interceptor candidates are homing IR sensors. The missiles should be similar to those used at low altitude. The IR sensors are more difficult since the targets, which have not yet been heated by reentry, are much dimmer. Lasers have been studied for high altitude, but the performance limits discussed earlier apply there, too. For undecoyed threats, railguns remain at a disadvantage, since chemical missiles are still more effective. If, however, countermeasures or nuclear effects drove discrimination altitudes down to 60-80 km, that would drastically reduce



Department of Defense

*The Army's HOE flight vehicle streaks skyward in the final fourth flight of the Homing Overlay Experiment program on June 10, 1984. Minutes later it destroyed its target, a reentry vehicle from an ICBM launched from Vandenberg AFB, California.*




*Model of a High Endoatmospheric Defense Interceptor (HEDI), a ground-launched interceptor capable of engaging ballistic missile reentry vehicles in the atmosphere. It uses an infrared or heat-seeking sensor. In this photo the HEDI is being subjected to hypersonic flow to test the effects of high speeds on the sensor's window.*

flyout times, placing the railgun's flyout velocity at a premium.

"Adequate sensors and interceptors are being developed, and again there is an obvious progression that starts with radars and leads to aircraft-based IR acquisition and discrimination. The highest leverage would appear to lie in the development of exoatmospheric discrimination techniques so the whole high altitude battle space could be used efficiently."

## Mid-course intercept

Again in a general discussion of the case of mid-course intercepts, relevant to his view for the SDI or TDI, Canavan opts for kinetic energy kill concepts. While this emphasis may appear practicable in the immediate next period, if we consider the SDI as a system which will evolve through successive generations of complexity with increasingly advanced technologies, then the criteria for deployment at any given stage must anticipate the contribution of that stage to future technologies. From this standpoint, we would take issue with his giving priority to kinetic energy weapons, even where they may seem attractive on the basis of cost.

While Canavan correctly indicates a problem for laser weapons consisting of the fact that RVs at this stage will be harder by factors of 10 to 100 than boosters and buses, nevertheless we would look to advanced laser concepts, including tunable free electron lasers and x-ray lasers, to achieve shockwave effects which would demolish the effectiveness of missiles without necessarily "knocking them out."

Two generic kinetic energy concepts are discussed by Canavan: ground-launched and space-based NNK missiles. He writes: "The former are being developed for a strategic exoatmospheric reentry intercept system (ERIS), which would launch the interceptors from the ground and require their small field of view IR homing sensors to reacquire targets that have already been discriminated. ERIS is a direct attempt to convert the technology demonstrated in the HOE experiment into a practical system by substituting smaller missiles and cheaper sensors. Its limited range, small field of view, and limited on-board discrimination should permit sensor and processor to be small, and the long flyout times should permit the missiles to be efficient.

"Alternatively, space-based buses or 'Porcupines' could economically carry small solid rockets that could be launched quickly in any direction. The buses could either be deployed on warning or predeployed in space. The goal for either deployment is to reduce the interceptors to little more than familiar IR-guided air-to-air rockets by shifting major acquisition, track, and discrimination functions from the individual missiles to the bus or another satellite altogether. In the former the cost of those functions could be shared by the bus's 10-100 missiles; in the latter the cost could be shared by all of the defensive missiles in the battle. If ERIS or Porcupine achieve their cost targets of a few hundred thousand dollars per intercept, they should be very cost-effective relative to offensive theater missiles. Offloading discrimination should make the sensors small, missiles efficient, and costs low.

"Discrimination can be classified as either passive or active. The former includes such concepts as imaging and radiometry; the latter ranges from low power inspection to high power interrogation. Passive and low power techniques should suffice against the penetration aids initially encountered in the theater. With time and development, however, theater decoys could be made to look much like RVs to them. Thus, for the longer term, active measures are required."

## Lasers

"Current candidates for active measures include passive lasers and particle beams. Each uses a familiar mechanism to probe remote objects to measure their mass. Lasers probe with impulse. When a laser delivers a pulse of energy to an object, material is blown off, whose recoil imparts a measurable velocity to the object. The ratio of the impulse delivered to the velocity measured gives a measurement of the object's mass. If that mass is significant, the object is almost certainly an RV.

"The appropriate lasers for impulsive interrogation operate at visible and shorter wavelengths. Achievable pulse energies can generate readily detectable velocities in both RVs and decoys; their difference should be a robust discriminant. Impulsive interrogation also deflects the objects by an amount that increases with the laser's energy and the RV's range. *Thus there is a real possibility of using mid-course lasers not only for discrimination but also to kill the RVs identified.* [emphasis ours.]

