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Is Strategic Defense Criticism Obsolete?

Rapid Technological Advances Have Changed the Entire Debate

Clarence A. Robinson, Jr.

Few Americans realize that strategic defense research did not begin with President Reagan's March 1983 speech calling upon scientists to see if they could devise a system for defending the United States against Soviet missiles. Actually, work on ballistic missile defense (BMD) has been going on for more than a decade. In the mid-1970s, the Navy initiated its Chair Heritage program for charged particle beam research at the Lawrence Livermore Laboratory, east of the San Francisco Bay area. Around the same time, the Army began a program called Sipapu (an American Indian word for sacred fire), a research effort into neutral particle beam weapons, at the Los Alamos Laboratory in New Mexico. Now called White Horse, that program is largely based on physics developed in the Soviet Union in the course of its BMD effort. Indeed, many BMD research programs in this country, especially in directed energy—lasers and particle beams—were initiated in Soviet laboratories such as Novosibirsk, Alexandrovka, Troisk, Sary Shagan, and Sarova.

The problem with the various BMD efforts in the United States during the late 1970s and early 1980s was that they progressed without any sense of coordination or coherence. There was no focused effort, constant service rivalries, and infighting over priorities and funding. Progress was usually made at the expense of other programs already in research. Sometimes there were impressive scientific breakthroughs, but they aroused little interest in a military bureaucracy that was, at the time, aiming its attention at redressing tactical forces and an offensive imbalance brought about by expansion of the Soviet ICBM force. Indeed, in the early 1980s, the Defense Research Projects Agency determined that 24 mid-infrared chemical lasers operating in low earth orbit could significantly blunt a missile attack by the Soviet Union. But the Pentagon showed little enthusiasm. At the time, it was trying to get support for the new MX missile and a survivable basing mode.

What President Reagan's so-called Star Wars speech did was give diffuse BMD programs a sense of strategic coherence and scientific coordination. Funding for strategic defense ended up being slightly less than what would have been spent on various technologies had they remained as separate programs under the Defense Research Projects Agency, the military services, and the national laboratories. But the level of funding was structured by the Reagan Administration to rapidly increase as the BMD research effort progressed.

No longer were breakthroughs to be overlooked. The various developing technologies were to be integrated by a central office that would structure them into a multilayered defense to intercept missiles and warheads in different phases of their flight.

From the beginning, the strategic defense initiative office (SDIO) was directed to conduct research within the context of the 1972 Anti-ballistic Missile Treaty (ABM) with the Soviet Union. (The treaty proscribes deployment of a defense against ICBMs, with the exception of 17 radars and 100 interceptors.) Further, SDI was aimed not only at devising the means for the layered defense, but also at developing measures to undercut the Soviet Union's ability to thwart such a defense. The problem of "countermeasures" was part of the SDI effort from the start.

Why the need for such a program at all? The reason is the changing strategic situation vis-a-vis the Soviet Union. In 1972, at the height of detente, the United States felt it had developed a way to restrict the growth of superpower arsenals. Offensive missiles were curtailed by SALT I, and deployment of defensive systems was limited by the ABM Treaty. Yet despite this, between 1972 and the present, the Soviet Union—sometimes in compliance with the treaties, sometimes in violation—developed and deployed five new classes of ICBMs and upgraded these missiles seven times. By contrast, the United States introduced its last new ICBM prior to the MX in 1969, and upgraded it only once. Soviet missile building resulted in a frightening asymmetry in force structures between the two countries.

CLARENCE A. ROBINSON, JR., *former senior military editor of* Aviation Week, *is currently president of Leading Technologies in Arlington, Virginia, which does research in areas of high technology weapons, including strategic defense, for the government. He is adjunct professor of national security and space studies at the Georgetown University graduate school.*

sure that if I had been able to devote myself full time to acquisition, I could have done a much better job.

At the same time, we believe it is important to maintain the services' traditional role in managing new weapons programs. The proposal for a single centralized acquisition policymaker is designed to help make decentralization work better. It is part of our recommendation for short, clear, and unambiguous lines of authority and communication between program managers and top-level acquisition executives. Rather than create more centralization, this proposal will create a climate in which real decentralized execution can take place.

My own experience at Hewlett-Packard confirms the importance of decentralization. Early in our history, we decided that there were two important reasons to decentralize the organization.

The first is that decentralization enables people to concentrate their attentions on a limited area, and therefore to develop a specialized expertise and competence. We also felt that breaking the organization into small units would make it easier for people to identify personally with our company. One of the lessons of the current books on excellence is that people make the greatest contribution at work when they develop a personal rapport with the organization. We thought that this would be easier to do if the company were broken into small groups.

One can see this principle in the military services already. The Marines are the smallest of the services, and in many ways they are the most devoted to their own corps.

The current Model Installations experiment, under the direction of Deputy Assistant Secretary Robert A. Stone, is an example of effective decentralization. Under this program, local commanders of some 40 bases around the country are relieved of some of the rules and regulations common in the Defense Department and given more flexibility in managing their commands. The program can demonstrate substantially improved performance at bases, when capable commanders are given the freedom to make decisions on their own.

We'd like to develop centers of excellence throughout the department. I think that's the way to achieve substantially improved performance. You cannot legislate excellence into an organization. And you cannot inspect quality into your organization any more than you can inspect quality into your product. You have to develop teams with the dedication to getting the job done.

Now in taking this approach, it's not effective simply to let everyone go his own way. That is one of the problems we've had. You need a central sense of direction, and a central goal, and then freedom to work toward the achievement of that goal.

Weapons that don't work, exorbitant prices for spare parts, and other evidences of a troubled situation did not originate with the current administration. I had to deal with the same problems when I was Deputy Secretary of Defense 15 years ago.

Yet the Defense Department has always been able to perform exceptionally well when it operates outside the normal system on a "crash program" basis. One of the most successful programs was the Navy's development of the Polaris submarine-launched missile in the late 1950s and early 1960s. This was an extremely complicated program and no one was sure it could be done. But Admiral Red Raborn put together a team of excellence, and the missile system was operational three years ahead of target date. The payload capability and reliability were well within specifications.

Defense acquisition is the biggest management job in the free world, and there ought to be somebody in charge of it on a full-time basis. Right now no one is.

The F-16 program that I started was one of the major programs that involved prototyping. The aircraft was on time and on budget, and it has turned out to be one of our best-performing aircraft in terms of flight performance and reliability.

The prototyping was effective because we were dealing with real hardware instead of paperwork, and we could evaluate performance by flying two competitors against each other. We tested the F-16 built by General Dynamics against the F-17 (now the Navy's F-18) built by Northrop. Both are very good planes.

Another successful crash program was the production of the U-2 and SR-71 high-altitude aircraft at the so-called Skunk Works in Lockheed under Clarence L. (Kelly) Johnson. Both programs were highly classified and way out in front in technology, and so it was easier to keep the number of people involved to a minimum. One reason for their success was that they enjoyed minimum interference from both the Defense Department and Congress. The lesson of this, of course, is not necessarily that we need more secrecy in programs, but that if you have capable program managers you don't have to double-check on them every five minutes.

These successful programs in the Defense Department followed management practices similar to the best found in private industry. If they were applied more broadly within defense acquisition, waste and delay in the development of new weapons would be minimized, and there would be greater assurance that military equipment would perform as expected.

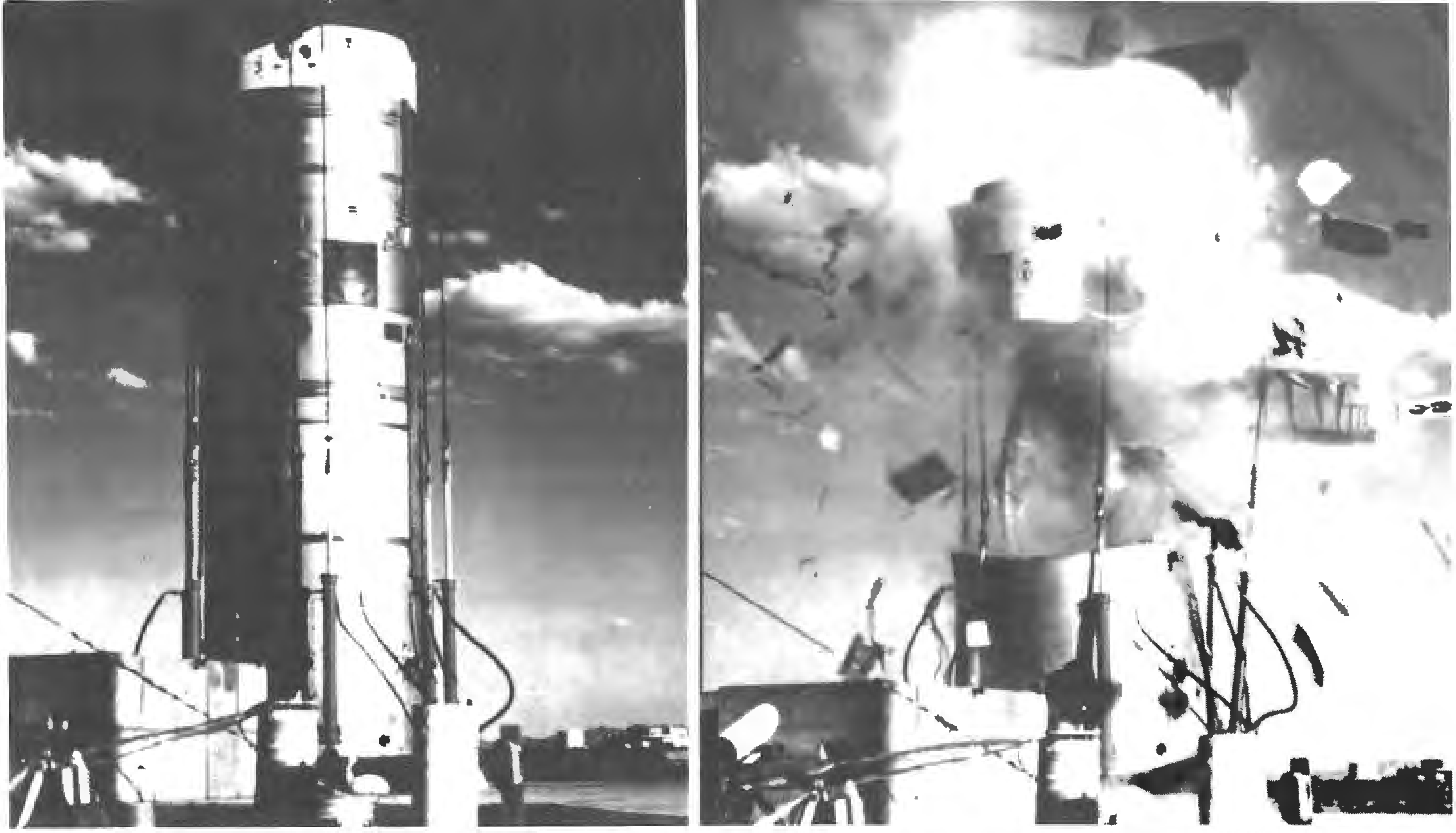
This asymmetry has military and political significance. With 1,400 ICBMs carrying 6,000 nuclear-armed reentry vehicles (warheads), the Soviet Union can threaten to attack American silos in a first strike with only its newest model SS-18 and destroy up to 90 percent of our Minuteman ICBM force. Conversely, a U.S. attack on Soviet ICBMs would destroy only about 15 percent of their force. This disparity is caused by a combination of factors: the United States has smaller missiles and lower-yield warheads, and the Soviet Union has up to 10 warheads on each missile, as opposed to up to three warheads on the U.S. Minuteman 3. The Soviet Union has also greatly increased the accuracy of its SS-18s to 800 feet Circular Error Probable—that means that 50 percent of the warheads fired will land within an 800-foot radius of the target.

At the same time as it expanded its offensive strategic force, the Soviet Union also proceeded with strategic defense. Now the Soviet Union has an operational anti-satellite weapons system based at Tyurantam. This system, using two types of sensors, successfully destroyed Soviet target spacecraft in a number of tests. Further, the Soviet Union has developed an extensive air defense network with some missiles that can function in an ABM mode, such as the SA-5 Gammon and the SA-12. Aggressive improvements are being made in Soviet radars, interceptor aircraft, and surface-to-air missiles. At Krasnoyarsk near Siberia, in violation of the ABM Treaty, the Soviet Union is constructing a missile detection and tracking radar. It is also stockpiling ABM engagement radars and interceptor missiles such as the ABM-X-3 phased array radar and the SH-04 and SH-08 missiles. Finally, the Soviets have built a variety of lasers, from gas dynamic to short wavelength chemical devices. All this creates a picture of a developing Soviet missile defense that could, in the aftermath of a Soviet first strike, absorb much of the weak retaliatory land-based arsenal of the United States. It is, literally, a scenario for Soviet nuclear victory. If unchecked, the Soviet Union will be in a position to achieve this in the mid-to late 1990s. American offensive deployments, constrained by budget allocations, cannot hope to significantly alter the picture. Hence the urgent need for strategic defense.

Missile Vulnerability

Strategic defense, in some portrayals, seems awfully fanciful and exotic. Actually, it is based on a very real and quite obvious fact—the incredible vulnerability of the ICBM. Missiles look to be indestructible, but in fact they are not. When missiles are traveling at high speed, 28,000 km/hr, even a small rock or ice cube placed in their path would destroy them on impact. Because the Soviet Union piles up to 10 very heavy warheads on its missiles, which the missile then has to carry for several thousand miles to the United States, the outer covering of the missile is built much like an aircraft—it is light, it is fragile, it is made of thin materials such as anodized aluminum and composite materials. Also, the internal pressure from the burning of propellents in the booster tanks applies force to the outer "skin" of the missile and it must sustain high gravity forces, increasing its vulnerability. The intense radiation produced by the burning propellent provides an infrared "signature" that makes detection and tracking of the missile relatively easy. The task of strategic defense is to locate the missiles and then destroy them.

In the last few years, influential groups of scientists have informed the American people that this is an impossible task—so remote that it is not even worth trying. They have advanced numerous "countermeasures" that the Soviet Union could supposedly use to render SDI useless. These countermeasures are proposed by critics as though they first thought of them. Actually, the countermeasures were considered in the Fletcher Report in 1983, prepared at President Reagan's request under the directon of James Fletcher, head of NASA. The report concluded that SDI was possible not only as a means of protecting American military targets but also as a population defense. As research into SDI has progressed since the Fletcher Report, defensive weapons have been devised for which there are no known countermeasures. Means for avoiding or defeating other countermeasures have been devised. The vast



A Titan booster is destroyed by the Navy's MIRACL laser during a September 1985 test.

majority of technical criticisms of SDI have been overcome and are not considered insurmountable obstacles by most scientists working on SDI, although they remain part of the political propaganda for groups opposed to strategic defense.

One of the most serious countermeasures proposed is fast-burn boosters, which would lift the missile out of the atmosphere with extra speed, causing it to discharge its warheads earlier, thus reducing the time the defense would have to shoot the missile down in its first phase of flight, when it carries all its warheads. Further countermeasures the Soviets could adopt would be to rotate or spin the booster to preclude focusing a sharp laser spot on the missile, coating the booster with an ablative shield to overcome the destructive thermal coupling from a laser beam; coating the booster with a lightweight material such as cork, for the same purpose; and providing a maneuvering capability for warheads along with additional "penetration aids" and decoys to bewilder the missile defense.

None of these would work very well. The fast-burn booster, for example, would require the Soviet Union to reduce the number of warheads on each missile and decrease its range in order to achieve the extra energy required in a given volume for the rapid acceleration capacity. This in itself would be a desirable result from the U.S. point of view. The SS-18 now has 10 warheads with a capacity of up to 34 warheads per missile. It would certainly enhance stability for that number to be considerably reduced for fast-burn prospects.

Naturally, the Soviet Union would be reluctant to trade weight and range in order to gain speed in the first phase of flight. Even if fast-burn boosters were deployed, the United States can develop kinetic energy interceptors capable of higher velocities so that the missile target could still be reached despite this shortened boost time. To do this, the United States would need to build rockets with a speed of 20 km/second. Today's rockets are capable of more than 10 km/second, but research progress is being made in speeding them up. Alternatively, it would be possible to fire projectiles at more than 10 km/second using electromagnetic energy. Oddly, groups opposed to strategic defense often advance countermeasures like the fast-burn booster and then oppose research into means to overcome them.

Spinning a missile the size of an SS-18 is no easy task. And it is complicated by the fact that the Soviet Union would have to spin its missile at the speed of precisely one revolution per second, and that's only to protect against mid-infrared lasers. A slower spin would not prevent a sharp laser beam from burning a hole in the skin of the ICBM and destroying it. A faster spin would have no effect on the lethality of the laser beam, either. Other lasers require different rates of spinning for the ICBM. Performance of the Soviet ICBM would have to be degraded to achieve what is, in itself, an enormously complicated ballistic task.

The use of the ablative coatings, which would be effective against continuous wave infrared high energy lasers, would be heavy and costly to deploy on existing missile boosters already operational in hardened silos. The weight of the ablator would severely curtail range and throw weight. Even if effective against infrared lasers, such coating could not counter pulsed, short wavelength lasers, kinetic hit-to-kill vehicles, or particle beam weapons which send sub-atomic particles into the body of the missile and explode from within.

The task of locating warheads and separating them from decoys and chaff during the later phases of the flight is a difficult one. But remarkable measures have been devised for "interactive discrimination," the process of finding the nuclear warhead. For example, laser beams such as the ultraviolet excimer laser could be used to cause fluorescence by dislodging electrons from the surface of the warhead to produce a signature. The pulses of the laser could also be absorbed to produce an infrared signature on the warhead. Particle beams can also be used to interact with warheads and produce a radiation signature. The warhead, once identified, could easily be shot down with any of a number of kill devices.

Multilayered Defenses

This is not to say that none of the criticisms of SDI have merit. But they are refuted by the concept of a multilayered defense. If the United States deployed not one but several systems of missile defense—kinetic hit-to-kill rockets, the electromagnetic coil and rail guns, directed energy neutral particle beams, chemical lasers, and so on—then Soviet missiles and warheads that eluded one aspect of the defense would be targeted and destroyed by another. There is simply no countermeasure against all the possible layers of a missile defense. As time progressed, such a defense could become comprehensive enough to guarantee that 99.9 percent of Soviet warheads would be shot down. But even in the near term, defenses can be deployed that would absorb a percentage of a Soviet first strike. This could cause uncertainty and eliminate the incentive of the Soviet Union to launch such a strike in the sure knowledge that only a fraction of its warheads would get through—and then it must suffer the consequences in terms of a U.S. retaliation.

At the present time, the Soviet Union only has to target two nuclear warheads on each U.S. silo to be assured of a 90 percent probability of kill. With even limited defense, the United States introduces enormous uncertainty in the minds of the Soviet strategic nuclear planning staff. Calculations show that with two layers of defense deployed—boost and terminal—the Soviet Union would have to earmark up to 300 warheads for each target just to obtain a 50 percent probability of kill. With a single layer, the Soviet Union would have to allocate 100 warheads per target to achieve that same rate. These ratios suggest an enormously unfavorable situation for the U.S.S.R., both in terms of cost and in terms of wasting large fractions of the arsenal to do limited damage.

There is a growing voice among many in Congress and in the Pentagon that, given these hopes for strategic defense, a terminal defense should be deployed now. In particular, some have urged that the United States build a defense for missile fields where the MX missile is being deployed in order to protect it from Soviet preemptive attack. But these ideas are mistakes.

The reason is that the terminal defense, though essential as part of a layered defense, would only permit the United States to defend areas of missile fields and certain military targets—population defenses would be limited. This would undercut support for the program. More important, terminal defenses—which mainly consist of shooting small interceptors at incoming warheads from the ground—could easily be overwhelmed by the attacker. They give the attacker the incentive to proliferate his ICBMs and add to the number of warheads per missile in order to overwhelm the defense. Thus terminal defenses alone might be more risky and destabilizing than they are worth.

At the time the United States agreed to the ABM Treaty in 1972, we could only deploy terminal defenses, and they were nuclear armed in nature. Detonation of a nuclear device in order to shoot down an incoming warhead would black out the ground-based radar sensors the ABM system relied on; thus successive warheads could not be located and would penetrate. Also, the Soviet Union could add missiles and warheads—proliferate and fractionate, as the jargon has it—in order to overwhelm the system in a cost-effective way. The advantage in the early 1970s clearly lay with the attacker. Now with a variety of homing sensors and onboard data processing on small interceptors, the situation is somewhat different, but terminal defenses alone do not obviously shift the advantage to the defender.

With two layers of strategic defense deployed, the Soviet Union would have to earmark up to 300 warheads for each target just to obtain a 50 percent kill probability.

What makes strategic defense viable is rapid technological developments in missile defense during the boost phase—the first phase of the ICBM flight. That provides cost benefit and military advantage for the whole defense. After all, in the first phase of flight, the booster has all its warheads on it—a single strike and not only the missile but all its nuclear warheads are lost. Wait until the second phase, and the warheads are discharged; each one must be located and killed separately.

Killing the booster when it has all its warheads on board totally eliminates the incentive for the attacker to fractionate or add more warheads to each missile, because that means even more warheads would be lost. The boost phase defense disrupts the plan of the attacker because he cannot know ahead of time which of his missiles will survive and hit their targets. Small kinetic kill vehicles which could cost a few thousand dollars apiece might be used to destroy giant missiles costing millions, if not tens of millions, of dollars.

Four Phases of Flight

Here is what an effective strategic defense has to do:

The flight of a ballistic missile is considered in four phases. The first is the boost phase which lasts from 300 to 500 seconds. During this phase, the first and second stages of the rocket are burning, producing an intense infrared signature for early warning satellites to detect the launch from geostationary orbits.

The second stage is the post-boost phase when the "bus" carrying the warheads or MIRVs separates from the main engines. This phase lasts approximately two minutes, during which the warheads are aimed and fired from the

Ground-based lasers can compensate for turbulence in the atmosphere to send sharp beams into space. Shown above at an Air Force facility in Maui, Hawaii.

bus, along with penetration aids such as chaff, balloons, and decoys. It is possible to engage the bus and destroy it before the warheads are deployed, taking advantage of ultraviolet and other signatures from the bus.

In the third or mid-course phase, the warheads and penetration aids travel in a "threat cloud" on ballistic trajectories through space above the earth's atmosphere. This phase lasts about 20 minutes and is the longest part of the trajectory. There is lots of time to destroy the warheads, but the problem is to find them. They are hidden among the decoys and optical and radar chaff, and must be found and tracked first.

The terminal or reentry phase lasts approximately 90 seconds as warheads come back into the atmosphere above their targets. The decoys, being lighter, are then slowed down by the earth's atmosphere; this filtering process enables immediate identification of the warheads.

In the 1970s, the terminal defense could only react in the final minutes of an incoming warhead's trajectory, making interception very difficult. Also, the system was reliant on vulnerable ground-based phased array radars. And battle management and computer capabilities were insufficient to handle the large volume of threats and to filter out, through signal processing, decoys and penetration aids early enough to get the warheads and avoid being overwhelmed.

Today, though, things are vastly different. Enormous technical advances have been made, especially in four categories: ground-based lasers, space-based lasers, space-based neutral particle beams, and ground-based charged particle beams. In addition, there has been rapid progress in kinetic kill weapons technology, nuclear-powered lasers, and the battle management and computer coordination required to operate these different defenses as an integrated system. All these developments ensure that the military and cost advantages are shifting dramatically in favor of defense.

Ground-based Lasers

Genuine breakthroughs have happened during the last year with *ground-based lasers.* Based on earth, these devices propagate the laser beam through the atmosphere to a relay mirror in space that redirects the laser beam onto the targets' boosters and reentry vehicles.

Basing the laser on the ground is more cost effective than placing a heavy device in orbit with enormous power requirements. The ground-based lasers being developed are short wavelength in comparison with the mid-infrared wavelength space-based chemical lasers. This means they require more power, but that can be supplied on earth; it doesn't have to be lifted into space. Using short wavelength visible lasers on the ground enables keeping the relay mirror in space small, a few meters or less in diameter.

Recently, SDI researchers have figured out how to make mirrors lighter, which is crucial for lifting them into space. A flat mirror was recently manufactured that is less than 10 percent of the density of the primary mirror in NASA's largest space telescope. This level of performance meets the requirements for space relay mirrors. It is also important to stabilize the mirrors in orbit. They have to be in a direct line with the laser beam and the target. Scientists have figured out how to stabilize mirrors better than ever before. New materials are being used for the mirrors—ceramics and composites with optical coatings. Not only does this have stabilization advantages, but it costs less to build and lift into space.

Perhaps the most significant technical advances are in the area of so-called *adaptive optics technology.* The problem with firing lasers from the ground is that they are diffused by turbulence in the earth's atmosphere and the beam is degraded. The beam's sharp focus is needed to burn through the surface of the ICBM. However, researchers have developed sophisticated sensors which measure the turbulence in the atmosphere. A remarkable device, the rubber mirror, is used to compensate for these atmospheric distortions and send a highly focused beam into space.

The rubber mirror essentially consists of scores of actuators behind the surface; these selectively deform the mirror in a way that cancels out turbulence. Recent compensation experiments at a mountaintop site in Maui, Hawaii, have demonstrated that a low average power visible laser, in this case an argon ion beam, can be propagated through the atmosphere with pointing accuracies within required tolerances. It works.

Sensor technology, which complements laser technology, has also developed. One significant accomplishment is the cryogenic cooler, which is used to cool infrared sensors. Because the job of these sensors is to detect heat, they cannot be allowed to get hot themselves—the cryogenic cooler serves this purpose. Very small and inexpensive coolers have been built which are now undergoing testing. There have been other developments, such as increased sensitivity, imaging infrared, new detection materials, and mosaic arrays. SDIO has initiated contracts for the so-called terminal imaging radar, a ground-based sensor that is particularly useful for high endoatmospheric (within the atmosphere) engagements. This is critical for the terminal phase of the defense.

The feasibility of infrared lasers was impressively demonstrated in August 1985. A Titan booster was mounted on a test stand. The booster was filled with water to the same pressure as fuel, and was stressed to the same gravity loads experienced during launch. Essentially, conditions were simulated to make the Titan similar to a Soviet booster actually powered from within. An infrared laser, operating with multi-megawatts of power in a continuous wave mode, instantly destroyed the Titan booster. The Navy's Mid-Infrared Advanced Chemical Laser, called MIRACL, demonstrated the lethality of lasers against boosters.

Chemical lasers in general have seen dramatic advances. These lasers are capable not only of shooting down Soviet missiles and space-based warheads, but also other lasers aimed at destroying our missile defense system. Chemical lasers can be used in "keep out zones" to destroy any lasers or objects that enter into those zones. The United States has greatly improved its nozzle technology, which enables it to add more power to a laser for a given size. For example, our Alpha chemical laser, developed as a 2.2 megawatt laser, can now generate five megawatts because of nozzle advances and added modules.

For different kinds of lasers, there has been progress in beam control and large optics technology. Perhaps most significant is the ability to join together several powerful laser beams into a single concentrated beam. Researchers have coupled six laser resonators and proved the potential for a very high density beam. Optical phased arrays are used to coordinate these beams. Essentially, this is a system for multiplying the power source: if a single laser is not powerful enough to get a target, the forces of several lasers are joined.

There have been developments in mirror and laser beam director technology that enable a much better focusing of the laser beam onto its space target. Recently a large optics facility was completed which enables diamond polishing of laser mirrors to degrees of precision and quality never before achieved. The SDIO surprised itself by the pace of progress in this area. Research has also brought about improvements in beam emittance. This enables control of the laser beam and the ability to rapidly switch the beam onto primary and secondary mirrors.

At the Lawrence Livermore Laboratory, research has been moving full speed ahead into *charged particle beam devices*. These move at nine-tenths the speed of light. Primarily for terminal defense, the particle beam penetrates the warhead to destroy and disrupt its internal subsystems—the so-called "exploding brick" effect.

An additional effect of particle beams is that a cone of radiation surrounds the channel of particles. It is sufficient to destroy the electronics in nuclear warheads and to cause slumping of the nuclear materials, halting detonation. There is no known countermeasure to this defense.

Previously it was thought that charged particle beams could not be used for ballistic missile defense because electrons, being electrically charged, would be affected by the earth's magnetic field. Thus the beam's trajectory would be bent and precision would be lost. However, using a lower power laser, researchers have figured out how to make the electrons adhere to the laser photons and cancel out the earth's magnetic effects.

What makes strategic defense valuable is rapid technological developments in the boost phase—the first phase of the ICBM flight.

Work on the *neutral particle beam* includes the White Horse program at Los Alamos. The particles in this beam are hydrogen atoms, which are neutral ions. The purpose of this, again, is to avoid the effects of the earth's magnetic field.

There have been two substantial advances with the neutral particle beams—the first in adding to its duration, the second in adding to the power. Oak Ridge National Laboratory has produced high ion currents lasting more than five seconds—an incredibly long period of time. At Los Alamos, the goal is to develop a very high current beam (100 milliamp) using a device known as a radio frequency quadruple accelerator, the second stage of a neutral particle beam. This means that longlasting, powerful currents can be produced.

Neutral particle beam technology includes recently developed techniques to provide precision boresighting with optical trackers. This enables accurate aiming of the weapon. Further, the neutral particle beam, when applied against a "threat cloud" containing warheads and decoys, produces a radiation signature from the warhead which enables it to be identified and then destroyed. According to the SDIO, these advances provide new evidence that neutral particle beams have practical applications in near-earth orbit for weapons missions and for interactive discrimination.