"Basing is a concern. Although such lasers are about 10% efficient at scale, producing the large required input electrical pulses in space or on aircraft would be difficult. Ground based lasers are relatively insensitive to those problems, since they can tap into or generate the required power. Ground based lasers could interrogate many targets directly, since they could see the deployment phase of launches up to 1,000 km away, and the apogees of launches several times further away. But direct illumination involves long slant ranges through the atmosphere. That distorts the beam, requiring sensitive corrections.

"To avoid those long paths and corrections—and to exploit the whole mid-course rather than just its latter phase—the ground-based laser could instead be used to provide energy to mirrors carried above the bulk of the atmosphere by aircraft or satellites. Those 'hybrid' mirrors would then redirect the beam to its target. Aircraft basing is practical in the theater, since the ranges would reduce the redirecting mirrors to the order of a meter, which is practical for airborne applications. Space basing the mirrors avoids aircraft survivability concerns and operational constraints, but introduces concerns about satellite survivability. In the theater, however, both issues can be avoided by using popup deployments.

"In a popup mode the defender would, on detection and confirmation of attack, launch the hybrid mirror on a roughly vertical trajectory. The mirror could begin to operate as soon as it reached altitude, making almost all of mid-course accessible—the 30 seconds or so required to pop up the hybrid mirror would only constitute a 10% reduction. Popup extends the transmitter's range far beyond that available with either ground or air-based systems without incurring the full absentee and survivability costs of predeployment in space. The ground based lasers would have to be made survivable and assured a clear path to the mirror. The main obstacle is size, but even with present scaling the lasers would have dimensions of 5-10 m, which is large but compatible with modularization for dispersal."

In the case of the Tactical Defense Initiative, only one laser-mirror pair is needed to handle the threat. Problems of discrimination are simplified because the number of reentry vehicles are less by an order of magnitude, and so he concludes: "But even if the attack involved 100 RVs with 10 decoys per RV, interrogating all 1,000 decoys during the 250-450 seconds available in midcourse would only require interrogation rates of a few objects per second, which is within the capability of a single repetitively pulsed laser-popup mirror pair. Since those performance levels are orders of magnitude below those required for strategic applications, theater mid-course discrimination could be an early application."

In the case of particle beams, Canavan also admits that while they are useful for purposes of detection, they can also destroy the RVs which they find. He writes: "When particle beams irradiate objects with hydrogen beams they produce a spectrum of neutrons, gammas, and x-rays, which can be detected remotely. The strengths of those signals are roughly proportional to the object's mass. That allows discrimination of the heavy RVs from the light decoys, which give essentially no return signal. Nominal beam parameters can support required interrogation rates and ranges.

"The beam's energy is set by the RV's mass, but its current and dwell time can be varied. Thus, particle beams could not only discriminate decoys but also destroy the RVs found. And they could do so quite effectively relative to both lasers and kinetic energy. Neutral particle beams would probably have to be predeployed in space because of their size, but they should still be survivable because of their ability to discriminate and defend against decoyed attackers.

"The principal problem in midcourse is the discrimination of the numerous, credible decoys possible there. Passive techniques look adequate in the near term; active concepts are required for the long. Pulsed lasers and particle beams look quite capable. Their interaction signals are strong, so they should be able to support robust discriminants. Popup basing looks practical for hybrid lasers; predeployment looks appropriate for particle beams. The key issue is their sensitivity to countermeasures. Given effective discrimination, the interceptors could be modest NNK missiles launched from the ground or a survivable space platform. Their combination would provide both a defensive footprint as large as the theater and the discrimination handover needed to fully exploit the endoatmospheric layers."

## Laser defense in boost phase

When Canavan moves on to discuss boost-phase intercept, he makes it clear that what he has in mind is not a variant of the Graham high-frontier proposal, which would substitute off-the-shelf rocket technology for the use of advanced concepts, and in particular the deployment of lasers. While there may be shadings of difference on the profile which Canavan describes, for a multi-layered defense, it is emphatically not related to Graham's Rube Goldberg schemes. He writes:

"In the boost phase it is possible to attack the missiles and buses, which are much softer than the RVs they deploy. That provides many-for-one kills on MIRVed launchers and eliminates their decoys altogether. The boost phase concepts have been widely discussed. There are five main categories: space based lasers, ground based lasers, particle beams, kinetic energy weapons, and nuclear concepts. Space-based lasers burn holes in targets by focusing their energy on small spots on them for a fraction of a second.