At the Lawrence Livermore Laboratory, scientists are working on *free electron lasers*. Mounted on the front of the accelerator, the laser absorbs its electrons and converts them into visible laser energy. The free electron laser is incredibly efficient—it has been demonstrated at 40 percent efficiency, while the highest efficiency of other lasers, including the short wavelength excimer laser, is around four percent. A free electron laser will soon be built at White Sands Missile Range in New Mexico to demonstrate the technology of visible wavelength at high sustained power levels. Free electron lasers can be based on the ground and hit targets in space during any of the phases of a warhead's flight via relay mirrors.

Scientist Edward Teller has been a powerful advocate of the *nuclear pumped X-ray laser.* This is a very valuable weapon which will enable the simultaneous destruction of massive salvo launches of ICBMs. The laser is powered with a nuclear bomb. It works by exploding a small nuclear device and then channeling its power through 50 laser rods at targets in space. The rod is first aimed at the target, the nuclear device is exploded, and the target is no more. The nuclear pumped laser is a weapon of awesome power; no known countermeasure could withstand the force of concentrated nuclear energy fired at such speed. The efficacy of this technology was demonstrated in a series of tests at an underground Nevada nuclear test site.

The nuclear pumped laser is a weapon of awesome power for which there is no known countermeasure.

The initial feasibility was demonstrated with the X-ray laser in Dauphine and Excalibur tests. These were followed by a series of tests named for cheeses: Romano, Cabra, and Cottage. The last test, Cottage, was held in March 1985. It proved the physics for the system and identified new high energy laser and optics schemes to direct the X-ray beams.

Since a nuclear weapon device is a pumping mechanism, the United States cannot base X-ray lasers in space and adhere to the space treaty. The weapon is, however, very small and a large number can be carried in the bus of a Trident submarine-launched ballistic missile for launch in the pop-up mode to engage targets in the post-boost or mid-course phases of trajectory. Depending on the submarine location at launch, the X-ray lasers could be placed in space very early in an attack. While a salvo launch by the Soviet Union might be able to overwhelm space-based chemical lasers, augmentation by the X-ray laser after a Soviet attack could blunt it.

In addition to lasers, there are *kinetic energy kill devices* which are enormously effective for boost-phase intercept. This hit-to-kill or kinetic weapons intercept option also exists for all phases of a ballistic missile's flight. Kinetic energy weapons could be used for boost-phase intercepts, since small rockets with homing seekers can be carried on satellites in low earth orbit. These same interceptors also can operate in other phases of trajectory. These hit-to-kill devices are called flying tomato cans because of their shape and approximate size. They can weigh 40 pounds or less and travel through space at 10 km/second to engage targets 1,000 kilometers away.

A different type of interceptor could operate from the ground to hit and destroy targets within the atmosphere in altitudes of between 10 to 30 kilometers. This would be useful for the terminal phase of the defense. For these small hypervelocity interceptor missiles, the non-nuclear warhead is guided to the vicinity of the incoming warhead through a series of external commands and onboard small radar sensors. Maneuvering to within a few meters of the target, the warhead explodes to form a "pellet cloud" that destroys the reentry warhead. This is sometimes called the shotgun approach because it operates like a shotgun, firing a maze of pellets, some of which are bound to find their target.

Recently, the homing overlay experiment (HOE) proved the capability of a non-nuclear interceptor launched from a fixed ground base to destroy an incoming ballistic missile outside the earth's atmosphere. The basic intercept technology was successfully demonstrated in an experiment on June 1, 1984. A Minuteman ICBM was launched from Vandenburg Air Force Base; its warhead was intercepted in mid-course by a kill vehicle fired from Mech Island in the Kwajalien atoll. This intercept is significant because it shows the kill capability available in the mid-course phase of defense in space.

Ultimately, kinetic energy weapons such as the HOE, which destroy their targets by simply colliding with them at closing velocities of 32,000 km/hr, could be an essential part of the multilayered defensive system.

Both target acquisition and tracking have been extensively analysed, along with the interceptor/kill vehicle for the terminal tier of the defense. The surveillance is performed by an airborne optical adjunct. This program is being carried out by mounting several infrared telescopes to look out in space atop a Boeing 757 transport aircraft designed to carry them to a high altitude. A fleet of the sensors would be operated to detect arriving reentry vehicles and track them. Then they would be shot down.

Problems That Remain

These are just a few of the technologies that are showing unforeseen progress in the SDI research effort. No mention has been made of the electromagnetic railgun, which can be used to fire kinetic kill devices. Or of advances in hardening high-density focal plane arrays and processors so they are not as vulnerable to nuclear radiation. Or of the new concept of a chemical rocket for boost-phase intercept.

The SDI program is experiencing progress in areas such as sensor imaging with phased array radar and with signal processing. There has been impressive progress with surveillance and sensor miniaturization, especially with optical sensors. Multispectral measurements of boosters, post-boost vehicles, and reentry vehicles have been obtained from both optical and radar devices.

This is not to say that technical problems do not remain. It is only to suggest that they are being successively overcome. Strategic defense has moved dramatically from the "whether" to the "how" stage: it is now a question of what is the best way to do it, not whether it can be done. In this sense, critics who continue to speak of SDI in terms of science fiction are behind the debate.

Perhaps the most intractable problems for SDI lie in the areas of battle management and computer programming. On this point, the critics' arguments have some validity. SDI must be capable of stopping not only a single or small ICBM launch, but the simultaneous launching of the entire Soviet arsenal. This means thousands of warheads launched at different places moving in different directions toward different targets. How to coordinate a system to get all—or virtually all—of them?

It is estimated that several million lines of computer code will be required for a viable SDI coordination program. That seems like a very daunting number. Actually, the telephone company has a program that uses several million lines of code. While the SDI program is quite different, it must be remembered that progress is being made now, and progress in this area has been extremely rapid in the past. Ten years ago, there was no indication of anything as ambitious as a 16,000-bit computer memory chip; today companies use 256,000-bit memory chips and research is leading us toward a four-megabit memory chip within a few years. Jumps like this in data processing can very quickly change the entire picture and make a previously formidable problem quite simple.

Recently, the SDI office established a panel from industry, government, and academia to examine the battle management technology and evaluate software capabilities for a defense system. The Eastport Study Group concludes "that computing resources and battle management software for SDI systems are within the capabilities of the hardware and software technologies that could be developed within the next several years." During the past year, a consortium of universities has been charged with the task of developing battle management algorithms to evaluate processor performance. The consortium will also work on synchronizing networks of artificial intelligence for the system. Because of the difficulty of writing a single program for a single machine with millions of lines of computer code, the plan is to write several separate programs and then integrate them to achieve the same effect.

A second major challenge is for SDI researchers to continue to work on ways to reduce the cost of launching material into orbit. Right now it costs several thousand dollars per pound to send up material on the space shuttle. A program has been established between the SDIO and NASA, as well as other defense agencies, to develop space logistics and lifting techniques to launch material more cheaply and efficiently.

New launch vehicle concepts are being developed that could cost substantially less. Components that need to be sent into space are being miniaturized. Ways are being figured out to keep as much as possible on the ground. Ultimately, this problem may be a litmus test for space-based weapons: unless costs of maintaining assets in orbit can be considerably reduced, SDI will be very costly to deploy in space.

A little more than three years after President Reagan's strategic defense speech, and a couple of decades since serious work began in the area of missile defense, scientists have to look back and say that the progress has been astonishing. Certainly, as old problems have been solved, new problems have arisen. But the direction of the research is toward finding better, cheaper technologies. None of the problems are viewed as insoluble, or not worth trying to solve. American scientists are proving equal to this grand enterprise, as they have proved equal to similar grand ventures such as the Manhattan Project and the moon landing in the past. It is up to the American people, however, to provide the support that is necessary for this country to find a solution to the menace of the nuclear threat.

Mr. Donaldson Goes To Washington

Politics and Social Climbing in the TV Newsroom

Dinesh D'Souza

There is an overwhelming, and sometimes quite vehement, conviction on the right that television journalists are East Coast liberals, raised in opulence, schooled at the Ivies, recruited into the profession to promote a radical elitist world view.

The evidence shows that most TV reporters are not products of the liberal establishment. To give a few examples: Mike Wallace of CBS grew up in the Midwest and attended the University of Michigan. Roger Mudd of NBC hails from Richmond, Virginia. Steve Bell of ABC grew up in Iowa. Ken Bode of NBC, a native Iowan, attended the University of South Dakota. Richard Threlkeld of ABC went to Ripon College in Wisconsin. Dan Rather of CBS was born in Wharton, Texas, the son of a ditchdigger, and went to Sam Houston State Teachers' College. Charles Kuralt of CBS was raised in Wilmington, North Carolina. Jim Miklaszewski of NBC grew up in Milwaukee and attended Tarrant County Junior College in Texas. Diane Sawyer of CBS grew up in Kentucky.

Bettina Gregory of ABC correctly notes that, in network journalism, "the emphasis is away from the East Coast liberal axis." The reason for this, producers say, is that TV news reaches into homes all over the country and thus needs faces and voices that are not parochial but have wide appeal. Midwestern accents and all-American looks are a real asset, and of late even Southern intonations seem to be fashionable.

No matter where he comes from, however, the aspiring TV journalist typically adopts a left-liberal world view as he picks up the tools of his trade. There is nothing conspiratorial in this. To get their stories on the air, TV journalists have to embrace the culture of network news, either consciously or unconsciously. It is only natural that an ambitious, social climbing reporter from the heartland who wants to please his colleagues and his superiors will absorb their ideas of what makes a good story, of what is considered responsible journalism. And since the culture of television journalism is liberal, it is hardly surprising that reporters get their idea of what is news—ultimately the most ideological question in journalism—from a whole range of left-liberal assumptions, inclinations, and expectations.

An interview with Sam Donaldson in the March 1983 *Playboy* offers a revealing look at political socialization in the newsroom. Donaldson did not start out as a liberal crusader. He was raised on a farm in El Paso, Texas. His mother was a devout Baptist. Young Sam was dispatched to the New Mexico Military Institute, perhaps to reform a burgeoning arrogance. Then he went to Texas Western College in El Paso. He is said to have supported Barry Goldwater for President in 1964.

It was not until Donaldson migrated to the city, and became part of its journalistic culture, that his values altered dramatically. "When I came east to New York and Washington," he says, "my view of the world and politics changed. When I went back home, I had violent political arguments with my mother and friends. I had left the fold. I was reading the *New York Times*, the *Washington Post*, and other so-called Communist-inspired newspapers."

Donaldson does not seem to view those shifts as ideological, but rather as signs of maturation. "I didn't think everyone who was out of work was really responsible for not having a job; I didn't feel someone who couldn't read and write English could be faulted for not finding a position as a computer programmer." These would be examples of intellectual growth, if indeed young Donaldson or his parents ever thought otherwise. But from Donaldson's caricature of his origins, one gets the sense that this same trivializing instinct is what causes him to ridicule strategic defense or supply-side economics: he regards them as notions straight out of the bovine world from which he was liberated.

Donaldson complains that "Under the Reagan Administration, reporters were invited [to White House dinners] but not their spouses. Why? Was the wife of General Motors chairman not invited? Oh no, she came. Was Gregory Peck's wife not invited? No, no, she came. The point was that press spouses were dispensable. The Reagans didn't really consider us on the same level as their Hollywood friends." This unusual outburst of class envy suggests how socially self-conscious Donaldson is, how eager he is to ascend the cultural ladder to greater heights of acceptance and accolade. Sam Donaldson definitely does not want to

Dinesh D'Souza *is managing editor of* Policy Review.

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RICHARD L. GARWIN

SPACE DEFENSE — THE IMPOSSIBLE DREAM?

President Reagan's dream of complete protection against nuclear missiles by an impenetrable defensive shield is being given concrete shape by a strong political-military-scientific organisation. But what are the true goals of SDI? Are they really attainable? And is there a cost-effective relationship between defense and offense that makes the results practicable and desirable? If the answers to these questions are negative, then fundamental alternatives, for instance in arms limitations and modernisation, could obtain far greater security at far lower cost. This is the thrust of Dr Garwin's enquiry and conclusion; his views are his own and not necessarily those of IBM or Columbia University.

Dr Richard L. Garwin is IBM Fellow at the Thomas J. Watson Research Center and Adjunct Professor of Physics at Columbia University.

Three years ago, President Ronald Reagan in his famous TV speech of March 23, 1983, revealed to the world his dream of a defense against strategic ballistic missiles which would "render nuclear weapons impotent and obsolete." The problem and solution were both clear in his mind: Although deterrence of nuclear war by threat of retaliation had worked and would continue to work, the U.S. and its allies deserved better than to base their security on the threat of destruction of another society. It was this dream that the President shared with the American people — a defense so perfect that not only would Soviet nuclear weapons be rendered impotent but ours would be rendered unnecessary.

Indeed, recognizing "If (defensive systems are) paired with offensive systems, they can be viewed as fostering an aggressive policy, and no one wants that," the President indicated that he would share such defensive technology with the Soviet Union so that they would have an effective defense at the same time as the West, if they did not achieve it by themselves.

DREAM TO CONCEPT

In a formal statement of September 13, 1985, Dr. John Bardeen stated that "President Reagan prepared his speech with no prior consultation either with technical experts in the Pentagon concerned with research in this area or with his own Science Advisor, Jay Keyworth." Dr. Bardeen was a member of the White House Science Council at the time of the Star Wars speech and is a physicist with two Nobel Prizes in physics — one for the transistor and the other for the theory of superconductivity. Soon after the President's speech, 50 scientists and engineers under the leadership of Dr. James C. Fletcher (the Defensive Technologies Study Team — DTST, or the Fletcher Committee) began a 4-month study to learn whether it was feasible to achieve the President's dream. At the same time, a group of six political scientists led by Dr. Fred S. Hoffman, constituting the Future Strategic Security Study began a parallel investigation. By October, 1983, the Fletcher Committee had completed its 7-volume report, judging that eventually a "robust effective" defensive system could be built, but conditioning this judgment on the limitation of Soviet offensive forces by arms control or other means. The Hoffman study, in contrast, was skeptical that a highly effective defense could be obtained, but was enthusiastic about the benefits of a nearer-term, perhaps 50%-effective defense against strategic ballistic missiles. This dichotomy has been papered over by the Administration, with the President continuing to assert his dream of a defense so good that nuclear weapons can be abandoned, while the bureaucracy in charge of spending the money for investigation of defensive technologies and systems ridicules the idea of a perfect defense as a strawman invented by critics of SDI.

The Fletcher Committee recommended a *layered-defense*, which would attack ICBMs and submarine-launched ballistic missiles (SLBMs) in boost phase, post-boost, mid-course, and in the terminal phases, to be investigated in a program which if there were no limits on funds available would consume $26 billion in five years, and some $70 billion in ten years, by which time only information would be available, not defense. The idea was to

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have a program which would provide by the 1990s a sound basis for a judgment as to what kind of defense could be constructed to fulfill the President's dream.

By March 1984, the Strategic Defense Initiative Organization (SDIO) had been created and Lt. Gen. James. A. Abrahamson selected to head it. For fiscal year 1987, the Administration has now requested $5 billion for the SDI, hoping to achieve something like the recommended spending profile of the Fletcher Committee. Why are we spending this money? What are the goals of a defense for which the technology is being investigated?

The ability of U.S. industry and that of the allies to spend $70 billion in ten years on technological investigations is not in doubt. These funds, of course, are not delivered from another planet, but are taken in taxes or fees or in loans which may or may not be repaid. In any case, these expenditures are a measure of efforts of our most capable scientific and technical individuals and industries toward investigating strategic defense, rather than defenses against Soviet tanks, the improvement of economic competitiveness, or the like. It is fundamental in the commitment of resources to understand the benefits which are sought and the likelihood that they will be achieved.

POSSIBLE GOALS

Three possible goals of defense systems resulting from the SDI program are:

— a defense so good that U.S. and allied security would not depend on the decision of the Soviet Union to avoid nuclear war, and which would allow us to give up our nuclear weapons for retaliation,

— a defense which would deny the Soviet Union confidence in achieving military goals by nuclear attack, so that they would be deterred from such attack not by retaliation but because the benefits would not be worth the expenditure, and

— a defense which would improve the survival of the 1000 silos in which U.S. Minuteman missiles are deployed, and thus *strengthen* deterrence by threat of retaliation.

The first goal is the President's dream, but it has in fact been rejected as infeasible by those working on the program. Right after the Star Wars speech of 1983, White House staff characterized those who advocated continued deterrence of nuclear war by threat of retaliation as "bloodthirsty," and lacking in imagination which would allow them to conceive of a defense which would allow us to abandon deterrence by threat of retaliation. The Fletcher Committee emphasized the requirement for "birth-to-death tracking" of warheads through the system, so that they might be effectively destroyed, and Dr. Fletcher, writing in the journal *Issues in Science and Technology* in Fall 1984 stated that "an enormous and error-free program, on the order of ten million lines of code," would be required for an effective SDI defense. In recent months, the leaders of the SDI Office and supporters of the SDI have been ridiculing critics of the SDI for ever taking seriously this SDIO requirement of 10 million lines of error-free code, just as in early 1985 they ridiculed these critics for stating that such perfection could not be achieved — an assertion now adopted by the SDIO! When I brought to the attention of Dr. (Major) Simon P. Worden, Military Aide to General Abrahamson, in a debate in Colorado Springs November 19, 1985, the fact that it was not the critics but Dr. Fletcher himself who had stated both the necessity and feasibility of ten-million-line error-free programs, Major Worden responded,

"I must confess some guilt in those statements, as I wrote much of the material Dr. Garwin has cited. I have been taken to task for these statements by certain software engineers. One of them has said that I must have been crazy or drunk when I wrote those statements. I was probably both! If one thinks about it, it is obvious that we don't need error-free code."

The perfect defense which (if it also extended to cruise missiles, trawlers, and the like) would allow us to abandon our own nuclear weapons is not being sought. It cannot be achieved, in part because we do not know how to make systems of a perfection which when challenged with 10,000 or 30,000 nuclear warheads (and a million decoys or more) could destroy all of them except one or a very few. More important in comparison of the requirement for an effective SDI with those for the Apollo Program for landing a man on the moon and returning him to earth, the Manhattan Project to build the atomic bomb in World War II or the space shuttle, is that the Soviet Union does not *want* to be disarmed by having such a perfect defense in the hands of the West. Options open to the Soviets to nullify this system are to underfly it (with cruise missiles); to overwhelm it with numbers; or to outfox it by blinding the necessary sensors, by rotating the missile in boost phase so as to spread out the heat from space-based lasers, by providing the real warhead in mid-course with decoys attached by cords, so that when a small homing kill vehicle collides with the warhead after several minutes of travel, it may collide instead with a hollow plastic balloon tethered at a distance of 20 m from the re-entry vehicle. All these countermeasures use pre-SDI technology, as does the general-purpose counter of a fast-burn booster, which can achieve full ICBM speed in some 50 seconds, rather than the present 120-300 seconds of existing ICBMs. Such fast-burn boosters with a single warhead (Midgetman) were studied for the Fletcher Committee by contractors, and a force of 1000 such mussiles (with research, development, investment, spares, and operating costs for 10 years) was estimated at $11 million each.

In February 1985, Ambassador Paul H. Nitze enunciated the requirement that a space defense must be "cost-effective at the margin," if it is to be deployed — then it must cost less to strengthen than it costs the offense to defeat. In a rigorous calculation published in *Nature* May 23, 1985, I showed that fast-burn boosters of 50-s burn time and hardness generally acknowledged achievable, could be countered by space-based lasers of power and quality far beyond anything thus far demonstrated, only if vast numbers of lasers were employed. Specifically, 3000 fast-burn boosters would exhaust 1000 space-based lasers of 25 megawatt power and perfect 10-m-diameter mirrors, even if these enormous mirrors could jerk from pointing accurately at one booster to pointing at another within 0.1 seconds.

Additional countermeasures available to the offense are *space mines* — small explosive-carrying satellites accompanying a defensive satellite always within lethal range and ready to explode at receipt of a command or when tampered with. In general, defensive systems deployed in space are regarded as very vulnerable to countermeasures by the other side. Edward Teller, generally known as the creator of the hydrogen bomb, and a strong supporter of strategic defense, has put it this way in numerous articles, interviews, and Congressional testimony: "But lasers stationed in space won't fill the bill — they must be deployed in great numbers at terrible cost and could be destroyed in advance of an attack."

Although the President's dream includes countering nuclear weapons "by means that are non-nuclear," one of the principal hopes for the SDI is the x-ray laser being worked on at the U.S. Department of Energy Livermore Laboratory, which would be powered by a nuclear explosion of intensity similar to that which is used on the strategic offensive weapons. Ironically, the SDI office sometimes asserts that the Soviets are ahead of the U.S. in the development of x-ray lasers, and that it is the investigation of how SDI satellites can

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survive against *Soviet* lasers which motivates SDI-related work on such nuclear arms. The SDIO and the Livermore Laboratory do not, however, note that Soviet advances would be stopped dead in their tracks by a comprehensive ban on nuclear explosions. In my opinion, any x-ray laser gap with the Soviet Union is like the agriculture gap — with 30% of the Soviet population on the farm vs. 3% of the U.S.

As for the third possible goal, to contribute to the survivability of the strategic retaliatory force and thus to *strengthen* deterrence rather than to replace deterrence — this is entirely feasible. It competes, however, with other means for providing survivable strategic retaliatory force and, as such, was thoroughly investigated by the President's Commission on Strategic Forces established by President Reagan in January 1983 and chaired by Lt. Gen. Brent Scowcroft, former National Security Advisor to Presidents Ford and Nixon. The Scowcroft Commission was charged with reviewing the entire strategic posture of the United States, not only strategic defense, and in their report strategic defense played no role in aiding future U.S. security and certainly not in *replacing* the strategic retaliatory force. In its public reports of April 1983 and March 1984, the Scowcroft Commission found that the vulnerability of Minuteman silos did not impair U.S. security, so long as these vulnerable silos were imbedded in a force which was not overall vulnerable — because it contained strategic aircraft (carrying cruise missiles) which could take off before being destroyed by a nuclear attack, and strategic submarines hidden in the vast oceans. The Scowcroft Commission was well aware that 40% of the strategic submarines are in port at any one time. With 200 warheads on each of more than 30 submarines, 4 submarines in a single port would provide 800 warheads vulnerable to a mere two Soviet warhead attack. Nevertheless, the overall retaliatory force was built large enough so that a Soviet first strike catching more than 2000 submarine-launched warheads in port would still leave a devastating retaliatory strike.

The Scowcroft Commission recommended that future U.S. and allied security be assured by the development of the small single-warhead Midgetman missile to replace the Minuteman (3 warheads) and the MX (10 warheads) in the longer term, deployed either in individual silos or on hardened mobile launchers. Furthermore, a small submarine carrying fewer warheads than the present Poseidon or Trident submarine would avoid vulnerabilities by providing more submarine targets at sea. I have long studied for the U.S. government small submarines weighing as little as 1000 tons and carrying small or large ICBMs horizontally in capsules outside the pressure hall of the submarine. These are eminently practical and should be developed.

Finally, if it is desired to *defend* the Minuteman silos in order to reduce their vulnerability to attack by accurate, numerous Soviet re-entry vehicles, that can be done with existing technology. There is no need to wait eight or ten years for the SDI research program to be completed in order to learn that we can indeed defend Minuteman silos effectively. On May 23, 1985, Dr. Edward T. Gerry of W. J. Schafer Associates, an important SDI contractor, and I published "15 Agreed Propositions" on the SDI. These were worked out word-for-word in more than a day of discussion and analysis at Dartmouth College, under the moderating eye of Dr. Arthur Kantrowitz. Proposition number 9 reads:

> "In the continuing context of deterrence of nuclear war by threat of retaliation, technologies already exist to solve the problem of strategic force vulnerability sooner and at lower cost than via layered defense with space components."

Dr. Gerry was in charge of boost-phase systems for the Fletcher Committee which studied strategic defense for President Reagan and which recommended the SDI program.

If the goal of perfect defense to allow elimination of Western nuclear weapons is regarded as incredible and is in fact not being sought; and if the goal of defending missile silos can be achieved sooner and more cheaply without the SDI, what goal is left which warrants the treasure being expended in SDI research? The only one remaining of our three is "to deny the Soviet Union confidence in the military goals of nuclear attack on the U.S. or its allies." It is not easy to define a nuclear attack which can be counted as gaining military goals in the absence of an SDI defense, and which can be denied by the presence of a modest defense.

On January 12, 1984, I spoke at the University of California at Los Angeles. Two individuals were asked to prepare 20-minute responses to my talk, one of them being Dr. Fred S. Hoffman. Challenged to provide an example of "military goals to be achieved by a nuclear attack", Dr. Hoffman stated that, at present, if there were a large-scale conventional war in Europe, the U.S. would be loading military resupply ships in four ports in the United States. Today, the Soviet Union could destroy those four ports with four reliable ICBM warheads, but assuming a 50%-effective space defense system, the Soviet Union "could not count on destroying those four ports, and therefore would not even try." As recounted in my testimony to the U.S. Senate of 04/25/84, I then asked Dr. Hoffman why the Soviet Union would not send over four nuclear warheads, learning in a few minutes via satellite observation of the nuclear explosions (or via seismographic detection) that two ports remained undestroyed. They could then send over additional warheads resulting in the destruction of the four ports by (probably) eight warheads of the 9000 strategic warheads in the Soviet inventory. Dr. Hoffman replied that they would not dare to do that because the U.S. President would respond with nuclear retaliation against the Soviet Union. I then inquired why the U.S. President would be willing to retaliate against four ports destroyed with eight nuclear warheads when he would not be willing to retaliate in the case of those same four cities destroyed by four nuclear warheads. No answer was forthcoming then or since.

Indeed one can assign tasks like destroying the 500 odd-numbered Minuteman silos, which could probably not be done now and could certainly not be done in the presence of any significant defense. But these are not militarily significant tasks, and the denial of confidence in achieving that task is not militarily significant either. In fact, none of the three goals of strategic defense is both achievable and significant.

COMPLETE PROTECTION

For completeness, let me mention two additional reasons which are often presented by "realists" as the reasons why they support SDI. These are the rogue-nation ICBM and the Soviet accidental launch.

The argument goes that Libya acquires an ICBM and mounts a stolen nuclear warhead on it equipped with a re-entry vehicle. It then holds New York hostage, threatening to launch its ICBM and thus to destroy New York City. Leave aside for the moment the question of what the U.S. would do against a Libyan trawler or commercial aircraft. Leave aside the undoubted capability for covert action (well merited, in this case) against the highly visible ICBM on its launch pad. I just mention the 450 Minuteman-II missiles in their silos, each equipped with a single powerful nuclear warhead. Long before any SDI capability would be available, existing U.S. infrared warning satellites could be teamed with a few of these Minuteman-II ICBMs to provide a capability for meeting the rogue-nation warhead in space (in mid-course) with a massive nuclear explosion which would certainly render it "impotent and obsolete."

The prospect of an accidental launch of Soviet ICBMs has been the subject of letters to the editor and short articles in the

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What The Churches Are Saying About "Star Wars"

RICHARD E. SINCERE, JR.

IN 1960, theologian John Courtney Murray, S.J., published his classic work, *We Hold These Truths*, in which he reconciled Catholic political and social teaching with the "American way of life." Murray's trenchant observations of the problem of war and peace in the nuclear age remain relevant today:

> There are those who say that the limitation of nuclear war, or any war, is today impossible, for a variety of reasons—technical, political, etc. In the face of this position, the traditional doctrine simply asserts again, "The problem today is limited war." But notice that the assertion is on a higher plane than that of sheer fact. It is a moral proposition, or better, a moral imperative. In other words, since limited nuclear war may be a necessity, it must be made a possibility. Its possibility must be created. And the creation of its possibility requires a work of intelligence . . . To say that the possibility of limited war cannot be created by intelligence and energy, under the direction of a moral imperative, is to succumb to some sort of determinism in human affairs.

For 40 years, the debate over nuclear weapons policy has been conducted on a moral plane as well as a political one, beginning even before Hiroshima with Father John Ford's 1944 critique of obliteration bombing. The 1983 pastoral letter of the U.S. Catholic bishops probably represents the peak of activity by religious groups in the nuclear debate. And while this letter received an unusual amount of media attention, it was by no means unique.

When President Reagan announced his Strategic Defense Initiative (SDI) in March 1983, he also couched his proposal in moral terms: "Wouldn't it be better to save lives than to avenge them?" The idea that innocent civilians should be spared the ravages of war is not new; it is entrenched in the Just War doctrine formulated during the Middle Ages and refined by theologians and philosophers, both Catholic and Protestant, ever since. But by the 1980s, many religious thinkers had abandoned the Just War doctrine as irrelevant, due to the

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to witnesses who in some cases included government personnel? The article even made a point of mentioning that witnesses must undoubtedly have witnessed real *contras* since the witnesses seemed to keep recalling "Chinese" Kalashnikov rifles, which only *contras* were said to carry. Arms experts might find this strange. To "civilians" Chinese and Soviet Kalashnikovs look identical. The *New York Times* article continued:

> Mrs. Barreda said that during her five days as a captive she witnessed the torture and murder of a peasant acquaintance who had been kidnapped by the Nicaraguan Democratic Force {the largest group of *contras*} in a separate incident.
>
> 'They asked him if he loved the revolution,' she recalled. 'He said, "Yes, I love the revolution, because it has given me land, which is more than Somoza ever did."
>
> 'So they started to gouge his eyes out with a spoon,' she said. 'Then they bayoneted him through the neck. They finished him off with a burst of machine gun fire,' she said.

Actually, small farmers around El Zapote are incensed at the Sandinistas because in mass relocation and forced collectivization schemes, they are *losing* the land they have always had. They are being systematically removed to camps by the tens of thousands, an inconvenience that need not disturb the perceptions of foreign observers who do not go into the hills to see it.

There are still other human rights reports which quote Digna Barreda's testimony. In a report prepared by a Sandinista-connected body for Catholic bishops visiting from the United States, Barreda says she saw a friend of her husband's, Carlos Aleman, done in by the *contras* when he was "thrown off a cliff." When I asked the couple about this, they both said that Carlos Aleman was still walking around Nicaragua. Any suggestion that he was dead was ridiculous, they said.

During the CBS videotaping, a silent crowd had looked on. Living all around the Barreda home in Esteli's Rosario housing project were families that were doubled-up and tripled-up in whatever housing they could find, because a flood of new refugees had been generated by the Sandinista People's Army projects of depopulation and relocation, for purposes of counterinsurgency and collectivization. Within blocks of Digna Barreda lived eyewitnesses who had seen the People's Army destroy churches and schools. These people were not sought out. Nor did they make much effort to intrude. It is thought among many ordinary Nicaraguans that the foreign press is dangerous, little more than *internacionalistas*—proletarian internationalists who have come to help support the Sandinista revolution.

The significance of all this—the political background of the Barreda-Ubeda couple, the contradictory statements, the thinness of the investigation and reporting—is not that it establishes that the reported incident of multiple rape did not occur. It is, rather, that no serious effort was made to establish the truth. Two of the pillars of the North American media reduced a complicated and ambiguous set of circumstances to a simple morality play. The grounds for doubt were glossed over.

The events recounted here are not meant to raise any sort of hue and cry that the press be somehow reformed. Instead, this is a cautionary tale for news consumers, a guide to some of the pressures at work on foreign reporting. The news is a commodity we very much need, but perhaps a footnote to freedom has been neglected: Buyer beware.

tremendous power of nuclear weapons. They argued that the nature of nuclear weapons meant that concepts like discrimination and proportionality were no longer workable principles for the conduct of war.

For a variety of reasons, religious leaders have generally lent their support to the deterrence doctrine known as Mutual Assured Destruction. Consequently, they have opposed SDI or "Star Wars" (as it came to be called). Yet it can be argued that the very premises on which the churches base their opposition to "Star Wars" may lead to a very different judgment—that the Judeo-Christian moral and political tradition urges a policy closer to strategic defense than to strategic vulnerability. Ironically, while the gauntlet tossed by John Courtney Murray has been picked up by President Reagan and "hawkish" defense scientists, the moral and intellectual challenge has been shunned by Murray's successors in organized religion.

What follows is an examination of statements by major church bodies, ecumenical organizations, and religious leaders in the United States and Canada on the question, "Should the United States pursue the Strategic Defense Initiative?" A few important groups—like the U.S. National Council of Churches—have issued no statements directly addressing SDI. But enough statements have been published to derive a few tentative conclusions.

Protestant Responses

Protestant Ecumenical Groups. Most Protestant organizations, ranging in size from the National Council of Churches to local parishes, have long opposed the nuclear arms race and have counselled American policymakers to negotiate arms control agreements. They have done this, however, at various levels of participation in public debate.

Such is the case with the Protestant churches' approach to SDI. Some large denominations—the Church of the Nazarene, the Lutheran Church-Missouri Synod, the Southern Baptist Convention, and the United Church of Christ, to name four—have not issued any statements regarding SDI. In fact, few national organizations have addressed strategic defense *directly* in their statements and resolutions. Nonetheless, it is possible to find indications of opposition to the Reagan administration's SDI in past texts on nuclear arms policy.

For example, Church Women United, described as "an ecumenical lay movement providing Protestant, Orthodox, and Roman Catholic and other Christian women with programs and channels of involvement in church, civic, and national affairs," has some 2,000 units formally operating throughout the United States. In June 1985 its board opposed SDI in a resolution that asked "Church Women United constituency to express this opposition by letter and telephone to their Congresspersons." The board noted past actions that had called for reductions in military spending and stated that "experts in foreign and defense policy say" Star Wars "only fuels the escalation of the arms race."

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Insight, a monthly newsletter of the National Association of Evangelicals (NAE), took note of the strategic defense debate in its August 1985 issue. Editor Robert P. Dugan explained that while NAE itself has not taken sides in the matter, "other religious advocates in Washington are expressing strong arguments pro or con along moral lines." Opponents of SDI, he said, "see it as fostering an ever-increasing arms race and abrogating the 1972 Anti-Ballistic Missile Treaty." Its proponents "assert that Pentagon research violates no treaty and includes no arms build-up." Dugan pointed at the "perverse and paradoxical" cornerstone of deterrence, Mutual Assured Destruction, stating that "if strategic defense could be deployed jointly by the U.S. and the USSR, as the President has suggested, that theoretically could provide escape from the dangling Sword of Damocles, i.e., MAD."

While not a U.S. Protestant organization, the views of the Canadian Council of Churches are important because they may have contributed to the decision by Prime Minister Brian Mulroney's government to forgo participation in strategic defense research. A July 1985 presentation to the Canadian government's Special Joint Committee on Canada's International Relations cited an earlier resolution by the Canadian Council of Churches which urged "the Canadian Government to take a strong stand against the Star Wars scheme" and committed itself and member churches to do "everything in our power to condemn the expansion of nuclear weapons into space."

Ernie Regehr, the church council's representative, explained the reasoning behind this stance: "[For] the United States or any other nation to have singular control over technology like SDI, the only appropriate phrase to describe the world's political situation would be 'a universal dictatorship.' Such a situation would be detrimental to the whole human community... regardless of how benevolent the dictator state might be."

The Council said, "We do not oppose strategic defense because we don't think it would work; we oppose strategic defense because we believe the world would be a more dangerous place if it did work." It argued that SDI would undermine arms control efforts and "would create incentives to expand nuclear arsenals." SDI, it said, is "a decidedly offensive weapon... designed to enhance the survivability of strategic nuclear warriors, the better to do nuclear battle." By enhancing strategic flexibility, therefore, SDI "includes the support of nuclear first-strike and war-fighting options."

The 1.6 million-member American Baptist Churches has issued a number of statements on nuclear arms policy. Most are based on a December 1978 General Board policy statement on military and foreign policy that called for radical disarmament measures "down to levels that provide for internal policing within nations and international policing as adopted among nations." This move toward world government would be preceded by "conscientious efforts... to reduce nuclear armaments and to impose safeguards on nuclear technology to prevent further proliferation," including "controls on weapons research and develop-

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ment." Such arms control agreements should "deal with the larger range of arms production, including non-nuclear systems."

A December 1981 statement called on the U.S. administration to "move toward an immediate freeze at present levels of stockpiles of nuclear warheads and delivery systems." It seems fair to conclude that the official opinion of the American Baptist Churches leans toward opposing SDI, although expected action on that specific topic at the denomination's 1985 biennial meeting did not take place.

More specific criticism of SDI came at the 1985 General Assembly of the 1.1 million-member Christian Church (Disciples of Christ). A resolution issued there, citing a 1983 World Council of Churches report, said "Nuclear deterrence is morally unacceptable because it relies on the credibility and intention to use nuclear weapons." It argued that "new weapons," such as the SDI, "contribute to the instability of the international order" and might cause the "increased production of nuclear weapons." Furthermore, it states, "the production and deployment, as well as the use, of nuclear weapons are a crime against humanity." Thus the General Assembly opposed "the introduction of the Star Wars system (Strategic Defense Initiative) and other new destabilizing systems."

In October 1984 the Church of the Brethren (164,680 members), a historic "peace" church with an active lobbying presence in Washington, issued a General Board resolution entitled "In This Time of Terrible Belligerence." The resolution focused on the human costs of the nuclear arms race and argued: "Millions of dollars are being spent to design and create space weaponry... scientists are openly skeptical about the possibility of developing the proposed defensive nuclear shield in space.... We believe an international agreement should be sought to keep outer space weapon-free and that funds should not even be used for 'Star Wars' research."

A Magic Shield?

Mainline Protestant Churches. While no national organ of the Episcopal Church (2.8 million members) has taken action on SDI, the influential Episcopal Diocese of Washington, D.C., has. It sponsored a report by an official Committee of Inquiry called *The Nuclear Dilemma: A Search for Christian Understanding*. The committee was chaired by Ambassador Viron P. Vaky, a senior associate at the Carnegie Endowment for International Peace, and it included a number of distinguished experts in foreign and defense policy. The committee heard testimony on nuclear weapons policy from over 40 current and former government officials, foreign-policy specialists, and religious leaders. Its report, therefore, will probably be taken seriously in both religious and policy-making circles.

The committee's draft report (which, it was careful to point out, "is not an

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official document of the Episcopal Church") concluded: "We oppose the Strategic Defense Initiative.... We do not oppose prudent research into defense technologies, but we perceive SDI as far more than a research program."

The committee argued further that "pursuit of SDI would foreclose efforts to significantly reduce offensive nuclear forces." It expressed worry that SDI would damage the 1972 Anti-Ballistic Missile Treaty, noting, however, that as long as SDI is limited to research within the terms of the ABM Treaty, committee members could tentatively support it. Such research presents a problem, though, because SDI "is much more than a prudent intensification of research... but has already moved into testing." At that point, when vast sums of money are spent on it, "SDI will create such vested interest in its continuance —jobs, military contracts, scientific research—that Congress and the president will face irresistible pressure to continue... creating such momentum that SDI could not be stopped no matter how urgent the strategic and policy sense to do so."

In sum, the committee concluded that SDI "offers no prospect of achieving any of the visions that have given it momentum." It expressed skepticism that SDI could "create a magic shield to protect populations." It offers, the committee asserted, "little prospect of substituting a defensive strategy for deterrence, or of improving the environment for arms control." Finally, the committee warned that "SDI may push the United States across a threshold that will put us irreversibly on the road to a more dangerous and unstable nuclear balance" and that SDI "offers no escape... from the hard fact of mutual vulnerability."

The 194th General Assembly of the United Presbyterian Church called for a nuclear weapons freeze and asked the U.S. government to reaffirm the 1972 ABM Treaty. The next year's assembly (1983), which was marked by a merger with the Presbyterian Church in America and the renaming of the denomination the Presbyterian Church (U.S.A.) (3.1 million members), passed a resolution which took special note of the military uses of space. "We are on the verge of a new, dangerous, and destabilizing space war race," it said, asking, "Can we stop the race before it begins?" The 1967 Outer Space Treaty, the resolution asserted, "is known to be inadequate to stop a 'space wars' scenario because it does not cover new and emerging technologies." The General Assembly then called on the U.S. government to resume "negotiations on the anti-satellite treaty" and to expand negotiations with the Soviet Union "to prohibit any introduction into space of military hardware other than passive technology." It also asked the government to prohibit "the use of the space shuttle for military operations." The 196th General Assembly in 1984 issued a similar call, urging the "preservation of space as a zone of peace." No specific reference to the Strategic Defense Initiative has yet been made by the Presbyterian Church.

The 345,000-member Reformed Church in America took action on SDI at the June 1985 session of its General Synod in Kalamazoo, Michigan. In a letter

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addressed to President Reagan, it urged him and Soviet leader Gorbachev "to cease further development of the Strategic Defense Initiative ('Star Wars' projects), and to seek instead a mutual and verifiable freeze of nuclear weapons at present levels." The General Synod had earlier endorsed both the nuclear freeze and the 1972 ABM Treaty.

The 1984 General Assembly of the Unitarian Universalist Association (169,000 members) passed a resolution entitled "Stop Space Weapons: Resume Space Cooperation—1984." The resolution noted that "satellites perform many beneficial services" but are also used for military purposes, causing them "to be prime targets for adversaries in periods of mounting tension." The development of anti-satellite (ASAT) weapons, by threatening the satellites of the United States and the Soviet Union, is a "condition that could lead to nuclear war." It went on to criticize SDI as "astronomically expensive, dangerous, and subject to relatively simple countermeasures."

In a pastoral letter that received considerable attention from both the secular and religious press, the Council of Bishops of the United Methodist Church (9.2 million members) condemned nuclear deterrence and strategic defense. The April 1986 letter asserted: "We say a clear and unconditioned 'No' to nuclear war and to any use of nuclear weapons. We have concluded that nuclear deterrence is a position which cannot receive the church's blessing. We state our complete lack of confidence in proposed 'defenses' against nuclear attack and are convinced that the enormous cost of developing such defenses is one more witness to the obvious fact that the arms race is a social justice issue, not only a war and peace issue." The bishops designed their statement as a teaching document and noted that it was "not meant to be a consensus opinion of our church or a policy statement of our denomination."

Roman Catholic Commentary

It seems unlikely that any official action either *for* or *against* the Strategic Defense Initiative will be forthcoming from the highest levels of the Roman Catholic Church. In the past, the Pope and other Vatican officials have been careful not to take sides in matters of defense and foreign policy on which reasonable men and women may in good faith disagree. This does not, however, mean that SDI has not been discussed in Catholic circles. Numerous Catholic writers have addressed the issue in both the secular and religious press, and some bishops and priests have also added their opinions to the debate. The disagreements among the discussants are notable.

At a Vatican press conference on January 25, 1985, the president of the Pontifical Academy of Sciences, Carlos Chagas, described a report sent to Pope John Paul II that mentioned space-based defense systems. Chagas said that the report dealt solely with the technical aspects of space defense, avoiding moral or political issues, so that the pontifical academy would not be seen as interfering in

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U.S.-Soviet arms control negotiations. Chagas also said that while useful technological developments could be by-products of space-defense research, "it's not necessary to have this fantastic project to have these new technologies." He added that such a system would take 15 years to develop, and "our world can't wait that long" to solve current nuclear arms problems. "And I don't believe that such a system will have a real efficacy," Chagas concluded.

The U.S. National Conference of Catholic Bishops made headlines in 1982 and 1983 when they were debating their pastoral letter on war and peace, *The Challenge of Peace: God's Promise and Our Response*, adopted by a near-unanimous vote in May 1983. The letter reaffirmed Catholic Just War doctrine and particularly emphasized the moral imperative of protecting civilian populations from war. Quoting one of the documents of the Second Vatican Council, the bishops said: "Any act of war aimed indiscriminately at the destruction of entire cities or of extensive areas along with their population is a crime against God and man himself. It merits unequivocal and unhesitating condemnation."

The general moral conclusion drawn from this is that the behavior of belligerent parties should be both *proportionate* (to the goals sought) and *discriminate* (in distinguishing military from non-military targets). Because of the nature of nuclear weapons, as understood by the bishops, however, they doubt that the use of nuclear arms can meet this moral demand. Thus they argue later in the letter: "While we welcome any effort to protect civilian populations, we do not want to legitimize or encourage moves which extend deterrence beyond the specific objective of preventing the use of nuclear weapons or other actions which could lead directly to a nuclear exchange."

A parallel letter, drafted by a group of lay Catholics led by theologian Michael Novak, appeared during the debate over the bishops' pastoral. "It is not our role to recommend particular weapons systems," said the letter's signers, "but it is important to recall that technology does not stand still and that the future is not determined." Technological developments, they noted, "could enable defenders to destroy ballistic weapons shortly after take-off. Long-range ballistic missiles would, therefore, be rendered obsolete." Noting that there is some disagreement among experts about when such technology could be accomplished, the letter goes on to say that such a defense "does not rely on counterforce or countervalue but on non-nuclear defensive instruments. Not only does its moral character seem to be superior, but its implementation would seem to remove the threat of land-based missile systems."

Perhaps the strangest aspect of the debate among Catholics has been the competing interpretations of strategic defense that may be drawn from the 1983 pastoral letter. Ralph McInerny, a philosophy professor at the University of Notre Dame and the publisher of the monthly journal *Catholicism in Crisis*, argues that "the problem with an offensive nuclear strategy is that it is morally questionable for the United States to target civilian populations." Thus, he says, "I am waiting for the Catholic bishops to applaud the president's strategic

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defense program. Even if it is expensive and technologically difficult to achieve, committed Catholics should support a defensive posture. It's completely in keeping with the bishops' letter. Indeed, the letter seems to demand precisely such a strategy."

But the two principal writers of the bishops' pastoral disagree—and so, too, it seems, do two of the bishops' chief spokesmen. Father J. Bryan Hehir, chief foreign policy advisor at the U.S. Catholic Conference, wrote in *Commonweal* in 1984 that "pursuit of both defense and offense can kill the ABM Treaty, doom the fragile hopes for a Comprehensive Test Ban, and foreclose the possibility of banning anti-satellite weapons.... Final answers are not in order at the moment, but it is clear that one need not be an enthusiastic supporter of the present offensive arms race to be quite unenthusiastic about opening the defensive frontier."

Professor Bruce Russet of Yale, who also helped draft the pastoral, conceded to an interviewer that "in principle anything that moves us away from the threat of attacking cities would be in conformity" with the bishops' letter. But he also argued that a 100 percent effective defensive shield would be impossible to build; the best hope is for a defense of our land-based missiles, not for our population. Russet concluded: "So our cities remain hostage to attack, and what we've done is strengthen MAD, not weaken it."

According to press reports, the bishops plan no specific statements about SDI. But two of the bishops who sat on the panel that oversaw the pastoral letter's drafting, Joseph Cardinal Bernardin of Chicago and John Cardinal O'Connor of New York, noted in testimony before the House Foreign Relations Committee in June 1984: "From the perspective of our pastoral letter, we support efforts to prevent the initiation of a nuclear race on yet another frontier—outer space."

A few months later, Cardinal Bernardin attempted to clarify his personal views on this topic in a speech at the University of Missouri. Comparing the introduction of the Strategic Defense Initiative to the decision to place multiple warheads on ICBMs, Bernardin said:

> The fact that we are now having a major debate is a significant improvement over the MIRVing decision. Without attempting to resolve the SDI question here, I wish to express my profound misgivings about projecting the arms race on a new frontier in space, even when the motivation for the proposal has entirely defensible moral intentions. Moral arguments are almost always multidimensional. One has to test not only the intentions of a policy but also its consequences. While I understand the motivation behind the SDI, I am very skeptical of its consequences on the arms race.

Life and Death Issues

Participation by religious leaders and groups in the debate over SDI appears to be on the rise—and rightfully so. Indeed, bringing moral considerations to bear on important aspects of military and strategic thought is commendable, provided that those contributing to the debate do so responsibly, thoughtfully

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and without rancor. A number of religious figures—right and left—whether supporting or opposing SDI, tend to polarize debate through superficial or soporific arguments rather than maintaining an intelligent level of discourse.

There are responsible critics of SDI. Responsible criticism of strategic defense does not include condemning strategic defense *research*, however, as some churches have done. Technology itself moves rapidly, and our adversaries are pursuing defensive technologies. It is prudent, therefore, to continue research while setting aside (for the present) the issue of deployment. That question will be decided by a future president and Congress. Today's moral obligation is to give future policymakers sufficient information upon which to base such a decision.

For that reason, responsible critics must avoid nagging partisan prejudice. Though official statements of religious bodies usually do refrain from partisan attacks, an undercurrent of trenchant anti-Reaganism often manifests itself among church bureaucrats who use criticism of SDI spending to inveigh against Reagan administration policies toward the poor.

Yet when religious groups question support for SDI in a time of mounting deficits, they are not being irresponsible. Indeed, this is an important argument that is central to the whole debate. It is, in fact, up to SDI's advocates to prove that the benefits of SDI research outweigh any harms to the economy or cuts in social programs that may accrue from spending *x* billion dollars for space weapons or laser research.

Responsible critics also acknowledge the existence of Soviet research in defense technologies. The extent of such research is arguable, but in the face of at least some hard evidence—the Krasnayorsk radar facility, for one—it is unreasonable and irresponsible to assert that Soviet activities can be ignored in the debate over American strategic defense programs. Yet the church statements examined here show no such acknowledgement. By their omission, they indicate that American decisions on SDI should be made without consideration of similar Soviet programs—a dangerous and naive posture.

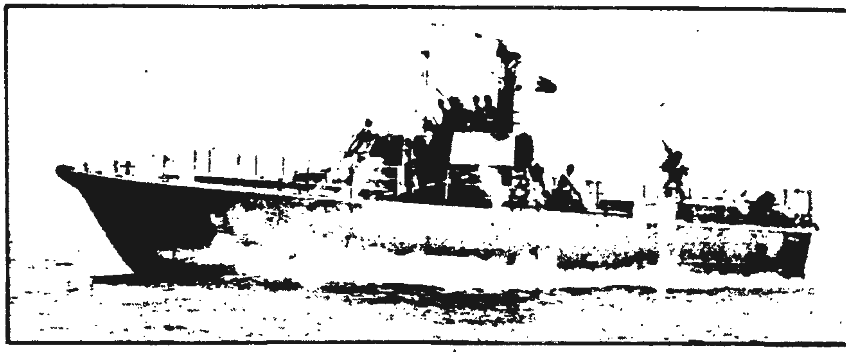
This information should serve churchmen, policymakers, and others interested in the moral dimensions of strategic defense by providing a basis for fuller understanding. The level of discussion can be raised quite simply in this way. But the exercise is not merely academic. President Reagan, in a speech shortly before his summit meeting with Mikhail Gorbachev, said: "The idea of using American technological genius to develop a system to protect us against nuclear missiles is moral and in the fundamental interests of our allies, and the cause of peace."

As long as the nation's top political leader continues to frame the debate in the language of morality, our moral leaders should respond likewise. As Cardinal Bernardin put it: "U.S. policies are life-and-death issues for many people. The role of moral argument in foreign policy is to call us to face our responsibilities squarely and to respond generously and wisely to them."

JANE'S DEFENCE WEEKLY 21 JUNE 1986 Pg. 1165

Israel faced by greater naval threat

ISRAEL is a country largely devoted to land and air defence, but the nation also faces a growing threat from the sea. Israeli Navy Commander Maj Gen Aberaham Ben-Shoshan talks to *JDW's Robert Hutchinson*



▲ *'Dabur' class patrol boat, backbone of the anti-terrorist patrol force. These craft are already armed with depth charge launchers at the stern and in war can be fitted with torpedo tubes for the Mk 44 46 ASW weapon (Israeli Navy)*

ISRAEL IS FACING a greater naval threat than during the 1973 Yom Kippur War from enemies now with "sufficient means to carry out all-out war at sea", according to Israeli Navy Commander, **Maj Gen Aberaham** Ben-Shoshan.

He told *JDW*: "It's very difficult for a country that has been ground-orientated most of its life and has never had a problem from the sea to understand what this threat can be."

In the last decade, Israel's enemies have been building up their naval strength, using technology from both the West and the Eastern bloc.

"Now we are facing a bigger threat, much more advanced technology, better enemy capability. Take the immediate threat, like Syria; they have got back all their losses of 1973; they have better Soviet equipment, better missile boats, better missiles. They are developing a better shore defence."

Israel was being forced to develop counters to technologies from both East and West. "Look at other nations that did not pay any attention (to technology advances), as happened in the Falklands when the British Navy faced Western technology that it was not prepared for, so the *Sheffield* was sunk."

Sale of equipment

The other problem was the sale of equipment to Israel's neighbours. "Today you can get everything for a good price." In the past year, some restrictions had been imposed but "as an overall policy, you can get everything in the market if you have the money to pay".

With the size of inventories of the Middle Eastern states, the threat can alter almost overnight, only by a change in intention. "One has to remember always that in the Middle East, to change a policy sometimes only takes bullets," said Gen Ben-Shoshan.

"Most of the countries around us and most of our enemies now have missile boats and submarines. They are getting new equipment. They have sufficient means to carry out all-out war at sea.

"This is the real threat for a nation that is located along a coastline, with most of the population and industry along the coastline."

The other vital threat came from terrorists trying to infiltrate Israeli defences from the sea.

"It is very difficult to detect a merchant ship that is carrying 28 terrorists coming to attack Israel."

Bases had been built in Lebanon from which attacks could be launched, using rubber boats from mother ships, speed boats, and initially, swimmers.

"Today they use speed boats and special yachts hired by Europeans.

"So we are facing a variety of means and the weaponry they are using is becoming more and more sophisticated and advanced. The decision-making process — who is the enemy? Is that an innocent ship or is it a merchant ship carrying terrorists? — is very difficult. The problem is that the guy doing the patrol has only four seconds to decide who is who and to respond with the right answer."

Gen Ben-Shoshan said it was true that all the Israeli armed forces "have a lack of money. But one has to remember that we differ from other navies in that we have a real threat that we have to be ready to answer every day.

"We don't have the luxury of being able to say okay, I will take time out, I will build a new navy and then I'll be ready. You have to be ready for day-to-day problems and day-to-day wars that can happen in the Middle East with no warning at all.

"The main problem is really how to split the cake; which part of your budget do you spend on day-to-day expenses and what do you invest for the future?

"This is the big task now, bearing in mind the state of the economy of the country. We have to act very carefully.

"The other point is how far the authorities understand the threat at sea. It is very difficult for a country that has been ground-orientated most of its life and never had a problem from the sea to understand this threat and how bad it can be."

The General stressed that much had been written about the airlift of equipment during the Yom Kippur War, "but actually it was only 5% of what we have got; 95% came by sea and we had to make sure that it came over safely.

"So we have to fight for our share (or resources) and I think we are not doing so badly."

Preliminary design work was almost completed on the new *Sa'ar-5* class of missile corvette. Gen Ben-Shoshan explained: "One of the possibilities was to build it in Israel but we don't have enough money to do it, so we must use different means.

"One possibility is to use (US) Foreign Military Sales (FMS) funds — that means that we have to go to the USA.

"On the other hand, we have Israeli shipyards. In the last five years they have had some difficulties, but I believe they are now overcoming these and trying to build up all the necessary means to be ready for the new programme.

"As for the (new) submarines, the American view is that no diesel submarines should be built within the States, we shall have to build them in a different place. We are looking now for the right place."

The *Sa'ar-5* will displace 1150 or 1200 tons and will be equipped with Israel Aircraft Industries' Barak anti-missile system. "It will be able to defend itself against missiles, helicopters, aircraft and smart bombs," said the General.

"Soft kill is not enough. We must have something that will kill the missile."

"Sometimes people describe this ship as a platform that is going to be built for fighting off Gibraltar, but we don't have this intention.

"We believe that the best way is to put pressure on the enemy, not wait at home to see what he will do."

As regards future smaller patrol boats, the Navy Commander said: "We are looking at some solutions. We checked on some patrol boats produced by the Western countries and most of them were not good enough for our needs, so we are in a state now of checking something different."

Mine warfare posed another threat and the General acknowledged: "You have to live with priorities. So when you have a limited budget, you have to decide what you want to do. I myself put the emphasis on offensive rather than defensive measures; to prevent the enemy sowing the mines and then, when it happens, I must be able to do something. In this area, we are working very hard."

Mine countermeasure helicopters were too expensive an option, although the General added that the Israeli Air Force had helicopters with an MCM capability.

training and assistance, and we did help save Grenada by force of arms. Yet at this moment, thanks to the Democratic leadership in Congress, our humanitarian aid program to the resistance forces in Nicaragua has expired, and for two years we have given them no military aid whatsoever. When we ourselves are unable or unwilling to act, I find it deeply unfair to criticize Latins who refuse to stand up to the communists over the issue of Nicaragua. If we won't stand up to this Soviet intervention, they will not get out in front of us. We are the great power in this hemisphere; like it or not, the responsibility for protecting it from the subversion of an extra-hemispheric great power is in the final analysis ours, not theirs. Let us not excuse our own indecision by hiding behind the uncertainties of our hemispheric neighbors.

Latins, too, know about avoidance. If—whatever our words—we accept a communist, subversive, repressive Nicaragua as our newest neighbor, so will they. Indeed, much Latin diplomatic activity in recent years has sought to define the terms of accommodation. But Latin leaders also know Nicaragua. They know who the Sandinistas are and what they stand for. They know about that attack on Colombia's Palace of Justice; they know what has kept the Salvadoran guerrillas in the field after repeated defeats and loss of popular support; they know all about the repression in Nicaragua; they know Managua is a terrorist base; they know Nicaragua is a pliant Soviet ally in the hemisphere; they even know who is torpedoing the Contadora talks.

Many Latin American governments are struggling with two problems: First the tension between traditional fears of U.S. intervention and the realization that U.S. cooperation is vital to resist Soviet intervention; and second, the concern that the firmness needed in Washington to resist effectively may in fact be wanting. The conclusion that our role is essential but missing can produce the same phenomenon of avoidance again; and if the conclusion means disaster, it is only human to avoid it by concluding that perhaps the United States is not needed after all.

If the United States is clearly active—if we are ready, willing, and able to defend our friends and our interests—all calculations change. Soviet and Cuban plans and activities must be reviewed, as they were after Grenada. Latin American views about likely winners and losers, likely patterns of stability and instability, likely rewards and punishments to those who resist and those who subvert, all change. Put less theoretically, it is easier to accept Sandinista aggression as inevitable if you think the U.S. will not oppose it. But it is also easier to conclude, and to say publicly, that Sandinista aggression is intolerable if you think the United States will not in fact tolerate it.

So we return to fundamentals. The Soviets are actively intervening in this hemisphere. Through Cuba and Nicaragua the Soviet Union has become a major actor in a region that extends to our southern border and is clearly vital to our security. This intervention must be admitted and it must be resisted and it must be defeated. If we are weak or indecisive, we will rally no one to our side. In Latin America the now familiar pattern of criticizing whatever we do as a half-measure while at the same time steering clear of commenting on Cuban behavior will continue and be repeated again and again. But if we are resolute in identifying and coping with the problem, the very clarity and firmness of our position will influence both the problem and the way it is perceived. It will help to win the support of many among those whose future depends on how the problem is resolved. That includes people inside Nicaragua and right here in the United States as well as in the rest of the Americas.