"Ground-based lasers use space-based mirrors to focus microsecond pulses of energy on the targets and punch holes in them—an extension to higher energies of the impulse coupling phenomena discussed above for discrimination. Particle beams disrupt or destroy electronics, explosives, and structural elements of missiles, buses, and warheads. Kinetic-energy projectiles kill boosters and buses by colliding with them. Nuclear directed energy concepts are also being studied. Their principles of operation, scaling and countermeasures can be described briefly.

"Space chemical lasers produce power by burning rocket fuels and deliver it to distant targets with large focusing mirrors. The Defensive Technologies Study (DTS) indicated that laser powers of tens of megawatts and mirror diameters of tens of meters should be attainable. Satellites with 20 MW lasers and 10 meter mirrors, the '20-10' concept discussed for strategic defense, could kill targets hardened to the DTS's limit at a range of 1,000 km at a rate of several thousand per second. Thus, the simultaneous launch of a thousand missiles from the current distributed configuration would require the presence of about 10 satellites in the battle—although the total constellation would have to be about a factor of 10 larger to account for 'absenteeism,' the satellites that are over another part of the globe when the missiles are launched. There is reasonable agreement that space lasers of this size with nominal performance would need a constellation of about 100 satellites to achieve strategic defense goals."

Despite the fact that part of the cost-effectiveness of a missile system lies in the value of the assets which are protected from missile attack, strategic planners are being asked to justify deployment of an ABM system by a 1:1 ratio between cost of offensive and defensive missiles. Even on a strictly cost-accounting basis, Lyndon LaRouche has estimated that a ratio of 1:100 would be sound, when one includes consideration of the cost of the potential target. In any event, however, Canavan shows that a laser defense is cost-effective even by narrow criteria, and this without regard to kind of cost reduction which will occur as the technologies implicit in the development of the SDI sift through the economy as a whole, raising productivities and thereby cheapening the cost of production of SDI hardware.

Canavan continues, "There has been less question whether the laser and mirrors could be built than whether it would be cheaper to deploy them or their countermeasures. The principal countermeasures are hardening the missiles, spinning them, decreasing their burn times, reducing the size of their launch areas, and attacking them. Hardening adds ablative material to provide more protection against the laser's radiation. Practical schemes must add protection over the whole booster. Since that area is about 1,000 times greater than that of the spot irradiated by the laser, the laser's preferential attack offsets the 100-fold advantage that accrues to the missile because the chemical efficiency of hardening is that much greater than that of generating the laser beam. Spinning the booster only decreases by about a factor of two the ten-fold net advantage for laser beams that track the heated spot on the target.

"The estimates above used a projected 100-second engagement time, although today's boosters have burn times and deployment times that are each about twice that value, giving them total engagement times of 400-600 sec. Fast burn boosters could ideally reduce theater burn times to a few tens of seconds. But if multiple warheads or decoys are required, their deployment extends the effective engagement time to about 100 seconds—even assuming that the buses can be made very hard while drifting to deployment altitude and deploy very fast once it gets there. Neither development is obvious. The buses face the same hardening penalties as the missiles, and they have to expose their soft interiors to off-load.

"Mathematically it is advantageous to the attacker to concentrate his missiles in a compact launch area—ideally a point—to try to punch a hole in the defensive constellation locally. With mobile launchers such a concentration of the missiles could be possible, but there are drawbacks. Simultaneous point launch onto anything other than a single, crowded trajectory means nonsimultaneous arrival at a given target, relaxing the time lines for the mid-course and endoatmospheric defenses. Conversely, simultaneous arrival for structured attacks requires nonsimultaneous launch, which lengthens the boost phase engagement time and increases their effectiveness.

"It is possible to get away from these 'point trajectories' by dispersing the RV's trajectories. But the fractional change in an RV's flight time is about half that in its apogee, and from the flight time and apogee of an optimal 1,000 km trajectory are 450 seconds and 250 km, respectively, so spreading the trajectories by even 100 km vertically would spread their flight times by about 90 seconds, which could either increase the duration of the atmospheric defense by a factor of five, or increase the duration of boost phase defense by 100 percent. The former would reduce saturation of the less expensive terminal defenses; the latter would offset the advantage to the attacker for having gone to the point launch in the first place. Point launch imposes no penalty on—and provides some advantages to—the area-insensitive popup-basing modes available in the theater.

"If the attacker is unable to penetrate the defenses without prohibitive losses, he could try to suppress them by attacking the defensive platforms just before the launch. For lasers the treatment of suppression largely covers the same issues as the earlier discussion of countermeasures, since the suppressing missiles would have to be protected by essentially the same techniques if they are to have any chance of reaching the satellites. But those techniques fail in suppression for the same reason they are ineffective as countermeasures. Against individual satellites they extract a modest penalty, but against full constellations, particularly ones that can kill boosters and discriminate decoys, defense suppression is extremely costly.