LOS ANGELES TIMES 22 JULY 1986 (23) Pt. IV, Pg. 1

Israel's Controversial Lavi Fighter Debuts

By DAN FISHER, *Times Staff Writer*

LOD, Israel—Israel threw a coming-out party Monday night for the newest and grandest weapon in its military arsenal, a futuristic jet fighter, amid boasts by some that the plane will propel the country into the 21st Century and warnings by others that it will only lead to economic disaster.

More than 2,000 invited guests were on hand here for the official debut of the Lavi, the product of by far the biggest and most expensive military-industrial project ever undertaken in the Jewish state.

The Israeli air force band played, soft drinks flowed and much of the country's leadership was on hand at the headquarters of Israel Aircraft Industries for the official rollout of Lavi Prototype No. 2. Prototype No. 1 is having instruments installed for the aircraft's first test flight, which is expected in October.

$1.2-Billion Price Tag

Underlining America's stake in the project, eight U.S. congressmen, including a possible 1988 presidential contender, Rep. Jack Kemp (R-N.Y.), attended the ceremony. Virtually all of the $1.2-billion bill for the Lavi's development to date has been paid by the American taxpayer, and billions of dollars more in U.S. funding will be required to build the 300 airplanes scheduled for production by the year 2000.

Defense Minister Yitzhak Rabin said 38 years of American-Israeli cooperation "has reached its peak" in U.S. support of the Lavi program.

Even as the Lavi rollout marked what its proponents would like to see as the program's "point of no return," however, its detractors have intensified their arguments that the plane is a technologically advanced millstone around the neck of Israel's already struggling economy.

If the project goes ahead, the critics predict, Israel, which is already the largest recipient of U.S. foreign aid, will soon be back in Washington seeking even more money. And Washington will face the unhappy choice of either paying up or watching passively as the economic strain of the program erodes the strength of its most important Middle East ally.

While the American defense Establishment could be expected to oppose the plane—each Lavi built means one less American plane sold to Israel—there are plenty of critics in Israel, as well.

Reflecting the fears of many of his military colleagues that the expensive effort to build the Lavi is putting too much pressure on other defense programs, Navy Commander Avraham Ben-Shushan recently commented wryly, "You could pay for the Navy's entire shipbuilding program just with the accounting errors on the Lavi."

Rabin conceded Monday that other military programs have suffered to keep the Lavi project going at a time of shrinking defense budgets. "We're taking tremendous defense risks for the sake of this airplane," he said.

But he and others said the Lavi represents much more than just a new warplane to Israel. Officials compared its economic impact to that of America's race to the moon, and they said its psychological impact may be comparable as well.

Prime Minister Shimon Peres, in a radio interview broadcast earlier Monday, called the Lavi "a superb achievement" that "only five or six countries all over the world" could hope to match.

Israeli officials question the Pentagon's cost estimates for the plane and note that nearly half of its components are to be built in the United States under contract.

A key test for the program is expected this fall, when the U.S. Congress reviews special provisions by which some U.S. aid to Israel is earmarked specifically for the Lavi. Sen. Gary Hart (D-Colo.), another 1988 presidential contender who visited Israel earlier this month, has expressed reservations about the Lavi program.

FT. WORTH STAR-TELEGRAM 16 JULY 1986 (23) Pg. 8

Army orders device to curb helicopter 'mast bumping'

By STAN JONES
Star-Telegram Washington Bureau

WASHINGTON — The Army, implementing a recommendation made two years ago by an investigating committee, has ordered production of helicopter hub springs to prevent a phenomenon known as "mast bumping" on its fleet of Huey helicopters.

Bell Helicopter Textron of Fort Worth was awarded a $5.9 million contract to build 4,350 of the springs — for $1,356 apiece — during the next six years.

A Bell spokesman said that initial deliveries of the springs, which were patented by Bell in 1978 but were never installed on military helicopters, will begin in June of 1987.

They will be mounted on all UH-1 Huey helicopters to keep the rotor blades from making contact with the mast during difficult maneuvers.

Mast bumping, a phenomenon unique to the teeter-rotor design used on Bell Huey and AH-1 Cobra helicopters, has been cited as a cause in crashes that have killed 241 servicemen since 1967.

A committee formed to investigate the problem recommended in July 1984 that the Army's Hueys be re-equipped with thicker masts and hub springs. The committee also recommended hub springs for the Army's 1,500 Cobras.

At the time of the committee report, only 739 of the 3,737 Hueys in the Army helicopter fleet did not have the strengthened masts. The Army ordered Bell to begin stepped-up production of the thick-walled masts to bring all Huey helicopters into compliance.

The Army decided to delay placing hub springs on its Bell fleet pending tests. The military feared that the springs would place added stress on the engine transmissions and force expensive modifications.

However, Bell spokesman Marty Reisch said the Army's concerns proved unjustified.

The $5.9 million hub spring contract awarded to Bell last week covers production costs only. Reisch said 3,350 of the springs are slated for installation on existing Huey helicopters, and the remaining 1,000 springs will be replacement sets.

A spokesman for the Army's Aviation Systems Command in St. Louis said that he was unsure whether Bell or the Army would install the springs after they leave the assembly line.

It was also unclear whether the Army plans to place hub springs on its Cobra helicopters also, as the committee recommended.

Army officials estimated in 1984 that the total cost of placing hub springs on its Hueys and Cobras would be about $36 million.

The committee that studied mast bumping was formed after a 1984 *Star-Telegram* series on the problem.

DENVER POST 13 JULY 1986 (23) Pg. 10B

Book says Sandinistas will never share power

Shirley Christian, a Pulitzer Prize-winning journalist, has written a book on Nicaragua. She calls it "Revolution in the Family," and it will not be popular with the pro-Sandinista movement now firmly entrenched in campus and religious circles.

GEN. T. R. MILTON

After years of covering Central America for the Miami Herald and lately The New York Times, Christian has not only made some careful observations, she has also arrived at a judgment on the Sandinistas. They never intended to share power.

Critical of Carter

From the outset, she says, they have carefully set about the establishment of a traditional Marxist state, and U.S. harassment has had nothing to do with it. She is severely critical of the Carter administration's weak policy toward the Sandinistas, a policy that was based on wheedling rather than pressure.

Christian's book comes at a good time, given the current confusion over President Reagan's Central American policy.

The administration's narrow victory on the question of money for the contras was in no sense a decisive one. That was a skirmish; the real battle lies ahead. One hundred million dollars, while not just walking around money, will not carry the contras very far. Certainly, it will not begin to match the kind of support the Sandinista government is receiving from the Soviet Union.

U.S. interests at stake

So much nonsense has been babbled about Central America these past few years that the real issue has been almost hopelessly obscured. The United States, with its interests and its security in mind, cannot willingly tolerate a Soviet-sponsored revolution in Central America. At the very least, the contras are serving a useful military purpose by keeping the Nicaraguan army preoccupied and thus unable to indulge in other mischief.

Lately, with all attention focused on the contras and Nicaragua, we seem to have forgotten El Salvador. A few years ago, that country was being written off. Journalists were making daily sorties from their comfortable bivouac in San Salvador's Westin Hotel, El Camino Real, to spend a few hours with the insurgents.

Like their Managuan comrades, El Salvador's Marxist guerrillas do a great job of romancing the press, so, not surprisingly, they received generous treatment in stories filed from the Camino Real. The irony of retreating at day's end to a home base made safe by El Salvador's soldiers was never reflected in any story I read, nor in any conversation overheard at the Camino Real bar.

Training made difference

El Salvador is pretty much out of the news these days, thanks in large part to our military assistance. The Salvadoran officer corps, once a politicized group of military academy cronies with little motivation, has been rejuvenated by an infusion of U.S. trained officers. American trainers, the current euphemism for advisers, have drilled their charges in tactics, night operations, and the strategic importance of proper behavior toward the populace at large.

Just as important, the Salvadoran Air Force now has enough helicopters to give the wounded a chance. Before, when air assets belonged in a museum, a high percentage of casualties were doomed to battlefield death. The effect on morale and fighting ability was decisive.

El Salvador is beginning to look like a success story, albeit an isolated one, for our Latin American policy. It won't remain so if Nicaragua, freed of harassment, can set about its declared intention of exporting Marxist revolution.

Gen. Milton is a contributing editor to Air Force Magazine.

NEW YORK CITY TRIBUNE 21 JULY 1986 (23) Pg. 3

Norway Watching Soviet Mystery Tug 7 Miles Offshore Very Closely

BY THE INTERNATIONAL DESK

OSLO, Norway, July 20 — A mysterious Soviet tugboat anchored off northern Norway has baffled the Norwegian military and is under close surveillance, military sources here said today.

"We do not know what operations the ship is engaged in. After being hailed by the Coast Guard, its crew said they were part of a contingency plan to aid distressed vessels in the area," said Army Major Jan Erik Lie.

"But because there are no Soviet naval maneuvers in the area at the time, and because of the length of its stay, we will continue watching it with Orion reconnaissance aircraft to find out what it is doing there," he added.

Since July 3, the 200-foot Gorynclass tug, part of the Soviet Union's Murmansk-based Northern Fleet, has kept the same position some seven miles off the coast of Soeroeya, Lie said.

"A cable has been observed dangling off the tug into the water, but because the ship is in international waters we are not permitted to board it for closer inspection," he added.

Soviet military support vessels have anchored at the same position several times earlier, most recently in August 1984.

Soviet military strategy is known to call for laying mines and communication networks, as well as devices that can detect submarines, at key choke points underwater along the West's geostrategic lines of communications.

One of the missions of a remote-controlled submersible robot, like the submersible "Jason Jr." is to find such underwater obstacles seeded there by the Soviets or their allies. Most recently, the Jason Jr. has been used to explore the hulk of the HMS Titanic.

ELECTRONIC WARFARE

JOURNAL OF ELECTRONIC DEFENSE JULY 1986 Pg.49

EW Canada

Looking Back, Looking Ahead

COLONEL W. NEIL RUSSELL (RET)

Colonel W. Neil Russell (Ret) *is the Director of Business Development for COM DEV Ltd.* ■

Publications dealing with the history of electronic warfare usually start with the "Battle of the Beams" as Churchill called it. That is to say, the measures taken by the British early in World War II to deflect electronic beams which the Luftwaffe used for blind bombing over the UK. The history texts then go on to describe the development of and use by American, British and German air forces of radar countermeasures and other EW equipment. It would appear that Canada is not well-known for its capability in EW. Canada, however, was involved in EW in the past, has significant current capability and plans even greater capability in the future.

A Canadian, Dr. Donald Sinclair, working with the General Radio Company, Cambridge, Massachusetts, led the team which developed the first effective broadband signal receiver, the SCR-587. And, as early as 1942, Canadian aircrews operating out of the UK employed "Window" (chaff) against German anti-aircraft radars.

During the invasion of Sicily in 1943, three squadrons of Canadian Air Force bombers were equipped with jammers in order to neutralize German Wurzburg and Freya radars. The Canadian army in World War II had "Special Wireless Sections" at the corps and division levels. Perhaps the least known of all Canadian units in World War II was "Number 1 Special Wireless Group" which was sent off to Australia in late 1944 to intercept and interpret Japanese morse code signals.

Canadian EW capability after World War II survived mainly through the Royal Canadian Air Force (RCAF). When the North American Air Defence Command agreement was signed in the 1950s, the RCAF contributed an EW unit. Equipped with C-119 Flying Box Cars, its role was to deceive and jam the NORAD ground environment so that controllers would be practiced in the events likely to occur during a bomber attack. In 1967, using the EW unit as a nucleus, the 414 (EW) Squadron was formed. Equipped with CF-100 and T-33 aircraft, its role was expanded to exercise and train maritime as well as air force aircrew and ground controllers.

PRESENT

To provide a picture of how seriously the Canadian Department of National Defence (DND) takes EW today, we can review the "order of battle" of the units involved. First, providing policy guidance in National Defence Headquarters, there is the "Directorate of Electronic Warfare." Second, at the Defence Research Establishment, Ottawa, there is an Electronic Warfare Division.

Created in 1978, the EW Division's purpose is to conduct research and development relating to the interception, location and jamming of communications and radar systems. Among its assets is a tracking radar simulator (TRS) used to demonstrate the effectiveness of radars against countermeasures, or conversely, the effectiveness of countermeasures against radars.

A third DND EW resource was founded in 1984 in the form of "The Electronic Warfare Operational Research Team (EWORT)." As part of the Operational Research and Analysis Establishment located in Ottawa, the EWORT provides theoretical analysis in support of air, land and maritime EW requirements.

Canadian Forces' EW activity has also grown in recent years. 414 Squadron is now equipped with twin-engined Falcon Fan Jets with electronic ECM suites and chaff dispenser systems. It also has a residual F-101 Voodoo equipped specifically to exercise Canadian Forces CF-18s. Canadian land forces have an electronic warfare squadron which deploys regularly, taking part in field exercises in Canada and Europe.

In Canada's maritime forces, the CP-140 Aurora Maritime Patrol Aircraft are equipped with IBM AN/ALR-47 surveillance receivers designed to detect signals of very short duration typically used by submarines. The new Canadian Patrol Frigates, as well as upgraded older destroyers, will be fitted with the M.E.L. Defence Systems' AN/SLQ-501 Canadian Naval Electronics Warfare System ("CANEWS") ESM system and "RAMSES" (Reprogrammable Advanced Multi-mode Shipboard ECM System). The newer ships will also be fitted with the Plessey "Shield" anti-ship missile decoy system and new submarines soon to be ordered are likely to have a miniaturized version of CANEWS.

The "piece de resistance" of the Canadian Forces current EW capability however, is the CF-18 configured for both the ground attack and air defense role in Eu-

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rope. Each has the following equipment:

- Litton ATD AN/ALR-67 radar warning receiver,

- Northrop AN/ALQ-162 CW jammer,

- Sanders AN/ALQ-126 (B) high energy pulse jammer tuned to I- and J-band radars, and

- Goodyear AN/ALE-39 flare and chaff dispenser.

From an ECM viewpoint, the Canadian CF-18 is, without doubt, one of the most survivable fighter ground attack aircraft assigned to NATO today.

INDUSTRY

For its industrial size, Canada has a comparatively large and sophisticated electronics industry. There are eight known EW systems and subsystems companies in Canada. Canadian Astronautics Limited (CAL) of Ottawa produces the Automated Computer Controlled Environment Synthesizer ("ACCESS") as well as the Tactical Signal Generator ("TASS"). Canadian Marconi Company (CMC) of Montreal and Ottawa produces S-band and X-band radars into which it builds frequency agility, techniques. CMC is currently developing a combined ESM/radar antenna for helicopter application.

COM DEV Ltd. of Cambridge, Ontario, although known primarily for its SATCOM subsystems, produces advanced technology radar pulse compression units and is developing three millimeter-wave subsystems, a high power passive/active phase shifter directional array, and an EHF SATCOM beam configuring and jam nulling system.

MEL Defence Systems of Stittsville (near Ottawa) is the only company in Canada devoted entirely to EW systems. Its AN/SLQ-501, also called "CANEWS," provides real-time threat detector and classification. The active counterpart, called "RAMSES," will be produced in Canada by MEL, but was developed jointly by MEL (UK) and Signaal of the Netherlands. MEL, perhaps in connection with COM DEV, is likely to extend the frequency range of CANEWS and RAMSES.

Miller Communications Systems of Ottawa produces mobile VHF and UHF spectrum monitoring systems. SPAR Defence Systems of Kanata (near Ottawa) produces the AN/SAR-8 Shipborne Passive Surveillance and Detection System. Telemus of Nepean (near Ottawa), produces a number of EW related broadband microwave integrated circuit components and subsystems. Its product listing includes microwave halvers and digital radio frequency memories. Varian Canada of Georgetown, Ontario, produces medium-power travelling wave tubes which can be used in ECM applications.

In addition to these eight companies directly engaged in EW, there are ten smaller companies who provide classified software for EW systems. Additionally, there are five subsidiaries of large US electronics companies who, although not producing EW equipment at present, market equipment for their parent companies and could produce subsystems if tasked.

Another program worthy of mention is the Electronics System Trainer (EST) version of the Canadair Challenger aircraft. Not much is known of this at present because the project definition phase is just beginning. However, it is known that the Canadian Forces have acquired seven Challengers, each of which will be fitted with a broad array of both passive and active EW equipment. Industry consortia are beginning to line up. One led by Canadian Marconi is likely to try to convince DND that, although some "black boxes" may be required from abroad, Canadian companies can accomplish most of the work. Another consortium will undoubtedly try to convince DND to reduce the risk and procure proven (US) systems. The outcome could have a direct affect on the degree to which Canada will have an indigenous EW capability in the future.

It should be obvious from the preceding descriptions that Canada has a swelling interest in EW. One might question why. First, Canadian defense analysts, like their counterparts on both sides of the Iron Curtain, recognize that to an ever-increasing extent, all command, control and weapons systems are becoming dependent upon electronics. In the next war, the side which best controls the electromagnetic spectrum is also likely to control the battle.

It would be unrealistic to describe Canada as a past, present or future EW giant. Yet, when all is considered, Canada has been involved since the beginning. In the CF-18 she has state-of-the-art capability at present, and Canada's comparatively large and sophisticated electronics industry shows great potential for the future.

MISCELLANEOUS

NATIONAL GUARD JUNE 1986 Pg.24

NATIONAL GUARD

Fights War On Drugs

By CPT Jean Marie Brawders
Assistant Editor

Paradise. Gold Coast. Land of Sunshine. Sobriquets all for Florida and Hawaii—America's own brand of heaven. But the two states, one piercing the Gulf of Mexico and Atlantic Ocean in the East, the other in the blue Pacific, have unwillingly become havens for drug smugglers and marijuana growers.

Both also have become active in the war on drugs, which includes using their states' National Guard assets to combat the problem. The first state to use the National Guard to fight the war on drugs was Hawaii when, in 1976, Governor George Ariyoshi began an ambitious project called Operation GREEN HARVEST that combined various local and state agencies to eradicate marijuana, which was fast becoming a billion-dollar business. In 1977 Operation GREEN HARVEST, an annual budgeted project, included the Hawaii Army Guard for the first time. In every case, the governor has put the Guardsmen on state active duty, a status preferred by most adjutants general in these cases, to carry out the operations.

Since then, more National Guard organizations have become actively involved in either the eradication or interdiction of drugs. The National Guard Bureau's (NGB) policy is to provide Guard support to the maximum extent permissable by law, according to officials from the office of Military Support, NGB. LTG Emmett H. Walker Jr., chief of the National Guard Bureau, in his address to the subcommittee on government operations May 19, 1983, said: "It is the policy of the National Guard Bureau to encourage support to civil law enforcement officials except where such support directly detracts from the National Guard's primary training for its wartime mission."

A June 23, 1985 *All States Letter* was published specifying support to drug enforcement operations following several clarifications regarding the use of Guard aircraft for training of state emergency response personnel. Missions performed by Guardsmen may be done in a state active duty status, or drill or annual training status (title 32) so long as it doesn't interfere with training.

While the Posse Comitatus Act prohibits the use of the active Army in a law-enforcement role to assist local police officials for domestic problems, the Guard is not restricted by that law because it comes under state control; in peacetime, its commander-in-chief is the governor. (An ammendment to the law passed in 1981 allows local law enforcement agencies to use the active services' equipment.) Yet many of the operations require helicopters that many law enforcement agencies do not possess. Douglas Gibb, Honolulu police chief, was blunt in his assessment. Without the Guard's helicopters and crews, he said, the "eradication program would have been severely retarded."

The Guard's role in drug enforcement operations, nationwide, took hold in 1983 when four states, California, Georgia, Hawaii and Kentucky, reported missions. Eight requests for Guard support were made that calendar year. By 1984, the number of states had increased to 14. By December 1985, 20 states were participating in drug enforcement support operations. More states plan to join the war on drugs.

The Guard's support falls into two categories: eradication and interdiction support. "Eradication support by the National Guard is when we assist the law enforcement in the identification and removal of domestically grown marijuana plants," said an NGB official from the office of Military Support.

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"The interdiction program is when we support civil authorities in the interdiction of illicit drugs coming into the United States."

For the states of Hawaii and Florida, the problem of drugs had become so widespread and severe that the states' governors believed it necessary to enlist the support of the Guard. Florida Governor Bob Graham, in testimony for a February hearing of the House Government Operations Committee's subcommittee on government information, justice and agriculture, stated that Florida Department of Law Enforcement seized 105 drug planes within the Florida borders in the past 2½ years.

"At least 50 percent of those had not been picked up by radar as they approached the coastline," he said. "That number is not even a fraction of what is getting through undetected . . . ."

In Hawaii, Ariyoshi is another governor who has taken a hard stand on the war on drugs. So strong are his feelings that he declares a state emergency every time the Guard is called on. MG Alexis Lum, adjutant general of Hawaii, said he budgets from $150,000 to $175,000 (in state funds) a year for Guard support, which includes the cost of reimbursement for direct hourly operational costs on the helicopters and mandays for Guardsmen.

Drugs have become serious business for growers and law enforcement officials alike. "During the past three years, use of National Forest lands for illegal cultivation of marijuana has increased dramatically. Illegal growers take extreme measures to protect their crops, including use of armed guards, guard dogs and various dangerous devices (e.g. firearms with trip wires, armed hand grenades with trip wires, camouflaged pits with punji sticks and treble fish hooks suspended from monofilament line at face height)." The statement was made by Frank V. Monastero, assistant administrator for operations, Drug Enforcement Administration, U.S. Department of Justice, during hearings before the subcommittee on crime of the Committee on the Judiciary, 1983.

Further complicating matters is the elusiveness of the growers. Stated Carlton E. Turner, Ph.D., special assistant to the president for drug abuse policy, during a hearing: "Last year (1982) the executive director of NORML, George Farnham, told a congressional hearing, 'Marijuana growers choose federal land for several reasons. The most obvious is that it is nearly impossible to arrest someone for growing marijuana on federal land unless that person is caught standing next to the plant.' In addition, the forfeiture laws have forced growers to public land. 'Their theory is that you cannot forfeit what you do not own.' " As a result, according to drug agents, the growers are resorting to smaller, though more and dispersed, plots of marijuana. The result is that law enforcement efforts become more labor intensive and, therefore, more expensive and difficult.

For Hawaii Guard officials and aviators, Hawaii law enforcement and NNBIS (National Narcotics Border Interdiction System under the direct control of Vice President George Bush) agents, these statements come as no surprise.

When Hawaii Army Guard aviators first started flying missions, threats were often made to the pilots, according to MAJ Eugene Young, state aviation officer. "We used to get threats like, 'You better not be well enough to fly tomorrow,' " he recalled. "Even though we have a big population, the state is still very small. Word gets around. When we went to other islands and made reservations, they would call the hotel clerks and know we were there. They used to find out our rooms."

Though no threats were ever carried out on the men themselves, Young and SGM Lester Nakaichi, plans operation specialist, military support division, Hawaii Guard, recall an assault made on one of the choppers that left the aircraft with a shattered windshield. Nakaichi said he remembers a vehicle driving by an operations area at a high speed and a rock being thrown at the aircraft.

Other intimidating tactics used included gas-tank caps being taken off a chopper giving the impression, according to Young, that the fuel had been tampered with. The fuel would have to be checked and the procedure would slow down the operation.

BG Irwin Cockett Jr., Hawaii's assistant adjutant general for Army, and an aviator who served three tours in Vietnam, recalled another mission he called "interesting." "We were having a meeting of minds going on with Kauai law enforcement guys in intelligence," he began. "They had received several reports (from individuals) that there were armed 'what appeared to be' foreigners. The weapons described looked like AK-47s. They were in camouflage (garb)." Cockett said the individuals who approached these 'foreigners' were told, with pointed weapons, to 'go away.' The general said his mission was to develop a team to go into the area to check out the reports.

"So we went into this forest and we did not find any of the people there but we did find large quantities of marijuana. We suspected they had air capability as well because of the difficulty in getting into the area." Bureau officials say that such incidents are isolated cases.

Cockett recalls another episode, though one with a bit more humor. He said during one operation the Guard went into an area where marijuana had been camouflaged with other plants. The police were lifted into the area and the marijuana was eradicated. The next day Cockett said he and his crew decided to fly back over the same area. "My crew chief couldn't believe what he was seeing," he said. Where the marijuana had been eradicated was an area that was covered with the vegetation once again. "Those people (growers) must have worked so hard all night long to move marijuana from one area into the area we had just cleared," he said with a laugh. "I don't think they expected us to fly over the same area again!"

Operation GREEN HARVEST, Hawaii's organized eradication program, is one that is carefully planned each year. Nakaichi said that every August he calls on the chiefs in the police departments' vice divisions. The Guard lets the police officers know what flying hours are available and the law enforcement officials talk about current needs. Sometime before a given operation is to take place the respective mayor makes a request in writing to the governor. The governor then orders Hawaii Army Guard elements to state active duty. The Hawaii Guard then responds and supports with helicopters and crew. The state supports the cost of Hawaii Army Guard assistance.

Despite the fact the operations are planned long in advance and that Operation GREEN HARVEST receives wide publicity in the local media, the growers still continue to grow, though the risk of losing money on a lost crop is omnipresent. (The program's concept is to go

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after and eradicate the marijuana; not to go after the growers for the reasons stated earlier.) "There's such a vast space," Nakaichi responded. "We can't hit all the areas." The growers presumably conclude the same.

According to statistics from Hawaii officials, in 1977, Operation GREEN HARVEST included seven operations involving 24 Army Guardsmen at a cost to the state of $19,567. The operations, however yielded 28,366 plants with a value of $6.2 million (value based on the conservative figure of $1,000 per plant). By 1981, there were 10 operations conducted involving 254 Guardsmen at a cost to the state of $180,674. The yield: 338,407 plants at a value of $23.2 million. From 1977, when the program began, through 1985, the state spent slightly less than $1 million to eradicate $229.2 million worth of cannabis.

But numbers do not tell the whole story. BG Cockett said the missions are excellent training, not just for aviators, but for the support personnel as well. "We get lots of mileage out of this training," he said. "It's the best training for my aviators. It goes beyond just control of the aircraft. Maintenance sergeants and NCOs need to continually be planning.

"We have to move fuel close to the operation. It was the same thing in Vietnam. (In Vietnam) our ordnance would be gone, and we'd have to fly all the way to base to rearm. All that took planning for forward area Army refueling points. The planning (now) is the same used in area of operations. Supply, maintenance and security are important."

Cockett said he was an aviator at the time the first mission was flown for Operation GREEN HARVEST. He said the first operation was conducted beginning at 0200 hours. Security was tight. Briefings were given and the forces joined together at a certain island. "We loaded that stuff right up to the roof (of the helicopter)," Cockett recalled. "We learned a lot from that first mission. About the only thing we're missing (in terms of combat realism) is someone shooting at us."

Interdiction, not so much eradication, is what concerns Florida officials. Florida officials say 75 percent of all cocaine that comes into the United States comes through Florida. A pier near Green Cove Springs between Jacksonville and St. Augustine, Florida, lined with dozens of confiscated boats, gives testimony to the increased smuggling of drugs through Florida borders.

"The interdiction effort, when it is supported or to the extent it's supported, pays heavy dividends and accomplishes a lot," said MG Robert F. Ensslin Jr., Florida's adjutant general. "And we just think more should be done on interdiction as well as investigation and as well as education really, to attack the demand side of this problem.

"Our borders are violated every night by small aircraft and boats bringing contraband into our state, and through our state to other states. And when our borders are not secure, we're talking about a national security issue that really only the Defense Department has the resources and capability to deal with. And so Governor (Bob) Graham is urging that military resources be applied against this problem."

Ensslin said there is resistance to this from some in Defense because of concerns that readiness will be hampered and that money from Defense will be diverted to law enforcement at the expense of preparedness.

"My position to them ... is that the Defense Department is preparing for a war that we hope never comes. But the drug problem is a war that we are already in, and that we are losing. And a war that we cannot afford to lose because of the way it erodes the fabric of our society.

"I feel there are some things that we can do beyond what we are doing—if it were resourced, either by the state or the federal goverment."

Ensslin said to date a memorandum of understanding between the Guard and the Florida Department of Law Enforcement (FDLE) has been signed under which the law enforcement officers teach Army aviators the techniques for detecting domestic cultivation of marijuana so that the pilots are alert for it while flying regular training missions. He said to date the state legislature has not earmarked funds so no operations like those in Hawaii can be conducted. Ensslin added: "We have been involved in joint exercises with the state of Georgia and the Georgia Air National Guard and the Florida Army Guard and the FDLE and the Georgia Bureau of Inves-

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tigation and Customs with the coordination of NNBIS. We ran an exercise in December that was a very productive exercise that resulted in the confiscation of a number of aircraft by FDLE, thanks to detection.

"The marijuana and cocaine comes in on the low-flying, slow-flying planes that are coming in under our current radar screens, undetected. What we did in our operation, which was really to beef up the detection capability, and beef up the radar coverage to pick up these low guys, and we found they are out there. Governor Graham makes the point that the airplanes that are coming in currently with marijuana and cocaine, that one day could be loaded with explosives with a terrorist on board eying lucrative targets they wanted to attack.

"I think with the heightened awareness that we have of terrorist capabilities, that it's not really stretching anybody's imagination a great deal to anticipate that something like this could happen."

According to Ensslin, the Congress in the appropriations bill for FY86 authorized and appropriated funds for air reserve forces, special operations wing. The concept of the Congress, he said, was that the wartime mission would be special ops, that in peacetime, in training and preparation for this mission, that this unit would fly customs agents in a detection mode, using these aircraft with a look down radar capability.

Drug enforcement agents and Guard officials agree much more could be done given more money. "We'd like to take a more active role," Lum said. "But certain things restrict us. Our primary mission is (combat) readiness. We have 5,000 plus hours of flight time." In 1977, 190 flying hours were used toward the program. In 1979 that number increased to 934 hours but has dropped back down to 375 hours last year. But Young said the problem is not so much flying time as the maintenance to support that time.

But drug enforcement officials, local, state and federal, praise the Hawaii Guard for the support it has given. "I think (the Guard's support) has been superb," said Rear Admiral Alred P. Manning, commander of the 14th Coast Guard District, and coordinator, Western Pacific District, NNBIS, based in Honolulu. "The Guard has been very responsive. It is reasonable to say that without the Hawaii National Guard we would not have been able to be as successful as we have been."

The admiral's feelings were shared by special agent Joel K. W. Wong, Hawaii statewide marijuana eradication coordinator; Joseph Brzostowski, Drug Enforcement Administration, U.S. Department of Justice, and Dick Cole, staff director, NNBIS. "Helicopters were a big problem," Cole said. "That's where the National Guard came in. The cooperation is great. Everybody works together well."

Wong said that having the Guard support made operations "much easier." Frank Su'a, a major in the vice division of the Honolulu Police Department, went a step further, "We wouldn't be able to perform eradication without the National Guard." He said that in Honolulu, much of the marijuana is planted on the Koolau and Waianae ridges that are inaccessible without the aid of choppers. The Guard has taught police officers how to rappel from choppers into these remote areas.

Everyone agrees that the Guard's support has put a dent in the marijuana problem. Honolulu police officials said the problem used to be much more severe in Oahu. Now, they said, many growers have either gotten out of the business or have moved to the Big Island (Hawaii).

~~B~~

1) precedents S 7 nd
2) Summit
3) Sinc

in I SU tried to block cruise, pershings etc (decided in 79) - tried to make out US as gun-happy & to .. diff strategic program of replace obsolescent submarines etc ....

Is pro WW2 tradition contained -

SU to protect peace maybe in Europe

NATO succeeded in deploying missiles - SU pulled out of talks for yr -

Summit - disproved their argument that buildup wd make peace impossible -

none of that pre detente phrases - of ideals of non-interfere in internal affairs - & leave issue to settle.

included "deal w" humanitarian problems"

quiet diplomacy re human rts - unless results will have public diplomacy -

SU proposal - "indigestible"

fix point - ambiguous - (until bad news)

Stage in reduction -

() 50% reduction of str. defense forces to include all US & Britain, SU - those capable of striking territory of other side -

including ours in Europe, earlier -

SU ones in stuff in SU

US cd get rid of all [illegible] Europe & his own

3/ linked to SDI
can't verify their stopping

3) limited freeze w/ of GB, French + Chinese - & they're not buying at all - want their ind forces

4) verification - press says - SU - results on site only of process of weapons destroyed -

Lack of Congress talking Soviet positions legislation
1974
150 K.t. limit on tests - (hard to verify) -
we propose technician to go to site to measure
SU says no - called for ratification as was -
Congress passed resolution saying ratify w/o conditions -
also ASAT weapons -

Soviet and Soviet military program that benefits
from espionage -
in 1984 35 SU agents expelled from Western
countries -
5 yrs ago 5 customs people on this - transferred
450 m to customs service - now over
1000 agents in field -
were building up 5 yr plan to espionage equipment
now factors not opening because.

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5 undersecretary - now to 2 -
said to 5 directors ch. of Jt Chiefs of staff to Cactus rotated)
should be dep. ch.

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oversight
Security Board
resources
denying Soviet access

6)

politically — COSATU, parents, etc. — Meanwhile — they + kids are making things very difficult for reformers — they're again calling for end actually causing disinvestment —

no one for reform — business, bd & better used universities, Buthelezi + Jewish community is for, & liberal newsmen

~~1) not~~

~~1)~~

1) will have some unintended consequences eg arms embargo brings

(only 70s — now SA exporting — 1 billion last year &

2 Roof

2) a) will hurt blacks most, poor; will decrease opptys for exploding have to create 1/4 m unskilled jobs yr to keep up.

no in education blacks — have to —

~~will~~ will ~~create~~ powder keg —

3) on other side will hurt white working class — push them to right

cd be exploding.

on right — eg ~~the same considered~~

Treurnicht — of opposition

HNP — of Afrikaners

~~Front~~ & far rt — death squads —

[cannot] slow down — dress Afrikaners back to ox wagons —

+ Afrikaners — + big ? much —

a problem —

~~which if~~ 3rd world + 1st world — + there's no —

one man, one vote, one time — 45 states in

Africa — no example of change by ballot

First let me thank you for inviting me to
~~speak. Your invitation has given me occasion~~
~~to think about what it is that I do at the~~
~~White House.~~
Speak. I welcome this opportunity. On the other hand
I do not want to abuse it.

Welch part 2 - B

patriot upgrade - good anti aircraft - ~~short~~ pt. defense - eg at the air base ~~5~~ miles - anti aircraft 50 miles.

Key - battle mgt -
~~sub... programs~~.
10 million lines -
~~at the~~ he (d write very sophisticated program
distributed architecture -

We have big advantage in computers -

eg 6 battery 7 interceptors - lose one. can it reconfigure w this knowledge -
even shorter range sld be 2 shots - 1) mid course
head eye - 2) short range. seeker on upgrade patriot -

cd revolutionize conventional battlefield - then sensors
smart system & micro miniaturization ~~at the~~ &
knock out tank -

Europeans
(DI) - to take these technologies - to apply to
conventional
battlefield problem - anti tank, anti
aircraft,
not by artillery launched - too. so small.

[DI] - more int. & from - on front line

ATBM - few hundred million / yr now -

partial upgrade is system dept - not in SDI

presidential directive to emphasize. 6-8 mo.

battlefield -

airborne optics - [Cd be 1/3 contingency - Boeing] Alabama

terrain imaging radar

kinetic - head eye.

technology list - including SR hi.D

Sensor technology - infra red detector applied.

[gd based laser - huge - bounce off mirrors -
2005]

4-5 passes by M...days -

(Betsy) (on army)

neutral particle beam - 90s - screw up

Sound System

&

laser designators as sensors -

rail guns - process

Army has program to transition - new to anti-tank stuff etc

[Day - of briefing]

1)
2)
3) what do they military
4) will Army sell endorse

Kuhn
Col. Pfeiffer - 1st 1:30

[illegible] [illegible]

Sens[illegible]

[illegible] [illegible] [illegible] super AWAC terminal

down to 3[illegible] ft -

Electro-magnetic [illegible]
gravity

AJAN
wd [illegible]

decoy -
[illegible] [illegible] → [illegible] left [illegible] for decoy
[illegible] [illegible] [illegible]

[illegible] [illegible]
Computer [illegible]

Patcheck
653 0053
653 013
6

[illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible]
[illegible] [illegible] [illegible]

[illegible] [illegible] for [illegible] [illegible]

optic [illegible] 7 electronic.

aimer -
interesting [illegible] + [illegible] [illegible]

5 [illegible]
dir -
[illegible] [illegible]
goes

Richard Bleich 653 0036

Jastrow

SU decision after Cuban ~
4th generation — 1st strike weapons, yield &
& accuracy to take out hardened targets.
~8-12,000
4000 top priority targets — each
∴ ~~retaliatory~~, we have 400.
SU 40B/yr in Strategic defense - us 1/15th
3B - civil D
12-15 - air defense. will stop B52 and cruise.
B1b uncertain at best.
25-50 B, + ABM -
close 1990s - ABM defense -
by 1990's: 5th generation arsenal:
how only 3B a year. 34/19.7 GNP ~19.7 defense budget

SU destroyed Israel - we wd wring our
hands - wldn't sacrifice US pop to revenge
in 1990's can deploy 90% of people
in infrastructure
in late 1990s - can protect more than 99%.

Soviets - is there Europe tomorrow - ~~bu~~
- Mideast

technology in ICBMs.
defenses v ICMB - cycle better against others - found
50 kilometers
ours will be less expensive for defense v theatre
weapons.
bec. short range in atmosphere longer.
smaller - fewer warheads
no decoys - bec air resistance separates them

c defense 10% effect y full scale SU attack -
will be 100% effective 4 3 for Qaddafi

space based platforms over SU
10 %, of time -
rest of time

Conventional arms
Arab arms buildup breaking back of Israelis economy

defense of tactical bombers, cruise missiles can be defended by fighters - now more upgraded
cost effective - high class AWACs &
direct of rays conventional weapons
of cluster types. clubbed into depots
a space platform
~~systems - surface~~
terminal defense could defend for Israeli.

cost ratio of 2:1 - 40/1 - y ~~surface to air~~
x conventional

5% of $ c arms
most planes
prod jobs - in point

US
c state - x 4 others - mid 90's

---

why haven't SU moved
restless empire
US doubled spending after N Korean invasion

(C)

(C)

STRATEGIC DEFENSE INITIATIVE

Common Cause MAY/JUNE 1986 Pg.32

SDI

Why I Quit STAR WARS

By Dr. David Parnas

A scientist and defense consultant confronts questions of conscience.

In May 1985 I was asked by the Strategic Defense Initiative Organization (SDIO), the group within the Office of the U.S. secretary of Defense that is responsible for the "Star Wars" program, to serve on a $1,000 a day advisory panel, the SDIO Panel on Computing in Support of Battle Management. The panel was to make recommendations on a research and technology development program to solve the computer-related problems inherent in a space-based defense system. We were told that there were substantial resources available (billions of dollars over the next few years) and advised to consider large (expensive) programs.

Like President Reagan, I consider the use of nuclear weapons as a deterrent to be dangerous and immoral. If there is a way to make nuclear weapons impotent and obsolete and end the fear of nuclear weapons, there is nothing I would rather work on. However, two months after joining the panel I resigned. Since then I have become an active opponent of the Star Wars program.

My decision to resign from the panel was consistent with long-held views about the individual responsibilities of a professional, which I believe go beyond an obligation to satisfy the demands of an immediate employer. As a professional:

- I am responsible for my own actions and cannot rely on any external authority to make my decisions for me.
- I cannot ignore ethical and moral issues. I must devote some of my energy to deciding whether the task that I have been given is of benefit to society.
- I must make sure that I am solving the real problem, not simply providing short term satisfaction to my supervisor.

Many opponents of the Star Wars program, or the Strategic Defense Initiative (SDI), oppose all military development. I am not one of them. I have been a consultant to the Department of Defense and other components of the defense industry since 1971. I am considered an expert on the organization of large software systems and I lead the U.S. Navy's Software Cost Reduction Project at the Naval Research Laboratory. Although I have friends who argue that "people of conscience" should not work on weapons, I maintain that it is vital that people with a strong sense of social responsibility continue to work within the military industrial complex. I do not want to see that power completely in the hands of people who are not conscious of their social responsibilities.

My own views on military work are close to those of Albert Einstein. Einstein, who called himself a militant pacifist, at one time held the view that scientists should refuse to contribute to arms development. Later in his life he concluded that to hold to a "no arms" policy would be to place the world at the mercy of its worst enemies. His later writings supported limited arms development with strong limitations on how arms should be used. Neither a ceaseless arms race nor nuclear weapons are consistent with Einstein's principles. One of our greatest scientists, he knew that international security required progress in political education, not science.

The project known as "Star Wars" began in 1983 when President Reagan called on scientists to free the world from the fear of nuclear weapons. He directed the Pentagon to search for a way to make nuclear strategic missiles impotent and obsolete, and in response SDIO has embarked upon a project to develop a network of satellites carrying sensors, weapons and computers to detect ICBMs and intercept them before they can do much damage. In addition to sponsoring work on the basic technologies of sensors and weapons, SDIO has funded a number of Phase I "architecture studies" each of which proposes a basic design for the system. The best of these have been selected and the contractors are now proceeding to "Phase II," or more detailed design.

From the beginning I wondered whether technology offered us a way to meet the president's goals. My own research has centered on computer software and I have used military software in some of my research. My experience with computer-controlled weapon systems made me wonder whether any such system could meet the requirements set forth by President Reagan.

I also had doubts about conflict of interest. I have a project within the U.S. Navy that could profit from SDI funding and I suggested to the panel organizer that this conflict might disqualify me. He assured me quite seriously that if I did not have such a conflict, they would not want me on the panel. He pointed out that the other panelists, employees of defense contractors and university professors dependent on Pentagon funds for their research, had similar conflicts. Citizens should think about such conflicts the next time

Dr. David Parnas has been a professor of computer science at the University of Victoria, British Columbia. This summer he will join the faculty of Queen's University in Kingston, Ontario. He is a U.S. citizen and a longtime consultant to the U.S. Naval Research Laboratory in Washington, D.C.

CONTINUED NEXT PAGE

military buildup in Asia has paralleled the growth of Soviet forces globally. Air and naval deployments at Cam Ranh Bay could provide a bridgehead for Soviet military operations throughout the region. The number of SS-20 intermediate-range nuclear missiles positioned in Asia has risen substantially since 1981. Soviet ground and air forces east of the Ural Mountains have expanded by leaps and bounds over the past two decades; and today the Pacific fleet is the Soviet Union's largest, having surpassed the size of the North Atlantic fleet some years ago. All of these forward projections have been designed by Moscow to intimidate its Asian neighbors and to attempt a weakening of cohesion among U.S. allies in the area. Fortunately, the Soviets have not benefitted politically from these overt, offensive gestures. In fact, the political consequences have been largely negative.

The Soviets have, however, begun to supplement their military pressures with shrewder and more sophisticated tactics intended to lure unwary Asian and Pacific states into false complacency about Soviet penetrations into the region. Soviet Premier Gorbachev's call last May for a multinational "Asian Security Conference" — a largely warmed-over version of a defunct Brezhnev proposal — fell on deaf ears in the region, but is still being promoted by Moscow as a confidence-building measure.

With almost equally dismal success, the Soviet Union has approached several South Pacific island states with financially attractive fishing rights proposals. Most of the South Pacific governments have rejected the offers, although one — the Government of Kiribati — has agreed to a limited Soviet fishing presence in its waters. This constitutes the first time that the USSR has established a formal relationship with an island state outside the context of diplomatic relations; and, although Kiribati has acknowledged its neighbors' concerns by limiting the accord to commercial cooperation, the longer-term implications of this Soviet "toehold" in the area are worrisome. Rumors persist that other island states may follow the Kiribati example.

The Soviet-supported Vietnamese occupation of Cambodia has been a source of regional tension and instability for seven years. The United States continues to support strongly the efforts of ASEAN to obtain a political solution to the problem, based on the withdrawal of Vietnamese forces and free elections under international control and supervision. In diplomatic exchanges with the Soviet Union, we have urged Moscow to persuade Hanoi of the need for a political settlement on these terms. We hope that such a settlement might eventually bring elusive peace to the suffering Cambodian people, but prospects depend a great deal on the cooperation of Moscow and Hanoi — cooperation which thus far has been virtually nonexistent.

Teamwork of Partners

Other challenges lurk on the horizon, and the United States always will try to stay ahead of events to protect peace and defend its interests and objectives. Destabilizing refugee flows in Southeast Asia, which fortunately have slowed somewhat, still place unacceptable pressures on area governments. We are trying to eliminate the causes for flight as well as to help ensure orderly management of refugee migration.

The production and export of narcotics in Asia is a challenge we are confronting with the assistance of the Asian governments. The United States will continue to cooperate in halting this pernicious traffic via extradition treaties, enhancing drug training programs and regular exchanges of information.

The political stability and economic health of the region has helped deter the terrorist tide affecting much of the world, yet we cannot be complacent about the possible spread of this form of "low-intensity warfare" to Asia and the Pacific. We welcome the opportunity to work closely with the region in providing antiterrorism training and in combining all our forces with the civilized international community to enforce sanctions against global terrorism.

Teamwork has been the hallmark of America's phenomenal achievements through history, and I believe it will spell success for our relations with the Asian-Pacific states as well. If we are able to work together — to consult, to cooperate, to combine our resources efficiently — there is no goal too high and no threat too imposing to blunt the aspirations of our peoples. Today there is talk of a "Pacific community," with a small "c," and the concept has stirred the imaginations of men with vision in every country of the region. The Pacific community concept appeals to that instinctive spirit of interdependence and sense of common destiny that is growing stronger over time within this historically diverse region. It is a concept of hope, of peace, and of social progress, not a blueprint for institutions or political networks.

Whatever course this particular concept may take over time, the fundamental theme of regional partnership charts the road to the 21st Century. As Americans, we will stand by our allies and friends, assist where requested, advise as necessary, and accept advice and support in return. Surely our own interests, objectives and values, and global stability in general, will benefit by it.

☆ ☆ ☆ ☆

> **"Taking money for developing a shield against nuclear missiles—while knowing that such a shield is impossible—felt like fraud."**

STAR WARS...CONTINUED

they hear of a panel of "distinguished experts."

The first meeting of the panel increased my doubts. In spite of the high rate of pay, the meeting was poorly prepared; presentations were at a dismayingly unprofessional level. Technical terms were used without definition; numbers were used without supporting evidence. The participants appeared predisposed to discuss the many interesting but soluble technical problems in space-based missile defense while ignoring the basic problems and "big picture." Everyone seemed to have a pet project of their own that they thought should be funded.

At the end of the meeting we were asked to prepare position papers on the problems that we saw. I spent the weeks after the meeting writing up my views and trying to convince myself that SDIO-supported research could solve the technical problems I had identified. I failed!

I could not convince myself that it would be useful to build a system that we did not trust. And if SDI is not trustworthy, the U.S. will not abandon the arms race. Similarly the USSR could not assume that SDI would be completely ineffective; seeing both a "shield" and missiles, it would feel impelled to improve its offensive forces to compensate for the defense. The U.S., not trusting its defense, would feel a need to build still more nuclear missiles to compensate for the increased Soviet strength. The arms race would speed up. Even worse, because we would be wasting an immense amount of effort on a system we couldn't trust, we would see a weakening of our relative strength. Instead of the safer world that President Reagan envisions, we would have a far more dangerous situation. Thus, the issue of our trust in the system is critical; it is important that Americans understand why responsible leaders would never trust a "Star Wars" shield.

SDI discussions often ignore computers, focusing on new developments in sensors and weapons. However, the sensors will produce vast amounts of raw data that computers must process and analyze. Computers must detect missile firings, determine the source of the attack and compute the path that the warhead will take. Computers must discriminate between threatening warheads and decoys designed to confuse our defensive system. Computers will aim and fire the weapons. All the weapons and sensors will be useless if the computers do not function properly. Software, which controls the computers, is the glue that holds such systems together.

Computer specialists know that software is always the most troublesome component in systems that depend on computer control. More traditional engineering products can be verified by a combination of mathematical analysis, case analysis and prolonged testing of the complete product under realistic operating conditions. Without such validation, we cannot trust the product. No experienced person trusts a software product when first deployed.

Software is a major problem for developers of any large system, but SDI would require software that is far more difficult than any we have ever attempted.

SDI software must be based on assumptions about target and decoy characteristics, but those characteristics are controlled not by the shield but by the attacker. We cannot rely upon our information about them. Indeed, the dependence of any program on those assumptions would be a rich source of effective countermeasures. Espionage could render the whole multimillion dollar system worthless without our knowledge.

Overloading the system will always be a potent countermeasure because any computer system will have a limited capacity, and even crude decoys would consume computer capacity. An overloaded system must either ignore some of the objects it should track, or fail completely.

An effective system will require data in many computers to be consistent and up to date. This cannot be done in a situation in which the network's components and communication links are unreliable. Naturally, they would be unreliable during a real battle because an enemy would attack the network.

Furthermore, it's impossible to carry out realistic testing of the integrated hardware and software. Thorough testing would require "practice" nuclear wars including attacks that would partially damage our satellites. Our experience tells us that many potential problems would not be revealed by lesser measures such as component testing, simulations or small scale field tests.

Unlike other weapons systems, SDI offers no opportunity to modify the software during or after its first battle. It must work the first time.

These problems are a function of the Star Wars concept, not of a particular system design. They cannot be evaded by proposing new system "architectures." SDI supporters cite examples of large programs that work. But none of these programs have these problems to begin with.

Before resigning I solicited comments from others and found nobody who disagreed with my technical conclusions. Instead, people told me the program should be continued, not because it would free us from the fear of nuclear weapons, but because the research money would advance the state of the art in our field. As it happens, I disagree with that notion, but I also consider it irrelevant. Taking money allocated for developing a shield against nuclear missiles—while knowing that such a shield is impossible—felt like fraud. I did not want to participate.

My next realization had to do with the way Star Wars is being sold to the public. Democracy can work only if the public is accurately informed, yet some of the statements made by SDIO supporters seem designed to mislead the public. For example, one SDIO scientist told the press that there could be 100,000 errors in the software and it could still work properly. Strictly speaking this statement is true: If one picks one's errors very carefully, they won't matter much. However, let's remember that a single error caused the complete failure of a Venus probe many years ago. I find it hard to believe that the SDIO spokesperson made his statement without being aware that it was misleading. Because of such disinformation, I decided to explain to the public that technology offers no magic that will eliminate the fear of nuclear weapons.

I have discussed my views with many individuals who work on SDIO-funded projects, and most of them do not disagree with my technical conclusions. In fact, since the story of my resignation became public, two SDIO contractors and two Pentagon agencies have sought my advice. In other words, they do not doubt my competence.

Those who accept SDIO money, given its technical contradictions, make a variety of excuses. "The money is going to be spent anyway, shouldn't we use it well?" . . . "We can use the money to solve other problems." . . . "The money will be good for computer science."

The issue of SDI software was recently debated at a computer conference. While two of us argued, on the basis of software

CONTINUED NEXT PAGE

engineering theory and experience, that SDI could not be trusted, the two SDI supporters argued that this doesn't matter. Rather than argue about the computer science issues, they tried to use strategic arguments to say that a shield need not be considered trustworthy. One of them argued, most eloquently, that the president's "impotent and obsolete" terminology was technical nonsense, then suggested that we ignore what "the president's speechwriters" had to say and look at what was actually feasible. I had to remind myself that he was arguing in favor of SDI.

Meanwhile, the panel from which I resigned has turned in its report. Although the panel adamantly supports the SDI program, according to the report all system designs produced in Phase 1 that they examined are deficient because the contractors didn't pay enough attention to the issues of software complexity and testability. Each of these designs was a $1 million effort. The panel's remarks were quite harsh. If correct, the people running the SDIO must be considered incompetent. If the panel's criticisms were unjustified, the panel's competence must be questioned.

Although I do not have access to much of the SDIO-sponsored work in my field, I have had a chance to study some of it. What I have seen makes big promises, but it is of low quality.

Traditionally, universities provide tenure and academic freedom so that faculty members can speak out on issues such as these. Many have done so. Thousands of scientists have signed a pledge not to accept SDI funds (see related sidebar on this page). Computer Professionals for Social Responsibility opposed SDI long before my views were formed. But there are institutional pressures in favor of accepting research funds from any source. The president of a major university recently explained his acceptance of a Pentagon-sponsored institute on campus by saying, "As a practical matter, it is important to realize that the Department of Defense is a major administrator of research funds. In fact, the department has more research funds at its disposal than any other organization in the country. . . . Increases in research funding in significant amounts can be received only on the basis of defense-related appropriations."

I consider such rationalizations dishonest and dangerous. SDI endangers the security of the U.S. and the safety of the world. By working on SDI these scientists allow themselves to be counted among those who believe that the program can succeed. If they are truly professional, they must make it very clear that an effective shield is unlikely and a trustworthy one impossible.

I believe in research; I believe that technology can improve our world in many ways; I also agree with Israeli scientist Prof. Makowski who wrote, "Overfunded research is like heroin, it leads to addiction, weakens the mind, and leads to prostitution." Many research fields in the U.S. are now clearly overfunded, largely because of Pentagon money. I believe we are witnessing the proof of Prof. Makowski's statement.

This is not an issue that should divide those who want disarmament and those who want "peace through strength." SDI will both accelerate the arms race and lead to a relative weakening of the U.S. position. People of both persuasions should oppose it.

It is a truism that if each of us lives as if what we do does matter, the world will be a far better place than it now is. The cause of many serious problems in our world is that many of us act as if our actions do not matter. Our streets are littered, our environment polluted and our children neglected because we underestimate our individual responsibility. The arguments given to me for continuation of the SDI program are examples of such thinking. "The government has decided, we cannot change it." . . . "The money will be spent, all you can do is make good use of it." . . . "The system will be built, you cannot change that." . . . "Your resignation will not stop the program."

It is true that if I decide not to toss trash on the ground, I will not eliminate litter. However, if we are to eliminate litter, I must decide not to toss trash on the ground. What I do does make a difference. We all make a difference.

Similarly, my decision not to participate in SDI will not stop this misguided program. However, if everyone who knows that the program will not lead to a trustworthy shield against nuclear weapons refuses to participate, there will be no program. Every individual's decision makes a difference.

Some Members of Congress have told me that they would like to vote against SDI but they do not want to be perceived as being weak on defense. It is important for citizens to tell their representatives that they know SDI will not strengthen the U.S. and that they will not interpret a vote against SDI as a sign that a Member of Congress is weak on defense. It is important that your neighbors do that as well. ●

SCIENCE FRICTION

Academics say no to SDI research

David Parnas is not the only scientist who has refused to work on Star Wars projects.

Close to 5,000 members of the academic research community—3,000 faculty members and 2,000 graduate students—have signed their names to a pledge "neither to solicit nor accept SDI funds." University of Illinois physicist Mike Weissman, an organizer of the pledge drive, says at least 56 percent of the total faculty of the nation's top 14 physics departments have signed on.

"Scientists must remember that we entered our fields to advance knowledge—not to make a living by selling quack nostrums, particularly lethal ones, to a frightened public," Weissman and another physicist wrote recently in the *Bulletin of Atomic Scientists.*

More than 100 scientists at federal laboratories also have signed the pledge. "I've decided that I must withdraw myself from any participation in work done under these funds. I do recognize the need for legitimate self-defense, but the choice of methods, more than ever before in the history of civilization, requires some heavy moral decisions," Ray Schramm, a physicist at a government laboratory in Boulder operated by the National Bureau of Standards, wrote in a letter to the director of his division.

The letter concluded,"My stand may cause some difficulty and possible embarrassment to the division. I am willing to relinquish my position to someone else."

Meanwhile, in an effort to prove to Congress that Star Wars has support within the academic community, High Frontier, a private lobby that aggressively promotes the Star Wars program, recently started circulating a petition of its own among universities. John Mosely, a spokesperson for High Frontier, says he doesn't know how many people have signed the petition, which states, "We are disappointed that some members of the scientific community are evaluating this proposal without hard scientific evidence." At least 3,000 scientists, Mosely said, have applied to the Pentagon for Star Wars research funds.

But Weissman doubts the High Frontier effort will be successful. "The reason why SDI supporters can't stand to have scientists speak out," he contends, "is because scientists are overwhelmingly against SDI."

—Judy Mathewson

SDI

HARTFORD COURANT 12 May 1986 (13) Pg. C-11

Bugs in Star Wars Software Could Go Undetected

David L. Parnas

President Reagan wants the Strategic Defense Initiative to eliminate the fear of nuclear weapons by making such weapons impotent and obsolete. Nuclear missiles would be destroyed in flight before they could do any damage. Many computer specialists believe that SDI could never be trusted and that, as a consequence, Reagan's goal cannot be achieved.

If SDI is untrustworthy, the United States would be unable to abandon deterrence. The Soviet Union could not assume that SDI would be completely ineffective. Realizing that the United States had both a defensive shield and missiles, the Soviets would feel impelled to improve their offensive forces to compensate. The United States, not trusting its defense, would build still more nuclear missiles to compensate for the increased Soviet strength. The arms race would escalate.

Even worse, because the United States would be wasting an immense amount of effort on a system that couldn't be trusted, Americans would see a weakening of their relative strength. Instead of the safer world that Reagan envisions, there would be a far more dangerous situation. Thus, the issue of our trust in the SDI system is critical. It is important that Americans understand why we would never trust a Star Wars shield.

SDI discussions often ignore computers, focusing instead on new developments in sensors and weapons. However, the sensors will produce vast amounts of raw data that must be processed and analyzed by computers. Computers must detect missile firings, determine the source of the attack and compute the attacking trajectories. Computers must discriminate between threatening warheads and decoys designed to confuse the U.S. defensive system. Computers will aim and fire the weapons. All the weapons and sensors will be useless if the computers do not function properly. Software, which controls the computers, is the glue that holds such systems together.

Computer specialists know that software is the most troublesome component in systems that depend on computer control. Traditional engineering products can be verified by a combination of mathematical analysis, case analysis and prolonged testing of the product under realistic operating conditions. Without such validation, we cannot trust the product. None of these validation methods works well for software.

The best tools for mathematical verification of software only work on small programs and make approximations that can hide serious errors.

Exhaustive case analysis of various situations can only be used when the number of cases is small or the product has a highly repetitive program. Software has a huge number of states — the variations of stored data, for example — and no simple pattern.

The number of input conditions (i.e., how many different attacks could be made) and internal states for software systems is so large that thorough testing is never possible. Computer specialists have long known that testing can show the presence of bugs, never their absence.

We can build adequately reliable software systems, but they become reliable only after extensive use in the field. Although responsible developers perform many tests, including simulations, before releasing their software, serious problems always remain. No experienced person trusts a software system when it is first deployed.