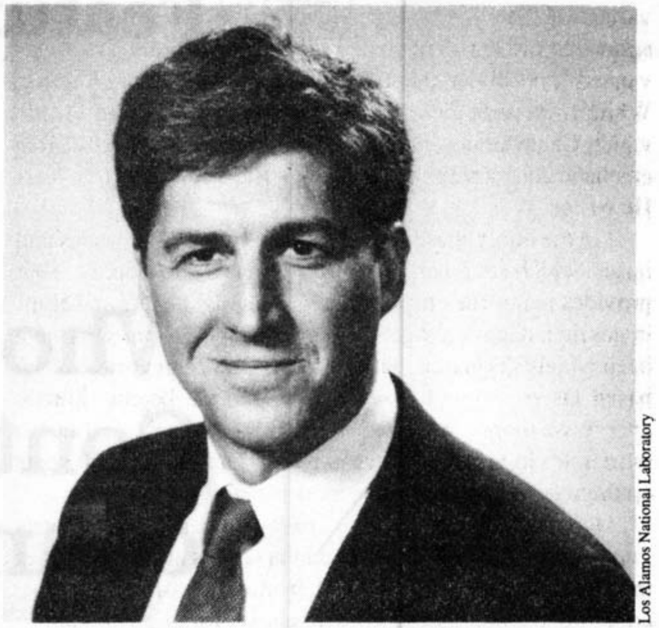
"Ground-based lasers obey roughly the same constellation-size scaling as space lasers, although visible lasers can produce the same brightness as infrared lasers of the same power with mirrors a factor of 10 smaller and 100 lighter. Ground basing takes the massive laser out of space, but it does so at the price of ground facilities that must be made survivable and provided with an unobstructed propagation path.

"Particle beams obey roughly the same scaling, with significant modifications for lethality, since they could kill targets at the same rate as lasers 100-1,000 times brighter. Countermeasures to particle beams are difficult. For a bus the hardening penalty would be about 1.5 tons, essentially its whole payload.

"The strongest constraint is fast burn boosters. Ideally, they could burn out as low as 70-80 km, while particle beams only penetrate down to 120-130 km. There is, however, a window for them to engage the buses, which should start to deploy at the altitudes the beams can reach in order to avoid drag. The particle beam's engagement time is then decreased to roughly the buses' deployment time which might only be a few tens of seconds, but even that overlap could be significant. During deployment the buses cannot tolerate disruption of their electronics. But disruption requires very little current, so the beam could split its large total current and disrupt many buses simultaneously, which effectively destroys it."

## Kinetic energy weapons at boost phase

"Kinetic energy concepts for boost phase are an extension of the NNK missiles discussed earlier. Their goals remain the development of small, cheap missiles with simple IR sensors. Their constellations scale somewhat differently than those for directed energy. For the current distributed launch configuration they scale at approximately the number of offensive missiles divided by the launch area, giving about the same size constellations as lasers. For point launch, the engagement time determines the scaling, giving constellations an order of magnitude larger, which could still, however, be acceptable if the defensive missiles meet cost goals.



*Dr. Gregory Canavan, author of* Swords and Shields

"Countermeasures to kinetic energy platforms are limited. Hardening has little effect at high additive closing velocities. Spinning has no effect for the same reason. Fast-burn boosters could burn out at altitudes that are inaccessible to simple IR homing sensors. But that is compromised by the buses; need to deploy at altitudes, which the defensive missiles can reach. The fact that this only affords a few tens of seconds to engage does not represent at constraint, since NNK engagements are effectively simultaneous.

"Constellation estimates must also consider the warning delays needed to control false alarm rates, but that need take only a few seconds. Current technology could detect and characterize the threat in a few seconds; newer technologies much faster. The real concern appears to be the limited time for human intervention. That implies automation, which is disturbing to those who view it as provocative. But automating the launch of a unique missile onto a non-threatening trajectory with a payload that could not reach, let alone destroy, anything within the atmosphere is not threatening."

The complexity of battle management, particularly with kinetic energy weapons, is a serious consideration in evaluating the feasibility of an SDI defense. In theater defense problems this is simplified by an order of magnitude. For theater defense, the threat is scaled down by about a factor of 10, so that the defenses can be reduced accordingly. This means that overall computational and control problems are reduced by somewhere between 10 and 100 times. In the next article, we shall develop this aspect of the question.