Software is a major problem for developers of any large system, but SDI is far more difficult than any software system that has ever been attempted.

SDI software must be based on assumptions about target and decoy characteristics; those characteristics are controlled by the attacker. The United States cannot rely upon the information it has about them. Espionage could render the whole multi-billion dollar system worthless without our knowledge.

The techniques used to provide high reliability in other systems are hard to apply to SDI. In space, the duplication of equipment required for high reliability is unusually expensive. The dependence of SDI on communicating computers in satellites makes it unusually vulnerable.

Programs that reliably meet strict deadlines are based on built-in schedules, computed in advance. For SDI, schedules must be based on assumptions about the structure of an attack. By making those assumptions, we make it easier to overload the system by using an attack strategy that violates the assumption. An overloaded system must either ignore some of the objects it should track, or fail completely. Overloading the system will always be a potent countermeasure because any computer system will have a limited capacity and even crude decoys would consume computer capacity.

An effective system will require data in many computers to be consistent and up-to-date. This cannot be done in a situation in which the network's components and communication links are unreliable. They would be unreliable during a real battle because an enemy would attack the network.

Realistic testing of the integrated hardware and software after deployment is impossible. Our experience tells us that many potential problems would not be revealed by component testing, simulations or small-scale field tests.

Unlike other weapon systems, there will be no opportunity to modify the software during or after its first battle. It must work the first time. This is not true in other large software projects.

SDI software that works the first time it is used may be theoretically possible. It is also theoretically possible that 10,000 typing monkeys could reproduce the Encyclopaedia Britannica. Both are highly unlikely. However, while the correctness of the monkeys' product could be verified, there is no way to verify the adequacy of the SDI software. We would never dare to trust it.

David L. Parnas, professor of computer science at the University of Victoria, British Columbia, Canada, was a member of the Pentagon panel overseeing the Star Wars program from its formation until he resigned last June.

BRADLEY...from Pg. 10

could be hurt by any major problem in its businesses.

FMC already is faced with the loss of two sources of Defense Department revenue. The company's amphibious assault vehicle contract ends in August and will mean an income loss of $150 million for the remainder of this year. And next year, for the first time, the federal government won't be buying FMC's M-113 armored personnel carrier, according to Highlander, thus completing its phase-out in favor of the Bradley. Reason: The M-113 lacks firepower. ■

U.S. NEWS & WORLD REPORT 19 May 1986 (13) Pg. 14

Why did Congress so overwhelmingly reject arms for Saudi Arabia? Fear of Stinger antiaircraft missiles falling into terrorist hands was one factor. But more important was a belief by lawmakers that the Saudis had failed to deliver on their promises in return for getting permission to buy AWACS radar planes in 1981—especially to help the Mideast peace process and try to control violence by Palestinian extremists.

WASHINGTON POST 13 May 1986 Pg. 14

1954 U.S. Test Provided Preview for Chernobyl

Victims Still Affected by H-Bomb Blast

By Walter Pincus
Washington Post Staff Writer

Thirty-two years ago, on March 1, 1954, U.S. scientists exploded the first deliverable hydrogen bomb on the tiny coral atoll of Bikini in the Marshall Islands. To their surprise, the explosion was more than twice the yield expected.

At 15 megatons (the equivalent of 15 million tons of TNT), the blast obliterated the island and heaved tons of radioactive fallout across the Pacific to the east rather than to the north as U.S. scientists had expected.

Within four hours, white radioactive particles began falling like snow on the 64 Marshallese men, women and children who lived on Rongelap, an atoll 105 miles east from Bikini. Four hours later the fallout began to drop on Rongerik, another Pacific island where 28 U.S. weathermen were stationed.

The "rain" of radioactive white powder continued for 12 hours. It came down on the roofs of the Marshallese houses and, with an evening rainfall, was washed into barrels that were the prime source of drinking water. It covered the fish and coconuts drying in the sun for that evening's meal.

This U.S. nuclear accident, the victims of which are still experiencing medical effects, carries dramatic echoes and lessons for the Soviet Union today as Moscow attempts to deal with the long-term effects of the Chernobyl reactor incident. The Soviets have been widely criticized for failing to publicly announce the disaster until it was detected in western Europe and for underplaying the health hazards involved.

Following the 1954 Bikini blast, the U.S. government initially was silent, waiting 10 days before acknowledging to the world that the Marshallese and American servicemen had been exposed to radioactive fallout.

That disclosure came only after a small U.S. newspaper received a letter from a U.S. Marine on Kwajalein reporting that natives and servicemen had arrived at that base "suffering from various burns and radioactivity."

U.S. officials initially maintained that the Marshallese had not been exposed to dangerous radiation levels, that they had been taken to Kwajalein "according to plans as a precautionary measure" and that no effects had appeared. In fact, some victims were suffering from classic symptoms of radiation exposure: burns, nausea and hair loss.

Seven years earlier, when the first atomic tests were conducted on Bikini and the weapons were in the relatively modest 15-kiloton range (the equivalent of 15,000 tons of TNT), Rongelap was considered in a threatened zone and the islanders were moved from their homes in boats.

For the 1954 blast, they were notified of the test but told that there was less danger and no need to take precautions.

The U.S. servicemen on Rongerik had a similar experience. However, they had been given fallout recording devices by Atomic Energy Commission (AEC) scientists, who told the troops that the devices were designed to record only low levels of radiation. If the readings went "off scale" and indicated greater contamination, the servicemen were to immediately notify their headquarters on the atoll of Enewetak.

Little more than one hour after a white mist began to fall on Rongerik, about eight hours after detonation, the devices went "off scale." At 3 p.m., calls went to the Enewetak headquarters which initially suggested that something was wrong with the devices. That night, after dust falling on tents began to glow, the troops were told to stay indoors and plans were made to evacuate them to a Navy hospital on Kwajalein.

For the Marshallese on Rongelap, it was not until March 3, more than 40 hours after the first radioactive fallout began, that a U.S. Navy destroyer arrived to evacuate them from the island.

As the contamination became public and it became an issue in the Cold War with the Soviet Union, the United States continued to put the most optimistic assessment on the event.

On March 16, more than two weeks after the blast, the Japanese announced that one of their fishing boats, the Lucky Dragon, has been caught in the radioactive fallout. Two days later, a U.S. official in Japan said the exposed fishermen, some of whom showed symptoms of radiation burns and sickness, would recover completely in about a month. Not long after, one died.

The question of public disclosure was eventually overshadowed by other serious issues—again, perhaps foreshadowing Chernobyl—including the question of how the released radiation would affect the health of the exposed individuals and the land.

The average Rongelap inhabitant received roughly a 175-rad dose, according to a 1982 U.S. government report. Under current standards, a worker in a nuclear plant can receive about five rads a year without ill health effects.

Four weeks after the explosion, the white blood counts of the Rongelapese dropped to 30 percent of what is considered normal.

On April 1, 1954, AEC Commissioner Lewis Strauss appeared at a press conference with then-President Dwight D. Eisenhower. He made the first public disclosure of the power of an H-bomb and, buried within the question-and-answer period, he declared that he had met with the Marshallese and that no serious illness had been uncovered.

For three years, the Rongelap people remained away from their island because it was considered too radioactive. When they returned in 1957, their diet was limited to imported food. Last year, 31 years after the blast, the northern islands of the Rongelap Atoll were found to still contain unsafe levels of radiation in coconuts and other crops; consequently, the Rongelap people finally abandoned their homes and moved to another atoll.

In the interim, all 15 children who were under the age of 10 at the time of the radiation exposure suffered thyroid abnormalities. One child, a year old at the time of the explosion, died of leukemia; miscarriages and stillbirths among the exposed women were more than twice the normal rate and deaths were 30 percent higher.

TIME 19 May 1986 (13) Pg. 21

Battle of the Punch Bowl

When the Navy decided to bring back the battleship five years ago, old hands could almost be heard humming *Anchors Aweigh.* Since then, two World War II–vintage battlewagons have been made ready for sea duty, and last week a third, the U.S.S. *Missouri,* was recommissioned in San Francisco as a crowd of 12,000 spectators cheered from its pier.

But no dreadnought is really shipshape, it seems, without a set of ceremonial silver. When the *Missouri* was mothballed back in 1955, ten years after the surrender ceremony ending World War II was held on her decks as she lay at anchor in Tokyo Bay, 338-piece silver set was returned to the citizens of Missouri, who had generously donated the finery. With the *Missouri* returning to action, the Navy wanted the silver back. Problem was, Missouri Governor John Ashcroft wanted to hang on to the ship's engraved punch-bowl set, which has been on display at the state capital in Jefferson City. Finally, with the U.S. Attorney in Kansas City acting as mediator, the Navy and the state compromised: when the *Missouri* is at sea, all the silver is hers. But when she is in home port, the Navy will make the punch bowl available to the state. Grog all around, mates.

WASHINGTON TIMES 13 May 86 Pg. 4

Army vehicles called 'gas guzzlers'

LONDON — The U.S. Army uses vehicles based on decades-old "gas guzzler" designs while Soviet forces are making slow but steady progress in modernizing their ground equipment, the world's leading military hardware publication said today.

Jane's 1986 "Military Vehicles and Ground Support Equipment" said the problem in modernizing the U.S. military vehicle fleet is its size — it is the world's largest.

NEW YORK TIMES 15 June 1986 (16) Pg. 1

Reverberations of the Space Crisis: A Troubled Future for 'Star Wars'

Officials Say Problems Are Minor, but Others Cite Wide Disarray

By WILLIAM J. BROAD

The Challenger disaster and a series of other major setbacks in the American space program have damaged President Reagan's antimissile plan in ways that are far more serious and extensive than has generally been realized, according to scientists and aerospace analysts.

Officials of the program, formally called the Strategic Defense Initiative and popularly known as "Star Wars," deny that there is serious damage, saying that any problems are minor and that the program as a whole is moving ahead vigorously.

Plans for Giant New Rocket

But during more than two dozen interviews with a wide range of aerospace experts both inside and outside the Government, analysts said the grounding of the nation's space shuttles and expendable rockets had thrown a schedule of complex space-based experiments into confusion and disarray, sending shock waves through space research programs across the country and demoralizing some scientists in the antimissile program.

Another repercussion of the aerospace crisis, they say, is its effect on a controversy over whether the Government should start now to develop a giant new unmanned rocket — far larger than the shuttle — that would be needed in the 1990's to lift thousands of antimissile weapons, sensors and various aiming and tracking devices into space.

The crippling of the nation's rocket power, the analysts add, underscores the need for the enormous battery of space vehicles that will actually lift the proposed defensive system into place. Even before the shuttle disaster, "Star Wars" officials estimated that the deployment undertaking was big enough to require up to 5,000 launchings of shuttles or shuttle-sized rockets.

In general, some analysts say, setbacks in research, transport and morale could result in a crucial losses for the antimissile plan. Senator William Proxmire, Democrat of Wisconsin, a critic of "Star Wars," suggested that the aerospace crisis had already contributed to "a loss of political momentum" in the program.

"There's been a tendency to race and push this program as far as possible," Senator Proxmire said. "Defense officials realize it's very unlikely that the next President, whether Republican or Democrat, will be as big an S.D.I. enthusiast as Reagan."

Whatever the ultimate impact on the program, many aerospace experts agree that the crisis could hardly have come at a worse time. After maturing for years in laboratories on earth, "Star Wars" research had reached a point where it was ready to burst into the heavens in some of the most spectacular experiments of the space age. The explosion of the shuttle Challenger, along with three other launching failures involving Titan and Delta rockets, have brought these plans to an abrupt halt.

Whereas delays might be bearable in a world of unlimited time and money, some experts said postponements could be a major setback in the world of Washington politics.

Senator Proxmire said the perception of crisis in the "Star Wars" program was one reason why 48 senators recently signed a letter calling for sharp cuts in the Administration's proposed $5.4 billion antimissile budget for next year.

Scheduling Delays And Technology Leaps

Other experts outside the "Star Wars" program say delays in the schedule resulting from the launching failures will almost certainly be great. "It could be as much as two years," said John E. Pike, director of space policy at the Federation of American Scientists, a private, nonprofit group in Washington that is skeptical about the antimissile plan.

Although conceding that minor damage has been done to the program, "Star Wars" officials say most of the problems associated with space setbacks will vanish with the renewal of shuttle and rocket flights, allowing space-based experiments to resume.

"The advance of technology is inexorable," said Dr. Gerold Yonas, chief scientist of the antimissile program.

Dr. Yonas stressed that any delays in space-based experiments had to be seen in relation to the overall research program, which he said was forging ahead. "We're making steady progress in many important areas," he said.

Other "Star Wars" officials dismissed questions of lost momentum. Lieut. Col. Lee De Lorme of the Air Force, director of public affairs for the Pentagon's antimissile program, said, "Some charges from critics are not worth addressing because they're without substance."

In contrast to program officials, some scientists who are part of the program said they have been demoralized by the delays.

"Part of the strategy was to do significant experiments before Reagan left office," said Dr. George Chapline, a key researcher in the antimissile program at the Lawrence Livermore National Laboratory in California. But he said that hope was "fading," a fact he said he and his colleagues found "depressing."

The recent string of aerospace disasters started Jan. 28 the $1.2 billion Challenger exploded 74 seconds after liftoff, killing seven astronauts, destroying a $100 million satellite, and grounding the nation's shuttle fleet for at least 18 months, until July 1987. Privately, officials of the National Aeronautics and Space Administration say the next launching is likely to be put off until 1988.

"We're going to have to delay and push back many of the programs we had planned for the shuttle," including antimissile tasks, Defense Secretary Caspar W. Weinberger said two days after the Challenger explosion. Some small military payloads could be put on expendable rockets, he said, "but a lot of the experiments were configured to the size and shape of the shuttle."

The next aerospace accident occurred April 18, when a Titan 34D rocket exploded after liftoff from the Vandenberg Air Force Base in California, destroying a secret military payload. It was the second Titan failure in a row. Then, on May 3, a Delta rocket failed about 71 seconds into its flight.

A Launching Squeeze Even Before the Crisis

"We were suffering from a shortage of lift capability" even before the disasters, Lieut. Gen. James A. Abrahamson of the Air Force, director of the antimissile program, told a group of business executives in May.

For the moment, the crisis has halted the nation's ability to lift major satellites into orbit and stopped its scientific tests in space.

Rocket power is no small part of the antimissile vision. By official "Star Wars" estimates, deploying what the Government calls a medium-sized defensive system in space could take up to 58 years and cost from $87 billion to $174 billion if the task was undertaken with existing rockets and space shuttles. This estimate assumes the nation has the capacity for 24 shuttle flights a year, which, before the accident, was the most optimistic prediction for the shuttle's flight pace. Today, experts say the most optimistic forecast is 12 flights a year.

Aerospace experts say one way to gauge the effect of the crisis on the "Star Wars" research program is to look at the way the program had begun to rely on space experiments, especially right before the Challenger disaster.

No known antimissile experiments had been carried out by the shuttle until its 18th flight, in June 1985, during which a beam from an earth-based laser was bounced off a special mirror aboard the shuttle Discovery. After that test, however, fully half of the six shuttle flights before the Challenger explosion carried either minor "Star Wars" experiments or civilian tests with results that were studied by the Pentagon's antimissile program.

Starting in 1986, the pace of testing was to have accelerated considerably, according to a schedule made public last year by NASA. The NASA plan said six major "Star Wars" shuttle tests, as well as "a variety of cabin and potential get-away special experiments," were scheduled to occur between 1986 and 1988.

"Star Wars" officials say that there were such schedules but maintain that they were tentative at best. Aerospace experts, on the other hand, have accused the program's officials of rewriting schedule history to try to play down the aerospace problems.

All agree, however, that preparations for both major and minor antimissile tests were picking up rapidly before the Challenger crash.

For small "Star Wars" payloads, a new handling installation was recently opened at the Cape Canaveral Air Force Station in Florida, adjacent to the shuttle launching pads at the Kennedy Space Center. Known as the Space Experimentation Center, the military installation includes a laboratory for visiting scientists, a training area for astronauts, and a clean room for payload assembly, checkout and storage.

"We have a center, but we're on hold," said Maj. Marcia A. Thornton of the Air Force, deputy director of the Space Experimentation Center, with headquarters at Patrick Air Force Base nearby.

"We'll probably have six experiments in the first year the shuttle is flying again," she said, discussing the cargo manifest. "But that estimate may be wrong because it depends on the manifest, which is a mess."

The first large test of 1986 was to have occurred in July during the first shuttle flight from the Vandenberg Air Force Base in California, which recently completed a $2.8 billion military launching pad.

Vandenberg was to send shuttles into orbit about the earth's poles, which is not possible from the Kennedy Space Center. Polar "Star Wars" tests are crucial since, in a war, a space-based defense would have to find and destroy enemy warheads streaking over the North Pole toward the United States.

A key experiment was to have involved the Cryogenic Infrared Radiance Instrument for the Shuttle. The instrument, referred to as Cirris, is a super-cooled infrared sensor meant to gather data about the earth's aurora and other natural glows. If not countered, such radiations might blind the anti-missile program's "eyes" in space.

The Air Force has said, however, that it might mothball the Vandenberg installation until 1991, when a replacement for the shuttle Challenger could become available.

"We're just rolling with the punches," said Lieut. Darrell Wright of the Air Force Geophysics Laboratory, a sponsor of the Cirris experiment, which is at Hanscom Air Force Base in Massachusetts.

One option under study is to fly Cirris on a shuttle launched into an semi-equatorial orbit from the Kennedy Space Center, although this prospect leaves researchers glum. Dr. Allan J. Steed, director of the Center for Space Engineering at Utah State University, which built Cirris, said: "Auroral measurements would be severely handicapped from the Cape. It will be depressing if we have to abandon the polar orbit."

According to the NASA plan, the big "Star Wars" shuttle test of late 1986 was to have involved pointing a laser beam and using it to track targets, including satellites and rockets. Such laser tests, known as Tracking and Pointing Experiments or T.P.E., were expected to be quite showy; some critics have called them "publicity stunts." Whatever their merit, the tests have been delayed.

Experts say it is hard to say how long the delay will last because of the chaos in the program and the fact that "Star Wars" officials often try to keep tenta-

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tive schedules and technical details of future tests secret, even from Government experts.

"It's been difficult to extract their space-based plans," said Dr. Arthur F. Manfredi Jr., an aerospace analyst at the Congressional Research Service of the Library of Congress.

According to the industry newsletter Military Space, the Pentagon's first tracking and pointing mission has been pushed back until October 1988, indicating "that the first major S.D.I. experiment will fly before the next U.S. Presidential election."

Experts are divided on whether the pace of delayed space-based experiments will be sufficient to keep the antimissile program on schedule.

"I'm a technological optimist," Dr. Manfredi said. "If we're back in the shuttle business by late 1987, that gives S.D.I. four or five years" for research before a decision is made on whether to deploy an antimissile system.

According to optimistic predictions, "Star Wars" payloads will be given top military priority once the shuttle fleet is again on its feet. Some aerospace experts note, however, that the military has a growing backlog of other critical payloads waiting, such as communication and spy satellites.

"The question," said Dr. Robert Jastrow, a geophysicist at Dartmouth College and a prominent proponent of the antimissile plan, "is whether S.D.I. tests will get high enough priority to keep the program on schedule."

Milton R. Copulos, the senior aerospace analyst at the Heritage Foundation, a conservative research institute in Washington, said, "A lot of stuff is going to be backlogged, no question about it."

Last week, General Abrahamson, the "Star Wars" director, told some of the program's scientists that the grounding of the shuttle fleet "isn't an immediate threat" to the program. "It isn't a crippling effect for right now," he said.

Aware that pressures will mount in the future, Pentagon officials have lobbied for an expanded shuttle fleet. On Feb. 19, Defense Secretary Weinberger told the House Foreign Affairs Committee that a shuttle to replace Challenger was crucial for antimissile testing.

But some experts say the rate of future shuttle flights, no matter how big or small the nation's fleet, will probably be slower than expected, putting a crimp in testing for the space-based antimissile program.

'Space Truck' Plans: Giant High-Tech Rocket

If, in the mid-1990's, the Government decides to go ahead and build an antimissile system, the Pentagon will need something other than the shuttles to lift thousands of space sensors and weapons into orbit. "Star Wars" officials drew this conclusion when they made their estimate that up to 5,000 shuttle flights would be needed to deploy an antimissile system in space.

The Pentagon has thus begun lobbying for a gigantic new highly advanced rocket, or "space truck," that is much bigger, cheaper and more reliable than the shuttle. The goal is to slash the cost of lifting payloads into space, making it at least 10 times cheaper than with the manned shuttles. Achieving this goal, however, will itself be expensive because — as "Star Wars" officials themselves say — a revolution in the structure and operations of the aerospace industry will be needed to create the rocket, reducing reliance on manpower and increasing the roles of computers and robots.

A leading candidate for the "space truck" is known as the Shuttle-Derived Vehicle, or S.D.V. This technological giant would be similar to a shuttle in that it has an external fuel tank and twin booster rockets. The difference is that the shuttle would be replaced by a huge unmanned payload carrier. According to Martin Marietta, the mostly reusable Shuttle-Derived Vehicle could ferry up to 150,000 pounds of cargo into orbit, more than three times the shuttle's lifting capacity. Other proposed new boosters would lift even more.

"Star Wars" officials say they are optimistic about the chances for a quick start on this type of big cargo ship, even though it will require a huge investment.

"The costs are going to be staggering," Col. George Hess of the Air Force, a senior "Star Wars" official, told an industry symposium in April. "You're looking at a $20 billion to $40 billion investment by this country to get to the point where you can realize lower operating and life-cycle costs."

The feasibility of building such a big rocket is already under intense study by NASA and the Defense Department. The first phase of this 26-month study is to be delivered to the White House National Security Council "shortly," according to Darrell R. Branscome, a special assistant to the director of NASA's shuttle program.

But aerospace experts see problems on the horizon. One is that big new boosters will have to compete with the need for many billions of dollars to rebuild the shattered space program.

"I don't think you're going to see a new start on a big booster anytime soon," said Mark R. Oderman, vice president of the Center for Space Policy Inc., a consulting concern based in Cambridge, Mass. "The near-term dollars will go into replacing the shuttle and buying shuttle-compatible launchers. The future push will be for mid-sized vehicles" that the Air Force wants for lifting medium-weight satellites into space.

Already, there are signs of deep divisions in the White House over whether and how to buy a Challenger replacement, the cost of which has been estimated at $2.8 billion.

In addition, a big new booster will have to compete against two new projects proposed by President Reagan: an $8 billion space station and a 21st-century spaceship that could take off from a runway and fly into orbit. The plane will demand research outlays alone of some $3 billion in the near future.

One solution to the Government's booster challenge, according to Mr. Copulos of the Heritage Foundation, is for the antimissile program to seek the aid of the private sector in trying to cut the cost of launching large payloads. "If the money is there from private sources, they should do it," he said. "It's very possible and it requires a considerable amount of free enterprise."

A difficulty with any plans for developing large "Star Wars" boosters is what one NASA official calls the "uncertainty" factor. By the 1990's, a need for large boosters may or may not materialize, depending on whether the Government decides to deploy an antimissile system.

Trying to Cut Costs As Uncertainty Grows

"The question," Philip E. Culbertson, NASA's general manager, told Congress last year, "is how to develop a system to handle that kind of uncertainty while at the same time trying to drive its cost down."

In addition, critics of the "Star Wars" program said the recent string of launching failures has increased the uncertainty surrounding the big new booster. Senator Proxmire said the crisis will "increase the time, cost and risk" of developing a big new booster. "At best," he said, "it will mean some postponement, perhaps a long one."

In contrast, some "Star Wars" proponents say the crisis could have positive effects, noting that the evolution of booster technology can be aided by mistakes. "The more information we gain about failures, the better we can improve reliability," said Dr. Peter E. Glaser, vice president of Arthur D. Little, a research concern in Cambridge, Mass.

No matter how much is learned, the prevailing view is that the cost of the education will be great. Aviation Week and Space Technology, a respected industry journal and firm supporter of the "Star Wars" plan, recently published an editorial saying the aerospace difficulties revealed a "quality control crisis developing within NASA, the Air Force, and the U.S. aerospace industry." It added there was "a lot of work to do in pulling the U.S.'s space act together before we take it on the road to the stars."

If the recent aerospace crisis increases the costs of future space transportation, it will have a direct bearing on a set of standards for the antimissile program known as the "Nitze criteria," named after Paul H. Nitze, the Government's senior arms control adviser. Last year he said, in essence, that antimissile defenses should cost less than Soviet countermeasures to thwart them.

In practice, this means that defensive weapons in space must be "survivable," a goal that calls for such things as heavy shielding to protect battle stations from attack and powerful jets to move them during space wars. Both those precautions mean defensive weapons will have to become heavier — and thus costlier to lift into orbit.

In Congressional testimony last year, General Abrahamson, the "Star Wars" director, reflected on the survivability challenge. "That is a very tough criteria in the whole research program," he said, "and space transportation is a large factor in that."

More recently, in April, General Abrahamson suggested that the Nitze criteria be replaced by a less rigorous formula: that defenses simply be "affordable."

A Blow to the Image Of Invincibility

The effect on morale is perhaps the most complex of all issues raised by the Challenger crash. Some proponents of the "Star Wars" program say they are depressed by recent developments, some program officials seem defensive, and still other advocates of the program seem almost philosophical, trying to find positive lessons.

Dr. Jastrow, the Dartmouth professor, said the crisis pointed up the problems inherent in firing any rocket, whether it is carrying astronauts or nuclear warheads. "It reflects on the vulnerability of offensive arms," he said. "Missiles are inherently fragile. With

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The Space Shield Plan: 'Star Wars,' 3 Years Later

On March 23, 1983, President Reagan called on American scientists to find ways to erect a missile defense shield to render nuclear weapons "impotent and obsolete."

In the months that followed, his proposal, formally called the strategic defense initiative and popularly called "Star Wars," began to be described as one of the biggest research projects of all time, a five-year, $26 billion undertaking that rivaled the Manhattan Project for the atomic bomb and the Apollo program to put men on the moon.

Today it is estimated that "Star Wars" research alone will not be completed before the mid-1990's, and cost at least $90 billion. Experts outside the Government have estimated that building a antimissile system could cost $1,000 billion or more.

The space "shield" would not really be a shield but rather a complex network of orbiting and earth-based systems, including laser beams, particle beams, electromagnetic "slingshot" rail guns and sensing, tracking and aiming devices, all requiring extraordinary coordination by humans and computers.

One of the most ambitious defensive systems now envisioned by military planners, out of the many possibilities under consideration, calls for a complex, seven-layered system that would consist of thousands of satellites with weapons intended to furnish nearly perfect nationwide protection.

AIPAC asks U.S. for protection against ground-to-ground missiles

Sharing Defenses

By Wolf Blitzer

WASHINGTON—The major pro-Israeli lobbying organization in Washington has called on the U.S. to develop an effective defense against conventional ground-to-ground missiles which it could then share with Israel.

"Israel's enemies are now being armed by the Soviet Union with a new generation of highly lethal surface-to-surface missiles, more accurate and more deadly than any previously available weapons," said Thomas Dine, Executive Director of the American Israel Public Affairs Committee (AIPAC). "Unfortunately, there are no comparable defensive systems available today that Israel could obtain to protect its vulnerable cities from bombardment."

Dine was testifying on Jan. 30 in open-door session before the Senate Armed Services Subcommittee on Strategic and Theater Nuclear Forces. The panel had convened to examine possible new defenses against tactical ballistic missiles.

Dine said this was a subject "of particular interest to those concerned" about the supply of such missiles by the Soviet Union to "its client states in the Middle East."

"These missiles threaten American security interests and the security of our only reliable, consistent and democratic ally in that part of the world," he said.

The hearing came as the Reagan administration has actively continued to push its controversial Strategic Defense Initiative (SDI) program, better known as "Star Wars." Israel has been invited to participate in the initial research and development stage of the SDI project.

Tom Dine

Israeli officials, in accepting the U.S. invitation, have been anxious to learn if some of the new missile defense technologies proposed in the SDI program might have a spillover benefit in conventional warfare. Thus, there are clear benefits for Israel in eventually receiving these state-of-the-art technologies.

Israel Vulnerable

During the hearing, Dine submitted a detailed paper on the threat these new ground-to-ground missiles, especially the Soviet-made SS-21s recently deployed in Syria, pose for the security of Israel. The paper was written by W. Seth Carus, AIPAC's senior military analyst.

"When fired from Syria," Carus said, "the SS-21 can reach targets throughout northern Israel, including one of Israel's major air bases, Ramat David. If deployed in Jordan, however, all of Israel would be brought within range."

An accompanying map showed the clear vulnerability of virtually all of Israel's major air bases which were identified as Ovda, near Eilat; Ramon, Hatzerim, and Nevatim in the Negev; Tel Nof and Hatzor near the coastal plane; and Ramat David and Mahanayim in the north.

"If there is a danger of an Arab attack," Carus said, "Israel will be forced to strike first, because it will not be able to take the risks of waiting and absorbing an Arab attack. Although such a strategy will make the Middle East a more dangerous place, the absence of a viable defense against tactical ballistic missiles will leave Israel with no alternative."

The paper suggested that "tactical ballistic missiles directed against (Israeli) cities could easily result in 5,000 dead and wounded Israeli civilians in a future Arab-Israeli war."

Thus, Carus called for a new defense against such missiles. "Although the Israeli military could take steps to develop defenses on its own," he said, "the development of such systems is too great a challenge to be handled by one small country.

"Clearly, any progress made in the United States to develop answers to the dangers posed by tactical ballistic missiles could have a fundamental affect on Israel's future security. And, it should be stressed, the benefits resulting from the development of such a system would be shared by other American allies who also find that they must deal with the growing threat of tactical ballistic missiles."

IAI Gets Bad News

Meanwhile, Israel received some bad military-related news the other day—portending possibly even worse news down the road.

Because of the Gramm-Rudman budget cuts, Israel Aircraft Industries (IAI) is now in danger of losing a proposed $10-12 million contract to sell mineplows to the U.S. Marine Corps.

The mineplows, which are attached to the front of M-60 and other tanks, clear away mines.

IAI officials were informed that the contract was now endangered because of the most recent federal budget cuts forced on the Marine Corps by the Gramm-Rudman law. The law is designed to reduce the massive federal budget deficit.

The Israeli company had been negotiating the deal with the Marines for nearly three years. U.S. officials said all the arrangements had been virtually completed until the Gramm-Rudman law forced a re-evaluation.

U.S. and Israeli officials pointed out that the Marine Corps, like the other branches of the U.S. armed services were currently in the process of sharply cutting back on procurement in a whole host of areas.

They strongly denied that the tentative decision to cancel the mineplow deal reflected any political irritation with Israel.

IAI officials had hoped that this initial sale to the Marine Corps would encourage other foreign nations to purchase the mineplows, which have been shown to be very effective.

In recent weeks, IAI, in a joint venture with Tadiran, had announced the sale of a new generation of pilotless reconnaissance aircraft—known as remotely piloted vehicles (RPVs)—to the U.S. Navy.

In addition, the U.S. Navy is expected to lease another 12 Kfir fighters for use during training exercises. A first batch of 12 Kfirs, based at the Oceana Air Naval Station in Virginia, already has been leased by the Navy to simulate Soviet-made MIG-21s. This proposed second shipment would be based in Arizona.

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Harold Brown

IS SDI TECHNICALLY FEASIBLE?

The program known as the Strategic Defense Initiative (SDI) includes research on a variety of technologies—many aimed at distinct phases of the ballistic missile flight path. For each phase—boost, post-boost, mid-course and terminal[1]—a defense would require successful surveillance, target acquisition, tracking, guidance of the weapons, and kill mechanisms. Are the objectives of SDI technically feasible?

The answer will depend primarily on what specific objectives strategic defenses ultimately seek to achieve—protection of population, of missile silos, of other military targets. Within that context, the answer will further depend on the capabilities of the technologies and on the potential countermeasures and counter-countermeasures of each side.

This article will assess the prospects for the various defensive technologies for both the near term (10 to 15 years) and the longer term. It will include recommendations on how to proceed with a realistic research and development program. It will also make tentative judgments on the technical feasibility of various SDI objectives, though definitive answers are not yet possible. The political desirability of SDI is a separate question, not addressed here.

Finally, in considering the prospects for the various SDI technologies, it is important to remember how long it takes to move from technological development through full-scale engineering to deployment. That time is governed by the budgetary and legislative process, as well as by the state of technology.

[1] The boost phase is the period during which the ballistic missile rockets operate to bring it to (or near) its peak velocity. In the post-boost phase the warheads (and decoys) are released from the last stage of the missile. It is followed by the mid-course phase outside of the atmosphere, the lengthiest part of the trajectory. The terminal phase is the period from shortly before reentry into the atmosphere until detonation.

Harold Brown, President of the California Institute of Technology, 1969–77, and Secretary of Defense, 1977–81, is now Chairman of the Foreign Policy Institute, School of Advanced International Studies of The Johns Hopkins University.

Denise Brown, Editor

Harry Zubkoff, Chief, News Clipping & Analysis Service (SAF/AA), 695-2884

—After the technology is proven out, full-scale engineering development of a moderately complex system will typically take five to eight years (a new ICBM is a good example).

—The course of deployment (unless there is concurrency of development with deployment, which has almost always proven counterproductive) takes five to seven years after completion of engineering development.

—Thus, if proven technology exists now, it will take 10 to 15 years before a new system employing the technology could be substantially deployed.

—If the technology needs to be further developed, even though the phenomena exist and are well understood, the time for that technology development will have to be added to such a period.

II

What kinds of technologies could be embodied in defenses against ballistic missiles that could begin deployment before or about the year 2000?

Terminal hard point defenses (e.g., defending ICBMs), using hardened ground-based radars and interceptor rockets, would require about ten years between a decision to deploy and having a significant force; the time to completion of deployment would approach 15 years from decision. The necessary technology exists now, and some subsystems have already been partially developed. What would be required would be the design of a new system involving—in sequence—some additional prototype development, full-scale engineering development, production and deployment. Such a system would include an interceptor like the Spartan missile aimed at reentry vehicles (RVs) outside the atmosphere, and another, rather like the Sprint missile, for intercepting RVs that have already entered the atmosphere.

Present designs of both missiles would require the use of nuclear warheads. Alternatively, non-nuclear versions could be developed using terminal homing devices in the interceptor. There is some question about how heavy a conventional warhead (and therefore the interceptor missile) would need to be in order to provide high probability of destroying the incoming RV and missile warhead; it depends on how close to the reentry vehicle the terminal guidance could bring the interceptor. If a

non-nuclear interceptor is chosen, this would lengthen by at least a few years the time to a substantial deployed capability.

An additional optical sensor, the Airborne Optical Adjunct (AOA), which would track reentry vehicles by detecting their infrared emissions or viewing them with visible light, could also be included at about the same time as a non-nuclear warhead.[2] Such a capability is feasible technologically and likely to be helpful in discrimination during or shortly before the offensive missile's reentry, but the technology would need some additional development.

Over the next 10 to 15 years it also appears technologically feasible to develop the components of a system using *space-based kinetic-energy weapons*. These chemically propelled rockets would intercept the offensive missile during its boost phase and destroy the target by impact or by detonation of an exploding warhead. The chemical rockets would be similar in nature to air-to-air missiles, but steered with reaction jets rather than aerodynamic surfaces. The targets could be designated to the interceptors by laser or radar tracks, provided by a set of tracking and fire-control satellites orbiting at a higher altitude than the satellites from which the interceptors would be fired. Short-range laser designation of ground or airborne targets exists, but the accuracies required for ICBM tracking would require significant additional technological development, as would imaging and processing the infrared data, and looking close to the horizon.

The interceptors would home onto the target, guided by their own passive observation of the infrared emissions from the target missile or by receiving reflections from the target of radar signals emitted from satellites (semiactive radar homing). Such a system, however, must find a way to direct the killer rocket to the actual ICBM booster rather than to its plume (exhaust), which emits the infrared signal. While presumably this can be done, it will add complexity and offer an opportunity for offense countermeasures. Though the technology for components of kinetic-energy kill and boost-phase intercept systems exists, solution of problems of this sort would require a considerable developmental process.

Several years of additional technical development could sig-

[2] Development or testing of AOA beyond the technology platform stage, as a component of an ABM system, even of a fixed ground-based ABM system, would appear to violate the ABM treaty because the AOA is itself a mobile component.

nificantly decrease the weight of the intercept rocket for a given kill probability. That approach is indicated because the weight determines a significant part of the total system cost. The cost of putting payloads in orbit with either the present shuttle or expendable boosters is thousands of dollars per pound. To reduce those costs to an acceptable level, a new "super" shuttle would probably have to be developed. This would involve a ten-year development process and a delay in deployment of a space-based kinetic-energy system.

Missile boosters in the upper atmosphere and in space can be detected, tracked and attacked through the infrared emissions of the missiles' exhaust plumes while their propulsion stages are burning; however, the actual effectiveness of such an approach will depend not only on the technical features of the defense, but on the actions of the offense in employing decoys, adopting countermeasures and suppressing the defensive system itself. For example, modest deliberate fluctuations in booster propulsion ("jinking") could require the kinetic-energy interceptor to make significant changes in its cross-trajectory velocity, and this would involve a large weight penalty for the defense. Fast-burning boosters would effectively negate such a defense system.

Nevertheless, the technology for a space-based boost-phase intercept system of some capability, using kinetic-energy weapons, could be ready for a decision as early as 1990–92 to initiate full-scale engineering development, with a significant deployment able to begin some time between 1995 and 2000. Soon after the year 2000 there could thus be deployed a space-based kinetic-energy kill system along with a high-altitude and low-altitude terminal defense. These would constitute three layers of a possible multilayered defense, the purpose of which would be to compound modest kill probabilities in each defensive layer so as to produce a high overall kill probability.

III

For the period five to ten years beyond 1995–2000, more elaborate space- and ground-based technologies *may* be feasible, with a corresponding period of deployment beginning some time between 2000 and 2010. Increased uncertainty, however, naturally attaches the further out we look.

Among the less uncertain of these later technologies are *space-based directed-energy weapons* such as neutral particle beams and chemical lasers.

—A *neutral particle beam* (NPB) would be made up of atomic particles, accelerated to a high speed in charged form by electric fields in an accelerator, then steered and pointed by a magnet, and then neutralized so that it will not be deflected by the earth's magnetic field.

—A *chemical laser* uses the energy created by chemical reactions[3] to create a highly focused, intense, highly ordered ("coherent") beam of infrared light, directed by a mirror.

As a measure of their status, both of these technologies could well be used toward the early end of the period 2000–10 for antisatellite purposes, which are less demanding than the antiballistic missile task. Demonstrations of the capability to kill an individual satellite by such means—most likely on cooperative targets—could be made still earlier, but these would not represent an operational military system.

Neutral particle beams are, in their present state of development, much brighter than any existing laser in terms of energy into a given solid (cone) angle. Today they produce particles of energy corresponding to acceleration by a few million volts of electric field (and could in the future be improved to 100 million "electron-volt" energies). Protecting ballistic missiles from such high-energy NPBs would require much heavier shielding than would protection from lasers. During the next 10 or 15 years, however, it is unlikely that NPB technology will be able to put more than ten percent of the primary energy into the particle beam itself. Such low efficiency means that a space-based NPB would probably require a nuclear power source, development of which would delay the possible deployment of a system.

In addition to the usual target acquisition and tracking problems, a defense based on neutral particle beams has several other critical tasks. The magnet necessary to point the beam before its neutralization is likely to be heavy—and expensive—to put into space. The tasks of developing an ion source capable of operation over some minutes and of achieving the necessary pointing accuracy will be difficult. Even more difficult is tracking the beam, since it gives off almost no signal in space. Finally,

[3] For example, the chemical combination of hydrogen and fluorine. If the population of the resulting excited molecules outnumbers that of the lowest-energy ("ground") state, stimulation of emission of light of the frequency corresponding to the energy difference occurs, resulting in an intense coherent beam.

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the system will need to find ways to detect the effect on the target, through nuclear emanations from it, because at the full range of a successful NPB attack, the target would not be physically destroyed. Even where NPBs cannot be used to kill targets, however, they might ultimately prove useful in discriminating among them, because the nuclear emanations from an object hit by an NPB would depend on the object's weight.

For chemical lasers several technological problems still need to be solved. One is getting high enough power while maintaining a low enough beam divergence. Another is the very large weight of chemical reactants required for providing the energy. A third is the feasibility of the large optical systems required. There are, however, some promising technologies under development for chemical and other lasers. Among them are: various phase-compensation techniques to improve the quality and stability of the beam; phase-locking separate lasers together to increase the overall brightness; using adaptive optics (rapid adjustment of segments of a mirror), both to compensate for atmospheric dispersion for ground-based lasers and to ease the problems of creating large aperture mirrors for space-based ones; and phased arrays of lasers to increase intensity and to steer them more rapidly through a small angle, so as to move quickly from target to target. But some of these technologies have yet to reach full demonstration of the physical principles involved, and all are still far from being developed.

IV

Less technologically developed, and therefore more suitable for consideration of full-scale deployment beginning 20–25 years from now, is the use of ground-based *excimer* and *free-electron lasers* (FEL)[4] to be used with mirrors in space as components of a system for boost-phase intercept. Both are now many orders of magnitude away from achieving the intensity necessary for the required lethality, the free-electron laser further away than the excimer laser, at present. But the free-electron laser's device weight is lighter and its efficiency greater (and thus, its fuel weight lighter) than that of the excimer laser.

[4] Excimer lasers use "excited" (higher-energy) states of molecules including a rare gas (e.g., argon) and a halogen (e.g., iodine). These excited states are quasi-stable, while the unexcited ("ground") states are not populated, because the rare gases are not chemically active in their lowest-energy states. Free-electron lasers use the effect of oscillating electromagnetic fields on electron beams to cause the electrons to emit phase-coherent (laser) radiation.

The FEL might perhaps therefore be deployable in space. But the weights of these lasers and of their energy supplies more probably would require either to be ground based. The laser wavelength for both would allow the beams to penetrate the atmosphere, if the atmospheric distortions problem is solved. Thus both seem more suitable for ground deployment along with mirrors in space. Other problems for the ground-based lasers are the large optics required, both on the ground and for the synchronous-altitude steering mirrors, and obtaining the same high power in each of a long series of repetitive pulses.

These two systems might also be suitable for "active" discrimination—also called "interactive" or "perturbing"—in the mid-course phase of a strategic defense. That is, they could impart energy or momentum to very large numbers of objects in mid-course being tracked by some of the more established technologies already discussed. The resulting changes in the objects being tracked, or in their trajectory, could offer some limited opportunities for discrimination of reentry vehicles from decoys and debris.

Significant technological disagreement exists about the potential of ground-based lasers (free-electron or excimer) versus space-based chemical lasers. Some believe that the smaller amount and lesser complexity of hardware required to be put in space will bring the time for availability of these ground-based lasers as close or closer than the time actually required for those entirely space-based.

Chemical lasers are more proven technologically than excimer or free-electron lasers, but many experts have dismissed their potential use because of the difficulties in designing an effective system. Chemical lasers (space-based because their wavelengths will not penetrate the atmosphere) could be of some use against ballistic missiles now deployed. They could well be severely inadequate, however, against the offensive systems (with, for example, fast-burn missiles and other countermeasures) that could be in place during the first decade of the next century, when a significant defensive laser deployment could be made. Surely such countermeasures would be put in place if defense lasers were deployed. And in light of the large weight of chemical fuel that would have to be deployed in space, the chemical laser system at present seems to fall into the category of technically feasible but ineffective as a system. New optical developments such as phased arrays and phase

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conjugation are now being investigated, however. These might be able to improve the brightness and stability of chemical lasers—and increase their lethal range—to the point where they would have some systems effectiveness even against a responsive threat.

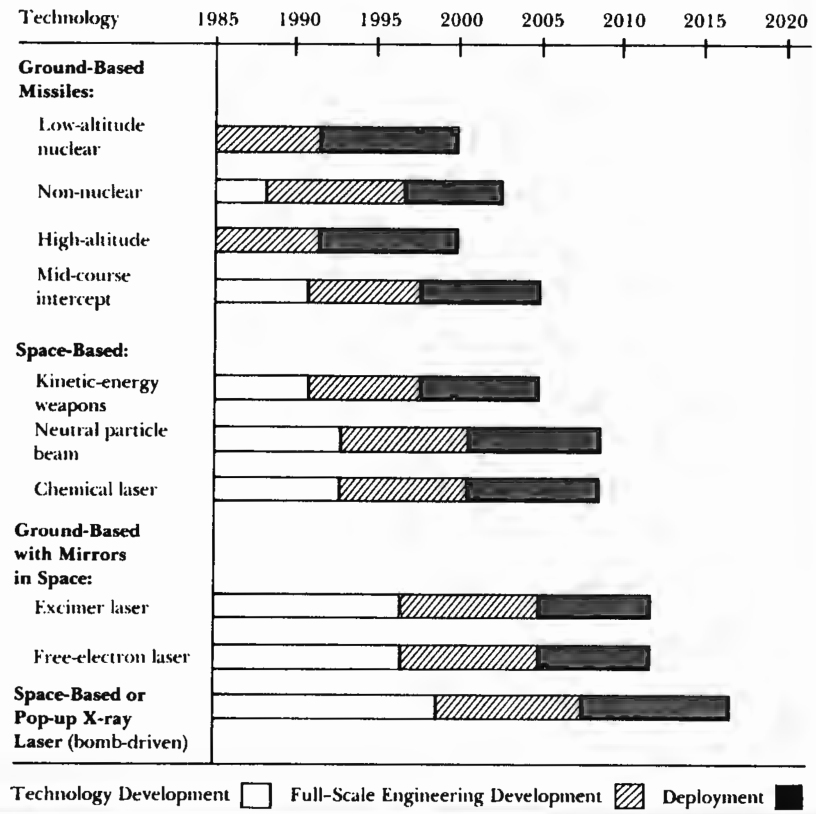
X-ray lasers powered by nuclear explosions are still further off than the other types of lasers, although they seem to offer some interesting distant possibilities. X-ray lasers would have wider beam angles and higher power per unit solid angle than optical ones. This would make them suitable for destroying clouds of objects or for actively discriminating heavy objects among them, and thus effective against such countermeasures as balloons and decoys. Proof of the most basic principle has been established, in that bomb-driven X-ray lasing has been demonstrated to be possible. But there is doubt as to what intensity has been achieved; it is in any event far less than necessary for use in active discrimination, let alone target kill. Demonstration of the physics of a possible weapon is at least five (more likely ten) years off. Weaponization would involve another five or more years, and only thereafter could its incorporation into a full-scale engineering development of a defensive system begin.

Rail guns, which accelerate objects to very high speed electromagnetically, may also have promise. But they are almost as far off as X-ray lasers. Multi-kilogram payloads would need to be accelerated to speeds above 15 kilometers per second, and a system (and power source) would need to be designed that could be used for multiple shots. New guidance and propulsion systems would also have to be engineered to survive such accelerations and to do the necessary terminal homing.

While many uncertainties exist as to future laser technologies for strategic defense, all laser systems would be vulnerable to other lasers. In general, the rules of the competition are that ground-based lasers will defeat space-based ones, larger ones will defeat smaller ones, and bomb-driven X-ray lasers looking up though the fringes of the atmosphere will defeat the same sort of X-ray lasers looking down into the fringes of the atmosphere. Vulnerabilities will also differ as between ground-based and space-based lasers. The former would have the weapons—or at least their energy source—on the ground, and presumably would include mirrors stored or unfolded in or popped up into space for the purpose of steering the laser beams.

As to time scale, when one is talking about time scales for deployment 25 or more years from now, corresponding to technologies whose full demonstration is more than ten years away, one really cannot know what the time scale will be to reach substantial deployment. The accompanying chart summarizes the time scales for these various systems. For the space-based systems, the pop-up systems and those with mirrors in space, lengthy technology development periods will be required. Depending on how that development is carried out, it may be possible to defer collision with the provisions of the ABM treaty until early in the process of full-scale engineering development. The calendar times differ for each technology, as shown in Figure 1.

FIGURE 1



V

A successful strategic defense would require not only kill mechanics but also a *battle management system* involving sophisticated *command, control and communications* (C^3). Estimates for the total number of lines of code of software required range from 10 million to 100 million. A measure of the effort involved can be derived by using the standard figure of $50 a line. Thus, the software costs could range from $500 million to $5 billion. The raw cost of such a system is therefore less important than the feasibility and methods of finding and correcting errors in it.

One problem would be with errors in the codes themselves. While this would not be trivial, it could be dealt with in part through automated software production and through artificial intelligence. The latter, though still mostly in the conceptual stage, nevertheless has real capabilities in terms of expert systems, and can be expected to produce real advances within the next ten years. The most fundamental problems for battle management and C^3 are: the establishment of appropriate rules of engagement; the probability of conceptual as well as mechanical error in the creation of the software, and the possibility of redundancy to compensate for it; the need to change portions of the software as new elements are introduced into the system without having the changes compromise the working of the rest of the software; and, most of all, the ability to check out the system, so as to make sure there are no conceptual errors in the software in such matters as handing over tracks of the offensive missiles, transferring automated decisions from one node of the system to another, avoiding loops in the logical sequence, and so forth.

How could such capabilities be tested? Can on-orbit testing be used? Such problems are just beginning to be addressed, and it will take a long time before conclusions can be drawn even as to what the state of this particular technology is compared with what is needed.

VI

In terms of future defensive technologies, what potential defense systems are technically feasible?

It is technologically feasible to create a *terminal defense* overlay of hard ICBM silos, deployed so that the missiles are moved among multiple silos and so that their position at any one time

is unknown to the attacker. Such a defense overlay can, by preferential defense—that is, defending only the occupied silos—provide a cost-exchange ratio favorable to the defense because the attacker must attack all silos. The same is probably true of defense of moderately hardened mobile missile systems by a terminal defense of corresponding mobility and hardness. In the case of hard-silo defense, a single layer of defense by endoatmospheric ground-based interceptors would suffice. For mobile hardened missiles, a two-tier ground-based system would probably be needed.

Modified ground-based defenses using similar technologies could protect some other military targets, for example command and control centers. The exchange ratio at the margin will vary widely, however, among classes of such targets according to their nature (hardness, area and mobility), their number and their cost. Such defenses could also be deployed for a thin protection of some urban-industrial areas, though they must be recognized as protecting such targets, if at all, only against attacks that are both limited in size and not responsive (i.e., not modified to take account of the defenses). Terminal defenses for these categories would use two-tier ground-based interceptors, and until the early 21st century would need to carry nuclear warheads in at least the exoatmospheric long-range tier. The defenses would be accompanied by space-based early warning and tracking sensors, and by airborne optical sensors to aid in the discrimination task during the terminal phase.

Advanced versions of infrared sensors deployed near or above geosynchronous orbit (an altitude of 20,000 miles) will be needed for attack warning and assessment in any defensive system, even if no boost-phase intercept is attempted. Infrared or other sensors in lower orbits (at altitudes of hundreds of miles) would also be useful to all layers of a ballistic missile defense system for tracking and discrimination. But the sensors must be able to survive. This suggests that they be provided with some self-defense, which in turn could be the first step toward boost-phase intercept.

As to weapons, kinetic-energy rockets based in space are technologically feasible. But an ICBM using a fast-burn booster clearly defeats them, and space-based defenses are vulnerable to defense suppression. Estimates of the exchange ratio for a *boost-phase intercept* defense layer based on kinetic-energy kill range from as low as two to one adverse to the defense at the margin (assuming unresponsive offensive threats and including sunk costs for the offense) to more realistic estimates, assuming responsive offenses, of five or ten to one. Defense suppression would probably further shift the ratio in favor of the offense.

Space-based chemical lasers seem feasible in technological terms but more questionable in practical systems terms. Though likely to be faster in response than kinetic-energy weapons, they still will not be a match for fast-burn boosters of offensive missiles. They will, moreover, be vulnerable to defense suppression systems based on other space-based lasers, and also vulnerable to ground-based lasers and direct-ascent antisatellite weapons. Ground-based lasers, whether free-electron or excimer lasers, are interesting future technologies and may be more effective than chemical lasers, but it is too soon to know.

It should be noted that even though fast-burn missiles could thwart a boost-phase intercept, this still leaves the possibility of a *post-boost tier* or layer in an SDI system. The deployment by the offense of warheads and decoys cannot occur until later in the trajectory than the boost phase, at a higher altitude in order to avoid atmospheric drag. But the technology for post-boost intercept capabilities is likely to be difficult to achieve, because it will require electronic examination of images (pictures), using ordinary or infrared light, to distinguish among various components: the burned-out upper stage of the missile, the post-boost vehicle, and the various objects released from it. These requirements, the countermeasures, and the potential technological capabilities for a post-boost layer of defense are just beginning to be considered.

Which technologies would be useful in the next tier, in *mid-course intercept*, is still less understood. Presumably the defense would want to use the same kill methods (kinetic-energy and directed-energy weapons) for intercepts as in the other tiers. This has the advantage of allowing some of the absentee satellites[5] to come into play because of the longer time period involved in mid-course flight of a missile. Discrimination among possibly colossal numbers of objects would, however, be a daunting problem. There are ideas about how to address it,

[5] Satellites in nonsynchronous orbit trace out a path over the earth whose pattern and timing depends on their altitude and velocity. Absentee satellites are those whose position in their orbits, at the time when the attacking missiles are launched, puts them over parts of the earth that are distant from the offensive launch sites.

but no confidence in any of them; that is why there is a drive toward consideration of "active" discrimination, which would impart energy to the objects in the threat cloud in order to be able to distinguish among them by observing the effect on their behavior. Thus, mid-course intercept is unlikely to play any role in a deployed system until well after the turn of the century.

Through all of these considerations is entwined a serious problem for space-based ABMs: however effective space-based systems may be against ballistic missiles, they would appear to be more effective in suppressing defenses. And direct-ascent antisatellite systems or ground-based lasers may be still more effective than space-based systems in this latter role.

In sum, given the state of present and foreseeable technology, a boost-phase or post-boost phase intercept tier is not a realistic prospect in the face of likely offensive countermeasures and the vulnerability of those tiers to defense suppression. It will also exhibit unfavorable relative marginal costs as a contributor to defense of population at any reasonably high level of protection. These judgments apply to any system beginning deployment at least for the next 20 years, and probably considerably beyond then.

There are interesting new technologies, however, that leave open the possibility that our estimates of the offense-defense balance might change after that time, especially if some of these technologies prove to have some mid-course discrimination and intercept capability, as well as some boost-phase effectiveness. Such a shift is very unlikely, but strategic thinking should include the possibility that it might take place in terms of deployed systems some decades into the next century.

VII

What would a defense system look like if the priorities of the Reagan Administration's SDI program (boost-phase intercept and population defense) were to be combined with the technologies that will be available and a reasonable development program leading to deployment around the year 2000?

It would be likely to have space-based components. It would perhaps include, for example: a dozen satellites at one-half to two times geosynchronous altitude to carry out boost surveillance and tracking; some tens of satellites at perhaps one thousand kilometers altitude to carry out surveillance, tracking and fire control for the attack of boosters, post-boost vehicles,

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and objects in the mid-course part of the trajectory, using infrared detection (short wavelength for boost, long wavelength for mid-course) and laser designation, and possibly some semiactive radar or laser radar tracking; some thousands of satellites, at altitudes of a few hundred kilometers, whose main purpose would be to carry kinetic-kill vehicles, of which there would be a total in the tens of thousands for use as actual defensive weapons.

In parallel, terminal defenses would also be deployed. These would include terminal radars and an airborne set of optical and infrared detectors. There would be some thousands each of exoatmospheric and endoatmospheric interceptors, deployed around missile (ICBM) silos, other military targets and major urban-industrial areas. Some of the endoatmospheric interceptors might even reach out into the later parts of mid-course flight. To moderate the costs of putting into orbit the space-borne component of the system, a new and advanced shuttle would be developed and put in use beginning about 1997.

A supplementary deployment or second phase could be expected to commence eight to ten years later, thus beginning somewhere between 2005 and 2010, and taking another five to seven years to complete deployment. During that phase there would be added satellites carrying chemical lasers for killing offensive targets, and lasers or neutral particle beams for discriminating in mid-course as well. Alternatively, ground-based lasers with mirrors in orbit would be deployed, perhaps as early or perhaps three to five years later still. This second phase carries us into the realm of hypothetical technologies and cloudy crystal balls; X-ray lasers and electromagnetic rail guns lie still deeper in those realms.

Whatever the system architectures, there must be consideration of the possibility—and the effect—of catastrophic failure of one layer of a multitiered defense on the subsequent layers. In both the quantity of hardware and the nature of the software (that is, the built-in operational procedures), the systems must therefore be designed to provide a way to avoid catastrophic failure of a later layer (and thus overall failure) because of a poorer-than-expected performance of earlier layers. The simple multiplication of attrition factors in a series of layers, the number of which is sometimes rather arbitrarily assumed, carries an inherent assumption of its own. The assumption is that the operation of each layer's sensors, tracking, kill mech-

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anisms and effectiveness is completely independent of the nature, physical components and effectiveness of all the previous tiers. The architecture of the entire system has to be such as to assure that this would in fact be the case to the maximum possible extent; also, to the extent it is not, to assure that the system degrades "gracefully." This will not be an easy or inexpensive task.

VIII

What would constitute an appropriate research and development program?

Though existing technology and system concepts for terminal defense can provide an effective defense of hard ICBM silos deployed in a multiple protective shelter mode, more advanced technologies—optical trackers, more accurate interceptors and lower interceptor yields—would increase the system's cost-effectiveness. For improving the contribution of terminal defense to protection of urban-industrial areas and, possibly, of military targets other than missile silos, the technology associated with non-nuclear kill and with terminal discrimination should be pursued. These would include greater tracking accuracy, homing warheads and the airborne orbiting adjunct. Deployment of a prototype developmental version of a terminal defense complex at a test range (Kwajalein) would be extremely valuable, and consistent with the ABM treaty.

Early warning and attack assessment systems should be further developed, including those based on detection of the infrared signal from missiles in a boost phase. To this end, improvements in the present Satellite Early Warning System should be carried out. Infrared, optical and radar tracking of objects in space from distances of up to about a thousand miles will also be useful for any defensive system. The corresponding R&D should therefore be vigorously pursued.

Because kinetic-energy weapons and conventional chemical lasers will be defeated by, or suffer a severe cost-exchange disadvantage from, offensive countermeasures and defense suppression, the R&D program should concentrate on the more advanced kill mechanisms and active discrimination methods that are further off in time. Such an approach, however, is legitimately subject to the criticism that "the best is the enemy of the good." Moreover, the effectiveness of future technologies is easily overestimated simply because less is known about them.

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If one judges that the good is not good enough, then it is appropriate to work on something better (and therefore usually further away in time). This conclusion depends, however, on a judgment that successful development of such an advanced technology has a good chance to improve the defense's position in the balance between defensive measures and countermeasures. This last criterion may turn out not to be met even by the more advanced technologies for active discrimination and kill. For example, it continues to appear that everything that works well as a defense also works somewhat better as a defense suppressor. But the balance between offense and defense seems even less likely to shift in favor of the defense as a result of the nearer-term technologies than as a result of the more advanced ones. Thus, it is appropriate to increase the R&D emphasis on such programs as:

—optical technology, including, *inter alia*, the following elements: adaptive optics, i.e., adjusting the wave-front shape to compensate for distortions in the laser source and in the atmosphere; locking the phase of separate lasers together so their amplitudes add, greatly increasing the brightness; using one laser to drive another; phased-array lasers (for improving intensity, steering capability and atmospheric compensation);

—combining lasers and particle beams as a way of focusing the beam better;

—excimer and (especially) free-electron lasers, and the kill mechanisms based on those technologies; application of advanced optical technologies to chemical lasers;

—ground basing of lasers, and pop-up mirrors (which should be less vulnerable) or mirrors that unfold and that can be more easily deployed to make them less vulnerable as targets;

—verification technology for computer programs, fault tolerance, expert systems and automatic programming—in order to improve confidence in software;

—active and perturbing discrimination and other mid-course signature work (since the mid-course part of the flight gives the defense a longer time to act, *if* discriminants can be found for use by the defense); and

—survivability of space-based defensive components, especially sensors.

Bomb-driven X-ray lasers could be very effective because they could achieve very high brightness and medium beam

width. But they are at such an early stage that the program, while deserving support, should be confined to demonstration of those two features. Rail guns may be useful but only if they meet very ambitious goals for speed, mass and multi-shot capability. Even then, conventional rockets accelerated to equally high speeds (and with correspondingly heavy propellant weight) may be competitive with rail guns; but neither is likely to be cost-effective.

Demonstrating the technology to achieve the above goals for X-ray lasers and rail guns should precede any consideration of a systems effort for them.

IX

In the light of the considerations set forth, what should be the emphasis of the SDI program? What should be the balance among systems design, component development, experimental demonstrations, and technology? What should be deemphasized or eliminated? These questions become more acute in the light of the substantial reductions in the funding of the research and development program from the proposals formulated in the Fletcher Committee Report of 1983.[6] Though congressionally approved funding is likely to exceed $2.5 billion in the current fiscal year, the scope of the program is so ambitious that schedules set only a year ago for systems decisions appear to be slipping, and some difficult choices about priorities will have to be made.

It would seem appropriate to emphasize technology that still needs to be proven and developed, rather than "spectacular" demonstrations—though at some point demonstrations would be needed to test the technology. Some technologies are sufficiently demonstrated, and the corresponding systems concepts sufficiently clear, so that engineering development could begin on them relatively soon. But doing so would make sense only after a decision as to the detailed nature and function of the defensive system.

1. Work is indicated to define the design of a ground-based terminal defense system, which could stand by itself or be a layer of a multilayer strategic defense system. This would involve updating the Spartan and Sprint missiles, and beginning

[6] The work of this committee, headed by Dr. James C. Fletcher, was published in the unclassified report, "Strategic Defense Initiative: Defensive Technology Study," U.S. Department of Defense, March 1984.

work on the design of a non-nuclear interceptor. This system should have the capability of being deployed as a defense of the U.S. ICBM force, as well as serving as a component of a population defense if that should ever prove feasible.

Initiation of full-scale engineering development for such terminal defenses should be deferred for several years. This would allow two prior determinations. One is the technical and military feasibility (and political acceptability) of less vulnerable modes of ICBM deployment. The second is whether mutual reductions in the size of strategic offensive forces can be negotiated, to reduce the need for active defense of ICBMs. An appropriate schedule would be to get the technology ready for a possible 1988 initiation of full-scale engineering development, and a start of deployment in the 1993 time frame if such a decision is taken.

2. Space-based kinetic-energy weapons appear unpromising in the light of the almost certain offensive countermeasures, and therefore should be deemphasized, even though such a system is the only space-based one that could be reasonably well specified today. By the same logic, it would make sense to delay a decision on detailed specification of and initiation of full-scale engineering development on any boost-phase intercept system until 1994 or 1995. By that time enough ought to be known about the technology of the various directed-energy weapons to allow a more informed choice among them.

3. A full-scale technology program (phasing into development as particular technologies reach that stage) on boost-phase surveillance, mid-course surveillance and tracking is fully warranted. Boost-phase surveillance capabilities will augment early warning of attack; mid-course surveillance and tracking will augment attack assessment capabilities. These functions are justified even in the absence of a decision to proceed with active defense of population. Like the terminal defense development activities, they are consistent with restrictive interpretations of the ABM treaty. But they would also constitute the eyes of a strategic defense of population or of military forces against ballistic missile attack, should such a defense be decided upon.

4. A full program on adaptive optics, phase compensation and phase conjugation devices, phased-array lasers and related optical technology should be emphasized strongly, since obtaining the brightness and beam accuracies required for effectiveness even in the absence of offensive countermeasures depends strongly on these technologies.

5. The electromagnetic rail gun, bomb-driven X-ray laser, and (probably) neutral particle beam programs all belong in the preliminary technology stage. If they work they would be useful in specific functional areas of a strategic defense system, but they are in too preliminary a stage to justify putting them in the component development category.

6. The directed-energy weapons segment of the program should be tilted toward the excimer and (especially) free-electron lasers, with emphasis on ground basing the energy sources and consideration of space-based mirrors as the pointing mechanism. Work on space-based chemical lasers should emphasize ways of making them brighter—such as phased arrays—within the limitations imposed by space basing; it is probably too early to abandon chemical lasers completely.

This orientation of the program would, as a separate matter, delay conflict with the ABM treaty while permitting rapid development and even preliminary testing of technology. It corresponds to an acceptance of the judgment that the program dates are ambitious even for the more developed (and less promising) technologies, and concentrates on the less developed but more promising ones.

That approach would defer until after 1995 the decision on full-scale engineering development for the directed-energy boost-phase intercept segment of the program that could involve space-based components generating or transmitting very high energy densities. Such a schedule, however, might prompt concerns that it was so far in the future as to undermine congressional and public support for the program. But that factor works both ways. Though there is real public support for strategic defense, both the expert and congressional communities are doubtful about the vision of protecting populations from a nuclear attack by means other than deterrence through the threat of retaliation. They are also concerned about the potential negative effects of SDI on arms control. Moreover, even those defense tasks and system components that look most promising are subject to serious policy objections regarding their deployment or testing. Thus a sign of willingness to pursue a more modest track, with long-term goals, and more care about arms control, would probably favorably influence a decisive segment of congressional votes on program funding.

To sum up, the near-term prospects for ballistic missile defense capabilities are reasonably well known. Technically, they appear cost-effective for defense of some kinds of strategic retaliatory forces. For defense of populations against a responsive threat, they look poor through the year 2010 and beyond. The prognosis for the longer term for this latter objective in the contest between defense and offense is less certain. It still looks questionable, at best, for the defense, because of some fundamental problems of geometry and geography, and the physics of offensive countermeasures and defense suppression in their contest with defense.

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Why Israel will benefit from Star Wars

By Charles D. Brooks

In March 1983, President Reagan formally announced a pioneering defensive strategy predicated on the notion that it is better to save lives than avenge them. The President's plan, called the 'Strategic Defensive Initiative' (SDI), was designed to replace the doctrine of 'Mutually Assured Destruction' (MAD), a dangerously obsolete and immoral doctrine of holding civilian population centers hostage to nuclear attack.

In Israel, a nation faced with the ultimate challenge of ensuring self-survival, the President's vision and the invitation to U.S. allies to participate were met with great interest. After preliminary discussions, Israeli Defense Minister Yitzhak Rabin formally responded to the American invitation agreeing "in principle" to participate in the initial research and development phases of the SDI program.

The strategic, economic and political implications of Israeli involvement in SDI are significant. The most immediate benefit to Israel will be the development of missile interception technologies. The invitation sent to the allies specifically states that the program will "examine technologies with potential against shorter-range ballistic missiles," and anti-tactical missile technologies are likely to be among the first to be developed.

The use of surface-to-surface missiles against major cities in the Iran-Iraq war has alerted the Israeli defense establishment to the urgent need for such technologies. Syria, Israel's foremost adversary, has already deployed highly accurate and lethal SS-21 missiles capable of reaching Israeli population centers, air bases, storage depots and other vital facilities. General Dan Graham, founder and director of High Frontier, the organization from which many of the concepts for SDI arose, has noted these implications for Israeli defense planning. Obtaining defenses against the SS-21s, he said, "would enable Israel actually to defend itself... rather than simply deter attack by threat of retaliation."

While the threat of retaliation has served Israel well in the past, this option may no longer be effective in light of the changing realities of modern warfare and the increasingly fanatical character of Israel's enemies. Such threats are unlikely to deter enemies whose scant regard for human life is reflected in suicide bombings in Lebanon and the use of poison gas in the Gulf War. To guard against the growing ballistic missile threat, Israel must move beyond deterrence to develop a defense against missile attacks if she is to survive.

In a recent paper presented in testimony before the Senate Armed Services Committee, W. Seth Carus, a military analyst for the American-Israel Public Affairs Committee (AIPAC), called attention to Israel's growing vulnerability to missile attack. Carus pointed out that by 1990 Arab armies will possess large numbers of surface-to-surface missiles armed with sophisticated warheads. As the Arab inventory of SS-21 missiles grows, he noted, a missile attack on vital Israeli installations would leave the country dangerously vulnerable. In addition, he wrote, existing technologies alone would be insufficient to defend against such attacks, even if Israel knew of them in advance.

Besides the utilization of missile interception technologies, Israel will also benefit in other ways from participation in SDI. Israel's industrial future will be greatly enhanced by being at the forefront of the SDI technological revolution while spinouts could include new computer systems, energy sources, communication devices, medicines and consumer products. Research funds from SDI will help revitalize the universities and the Israeli scientific community.

SDI cooperation will be of critical importance to the Israel defense industrial base that will otherwise be subject to foreign aid cutbacks generated by the Gramm-Rudman deficit reduction bill. In particular, SDI will provide jobs and revenues to defense related industries which have already been forced to cut back on research and development activities because of lack of funds.

Israel is unable to match other countries' weapons accumulations, but involvement in SDI would give her a qualitative edge necessary for survival

America will also benefit from Israeli involvement in SDI. Israel's high state of technological and scientific capability can be utilized in SDI research. The Israeli Defense Forces demonstrated an unforseen mastery over command, control, and communications by downing over 80 Syrian Jet fighters with no losses during the recent Lebanon conflict. Their expertise in battle-tested technologies would immensely enhance development of weapon systems. In addition, the Israelis are known for their rapid turn around times from research and development to making weaponry operational. Israeli involvement can serve to catalyze the entire SDI program by accelerating the pace of the effort.

Israel's acceptance of President Reagan's invitation to participate in SDI should yield invaluable dividends particularly in the critical area of development of ballistic missile interception technologies. Unable to match the quantitative advantage in weaponry accumulated by her numerous adversaries, Israel's involvement in SDI should enable her to maintain a qualitative edge necessary for survival.

Israel can only be part of this strategic, technological, economic and political revolution if SDI is funded and promoted by Congress. With the help of Israel's friends in America, SDI may prove to be the most important project ever undertaken by the two allies.

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Charles D. Brooks is a Liaison to the Jewish Community for High Frontier. He also serves as Outreach Director for the National Jewish Coalition. He was educated at DePauw University in Indiana, the Hague Academy of International Law and holds an M.A. in international relations from the University of Chicago.

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The Wonders of Star Wars

Lord Zuckerman

Star Warriors: A Penetrating Look Into the Lives of the Young Scientists Behind Our Space Age Weaponry
by William J. Broad.
Simon and Schuster, 245 pp., $16.95

How to Make Nuclear Weapons Obsolete
by Robert Jastrow.
Little, Brown, 175 pp., $15.95

Ballistic Missile Defense Technologies
Congress of the United States,
Office of Technology Assessment.
325 pp., $12.00

1.

The Geneva summit has come and gone, leaving Mr. Gorbachev adamant that the Strategic Defense Initiative program is a critical impediment to any significant nuclear arms control agreement—for the simple reason that it would inevitably drive the arms race into space. President Reagan on the other hand, remains bewitched by what he continues to call his dream, a dream of a shield of defense systems in space which would liberate mankind from "the prison of mutual terror." So there it is—as the USSR sees it, a choice between survival and mutual suicide; for Mr. Reagan, a beautiful dream. Where does reason lie? Will there be anything new at the summit later this year?

Had anyone other than the American president ever invited scientists to try to render "nuclear weapons impotent and obsolete," the suggestion would probably have attracted no more attention than had they been asked to square the circle or solve the problem of perpetual motion. But it happened to be the President, and he spelled out his vision of a future over which the nuclear bomb no longer casts a shadow in such homely terms that it all sounded real. How could the message fail to appeal? There was also a promise of vast resources for R&D—a vision therefore not only of peace but, at least in the meantime, of work, prosperity, and excitement for some. For those who might object that the idea was strategically naive, the President even acknowledged that it would "take years, probably decades of effort" for the dream to become a reality, and that in the meantime defensive systems, "if paired with offensive systems," could be "viewed as fostering an aggressive policy."[1] However fantastic it was, the challenge therefore had to be taken seriously, even by the President's defense secretary who, it had been widely rumored, had been skeptical about the idea until the moment it was suddenly proclaimed to the world.

The upshot is that within the space of two years, SDI has become one of the best-known acronyms in the world. It has stimulated a global debate. Instead of reducing tensions between East and West and "introducing greater stability into the strategic calculus of both sides," it has exacerbated the tensions. It has also generated strains in the Western alliance. Even more important, it has divided that part of the American scientific community to which the challenge was particularly addressed, with respect both to its technological implications and to its strategic desirability—a part of the debate in which politicians, military people, and ordinary citizens have also engaged. And of course the debate has produced a mountain of comment, including books such as the three under review.

[1]*Essays on Strategy and Diplomacy: The Strategic Defense Initiative, No. 3*, The Keck Center for International Strategic Studies (May 1985).

In some respects the debate is a rerun of the controversies that culminated in the 1972 ABM Treaty, when both sides implicitly acknowledged that it was then beyond their power to design meaningful defenses against intercontinental ballistic missiles (ICBMs). Both had set about the job in the same way, just as they deployed the same variety of anti-aircraft defenses. There were "acquisition radars" which scanned the horizon for incoming warheads; "tracking radars" linked by computer to nuclear antimissile missiles whose explosion outside the atmosphere would emit X-rays to which the attacking warheads would in theory be vulnerable at great distances; and then there were terminal radars and terminal anti-missile missiles to deal with such warheads as would not have been destroyed. By the late Sixties enough hardware and computer links had been developed to justify deployment, or so it seemed.

But doubts had already started to set in.[2] Could an ABM system work? It would have to deal not only with nuclear warheads but with a variety of decoys and other "penetration aids" which the missiles would release in order to confuse the radars. Warheads might be exploded outside the atmosphere to create an electromagnetic blackout that would make the task of the radars almost impossible. The large radars themselves were clearly vulnerable to direct attack. The scale of an attack could itself be so great as to swamp any defensive system. Each ballistic missile could carry not one but several warheads which, as was clearly recognized as early as the mid-Sixties, could be made independently maneuverable—what we now call MIRVed.[3] And then there was a political problem—people did not want defensive nuclear missiles planted in their back yards. Finally, neither the US nor the USSR could afford to deploy more than a handful of defensive complexes. If these could be made to function effectively, which was the first question that needed an answer, there was then a second problem, who or what was to be defended.

[2]See, for example, J.P. Ruina and M. Gell-Mann, "Ballistic Missile Defence and the Arms Race," *Pugwash Proceedings* (1964), pp. 232–235.

Despite all the doubts, in 1967 the United States started deploying a "light" ABM system, code-named Sentinel, to defend against a possible missile attack from China. The USSR had started a few years before to deploy one for the presumed defense of Moscow. For, as Mr. Khrushchev saw it, if his ballisticians knew how to "hit a fly in the sky," so too they could hit incoming warheads. It was therefore only rational to try to defend his capital city. President Johnson was not so sure. In 1967 he asked the only question that mattered: Would an ABM system work? The answer from those best qualified to judge was "no."[4] No ABM system could reduce significantly the vulnerability of the United States; no president could initiate or agree to the initiation of a nuclear exchange without realizing that once it had begun, he could never be sure where it would end—that the risk, were he ever to agree to the actual use of nuclear weapons, was the total devastation of his country. In 1967 President Johnson and Robert McNamara, his defense secretary, tried hard at Glassboro, New Jersey, to persuade Kosygin, Khrushchev's successor, to accept these propositions. Gradually he and the Politburo saw the light. Dubious ABM systems only destabilized a state of mutual nuclear deterrence.

[3]See Richard L. Garwin and Hans A. Bethe, "Anti-ballistic missile systems," *Scientific American* (March 1968), pp. 21–31.

[4]Herbert York, *Race to Oblivion* (Simon and Schuster, 1970).

The result was the ABM Treaty of 1972, a treaty that limited ABM deployment to two sites only—later changed to one—in each country. The treaty did not bar development work that improved the radars, computers, and defensive missiles deployed within the two sites, but specifically prohibited the development of any type of space-based ABM system. Stability was then the order of the political day.

And that was the moment—not March of 1983 when President Reagan spoke—when SDI really began. For, not surprisingly, the American and Soviet scientists and engineers who had been working on lasers and particle beams as possible Ballistic Missile Defense (BMD) weapons did not cease their experimental inquiries when the 1972 treaty was signed, any more than did the scientists and engineers who were trying to improve the power of the permitted radars and computers, and the design, thrust, and speed of their defending missiles. The military chiefs on both sides, who had anyhow been dubious about the wisdom of the ABM Treaty, were only too ready to encourage them to continue, however little they understood the intricacies of the systems concerned. Most of the scientists and engineers needed little urging. After all, it was their jobs that were on the line.

An important figure who was in no need of any encouragement was Edward Teller, the well-known refugee theoretical nuclear physicist who had worked on the atom bomb under Hans Bethe during the war years. Teller is regarded by some as a distinguished, by others as a notorious, physicist. During the McCarthy years he had played a critical part in the downfall of Robert Oppenheimer, the wartime scientific director of Los Alamos, whether because of jealousy and frustration or because he had conceived of himself as some kind of superpatriot—*plus royal que le Roi*—it was difficult to say. Whatever his motives, Teller lost the respect of most of his scientific peers, from whom he rapidly became isolated.[5] On the other hand he was eagerly supported by members of the defense establishment, particularly in the Air Force, who were only too ready to agree that a more powerful nuclear device than the atom bomb, the "second generation" hy-

[5]"If a person leaves his country, leaves his continent, leaves his relatives, leaves his friends, the only people he knows are his professional colleagues. If more than ninety percent of these then come around to consider him an enemy, an outcast, it is bound to have an effect." Teller, quoted in Stanley B. Blumberg and Gwinn Owens, *Energy and Conflict: The Life and Times of Edward Teller* (Putnam, 1976).

drogen bomb, would be a valuable addition to America's nuclear arsenal.

They also supported him in his campaign to found a second nuclear warhead laboratory at Livermore as an offshoot of the University of California. Teller had persuaded them that the Los Alamos research center was too liberal. He vehemently opposed the Partial Test Ban Treaty of 1963, basically because it interfered with the testing of new warhead designs, but protesting too that the Soviet Union would be bound to cheat—and that anyhow there was no reason to suppose that the radioactive fallout from nuclear tests in the atmosphere did any harm, it might even do good.[6] He became the chosen scientific mouthpiece of the "hard-line right," a term that Europeans have come to identify with those Americans who are intrinsically against arms control, who uncritically assume that more destructive nuclear power than what already exists means more military and political strength, and who, whatever the risks, wish to oppose the Russians and communism at all times and wherever possible.

Teller was also loud in his protestations against the ABM Treaty and against SALT I and II. The Livermore laboratory, his creation, was going to give birth to a third-generation nuclear device that would transform the entire strategic scene. According to William Broad, the author of *Star Warriors*, the picture of this third generation of nuclear devices that Teller painted for the President was largely instrumental in instilling in Mr. Reagan's mind a vision of a future in which nuclear weapons could be made impotent and obsolete.

Teller thus lurks behind almost every page of Mr. Broad's book, which focuses on a small but select group of the employees of Livermore, who now number, so we are told, some eight thousand, and who cost the federal government more than $800 million a year. Although Livermore does many other things, its primary function is the design of warheads, a field in which it competes fiercely, and presumably very successfully, with the older Los Alamos laboratory. A glossy brochure that was issued to celebrate the station's silver anniversary claimed that Livermore was responsible for nine of the ten strategic warheads now in the American nuclear stockpile. As Mr. Broad was told by a member of the special group with whom he spent a week in the Livermore compound, warhead and weapon designers are free to follow their heads—the number of possible designs is "limited only by one's creativity." The young men Mr. Broad was getting to know were the ones who were responsible for Teller's third-generation nuclear breakthrough.

Their leader, and Teller's main disciple, is Dr. Lowell Wood, now aged forty-two. For a week Mr. Broad stayed with him, consorting during all hours of the day and night with his host's team, which was designated O Group at Livermore, and which numbered no more than a dozen or so young scientists of average age less than thirty. Associated with them were as many part-time workers, some of whom were no more than graduate students. Many of the team had begun as research fellows of the Hertz Foundation, on whose board both Teller and Wood sat, and for which Wood served as the recruiting sergeant. With employment prospects bleak, and competition for jobs fierce, he was able to select from all the universities of the US young scientists and engineers in whom he discerned "outstanding capability that has been developed and exercised in some direction"—usually in mathematics or physics. Apparently men with general interests but no specialized technical accomplishment were not wanted.

Successful candidates were invited to work at Livermore for a summer in an intern program, and were kept on if they made the grade. All but a few of the group were, like Wood himself, bachelors. Few had set out to be bomb makers; but it was either that or, as one of the group told Mr. Broad, working in a beet factory. There was the further attraction that Livermore had the most marvelous equipment with which to work, as well as access to the underground nuclear testing grounds of Nevada, which were shared—in effect as an outstation—with Los Alamos and the Sandia nuclear development establishment at Albuquerque.

Lowell Wood's young men both collaborated and competed with one another, and celebrated their triumphs at parties at which they ate masses of ice cream and drank gallons of Coca-Cola. Mr. Broad tells us that there were no women around and that O Group was not entirely popular in the main Livermore establishment, one member of which told Mr. Broad that the team was made up of "bright young hotshots" with "no outside interests... who are socially maladjusted."

If the week that Mr. Broad spent with the hotshots was typical, they also seemed to converse only with one another, and when not discussing their work, exchanged naive views about politics. One would imagine from the conversations Mr. Broad describes that the only problem in the world for O Group is the competition for power between the USSR and the US. Their part of the problem was to construct a shield to keep out Soviet warheads. One of the group told Mr. Broad that as soon as that was done, the US would leave the USSR technologically "in the dust," and that success would "prove to the world that democracy works." Another told him that if the Russians "owned the planet" they would not allow the evolution of technology to continue. So far as this young man knew, "the only reason they are going with technology is that they can't afford not to." He clearly was unaware that in the 1930s the USSR had shocked the West with a revelation of a totally utilitarian view of science and of its absolute commitment to technology. As propounded by B. Hessen, the Russian ethos holds that science cannot advance in a society which restricts technological advance, that "science develops out of production, and those social forms which become fetters upon productive forces likewise become fetters upon science."[7] I imagine that this proposition would have appealed to Lowell Wood and his team. They are doers, not philosophers or political scientists. Their business, like that of their opposite numbers in the USSR, is to put scientific knowledge to work.

2.

Long before any of them was born, long before the era of ICBMs, physicists had been building machines—for example, cyclotrons and proton synchrotons—in which the subatomic particles that make up the atom are accelerated into extremely powerful beams of energy. These "par-

[6]Blumberg and Owens, p. 411.

[7]*Science at the Crossroads*, papers from the International Congress of the History of Science and Technology, 1931 (London: Frank Cass, 1971).

ticle beams," if directed into space, might, it was later thought, intercept and destroy nuclear warheads. Then, in 1960, came the laser. Ordinary light, as emitted by the heated filament of a light bulb, consists of an incoherent emission of a very wide band of electromagnetic waves—from the longer ones at the red end of the visual spectrum to the shorter ones at the blue. The laser focuses all the energy of a very narrow band of the electromagnetic spectrum within a coherent beam or jet. The discovery[7] was seized upon by scientists the world over for a myriad of different purposes, from an instrument that can be used for operations on the retina of the eye, to an aiming device for marksmen.

It was not surprising that "defense scientists" also saw in the laser, as in the particle beam, a device which, if furnished with sufficient energy, could operate at great distance—the sort of thing an older generation would have called a death ray. Retired generals started to talk about particle beams as though they were particles which could be poured from one hand to another. The newspapers were not slow to hint at a new generation of wonderful weapons.

The main achievement of O Group, and in particular of Peter Hagelstein, whom Mr. Broad introduces to his readers as the brightest star of Lowell Wood's team and as a young and troubled engineer who is also interested in classical music and French literature, was the presumed invention of the "nuclear-pumped" X-ray laser. Other workers, including an older Livermore scientist, had also bent their talents to this problem, but in vain. X-rays belong to the extreme shortwave end of the electromagnetic spectrum (about one thousandth the wavelength of visible light). If a coherent beam of X-rays could be provided with sufficient energy, it would travel outside the atmosphere at the speed of light for thousands of kilometers, imparting its energy to the "first fraction of a millimeter of the aluminum skin of a missile [in its path]. This paper-thin layer would explode, sending a shockwave ['thump'] through the missile," so destroying it.[8] This is the concept that was Teller's basic justification for believing that a space-based ABM system was a possibility. A sufficiently powerful X-ray or other laser or particle beam traveling at the speed of light, that is to say at 186,300 miles a second, could, if properly aimed, destroy a warhead whose maximum speed was less than ten miles a second.

Were an X-ray laser to serve as an ABM weapon, it would, however, be necessary to use as a source or "pump" of energy a nuclear device, i.e., bomb, of significant force (maybe 100 kilotons in yield or more). On the other hand, in theory the X-ray laser is not the only laser that could do the trick. Los Alamos, among other laboratories, is working on an "excimer" or chemical laser whose wavelength, although much longer than those of X-rays, would be equally effective (but by heating, not "thumping," the target), without the disadvantage that X-rays could be made to lase only at the enormous temperatures associated with the explosion of a nuclear weapon.

Edward Teller

Since X-rays are absorbed by even a thin layer of the atmosphere, another disadvantage of the nuclear-pumped X-ray laser is that it is a device which in practice could only be effectively fired when shot up into space, or shot from a space satellite, a so-called space battle station—which indeed would be necessary for most subatomic particle-beam weapons. An X-ray space battle station would, of course, be a one-shot device, since the whole thing would be destroyed an infinitesimal fraction of a second after the nuclear explosion that generates X-rays, which would be directed along, and amplified by, a series of lasing metal rods built around the whole device. Given certain conditions, the rods could in theory be independently aimed in that millionth of a second at a number of enemy launchers as they rose from their silos.

Only land-based weaponry was involved in the ABM systems with which the 1972 agreement was concerned. There was no possibility then of hitting ballistic missiles during their launch phase; since decoys and other countermeasures ruled out effective interception in space, warheads would have become vulnerable only when they reentered the atmosphere on the way to their automatically designated targets.

The 1983 system, if SDI can be called that, differs completely because it is a space-based concept. The theory is that beam weapons or rocket fire could be directed from artificial satellites against enemy missiles during the few minutes of their launch phase, before the ejection of their multiple warheads, and thousands of miles from the targets which they would be programmed to destroy. The same arguments would apply to the electromagnetic rail-gun, another device now being worked on, which uses intense magnetic fields to create the force to shoot out small projectiles ("smart rocks") at very high velocity.

Were it ever possible to bring laser, particle-beam, or electromagnetic rail-gun weapons into action during this initial phase of the flight of a missile, the defensive system would also have to include enough artificial surveillance satellites to ensure that as they circled the globe, there would at all times be at least one that was looking down on the Soviet missile fields. Otherwise the curvature of the earth would make it impossible for one or the other side to see its opponent's missiles before their warheads were well into space. The weapons on the "battle stations" circling the earth would have to be ready to be aimed and to strike on automatic command.

But here lies the first major problem. Teller, who we have been led to believe started the whole thing, is convinced that battle stations permanently in space are too vulnerable to enemy attack to be contemplated. Even if, as Lowell Wood suggested to Mr. Broad, they were placed in geosynchronous orbit more than 20,000 miles above the earth, they could in theory be "fooled"—for example, by decoy launches on the ground or by decoys in space furnished with transmitters to send out false signals to confuse the BMD sensor systems.[10] Or they could also be destroyed by space mines, small satellites that would follow the battle stations and would always be ready to explode.

Space-based attacking systems also suffer from an additional handicap—the power sources by which they would be activated would be both very heavy and very bulky. Teller's view is that the X-ray laser, his favorite weapon, should be carried in submarines, and launched into space—"popped-up" is the happy-go-lucky term that is used—by ballistic missiles which would react automatically when commanded to do so by the surveillance satellites that registered the Soviet SS18 and other missiles rising from their silos or launch pads.

Once shot into space, the X-ray laser devices would automatically be focused onto the presumably unprotected boosters, which, as they rose above the atmosphere, would be "thumped" by an X-ray laser beam set off by the explosion of a hydrogen bomb. Excimer or chemical lasers on the ground might in theory reach their targets by way of a system of folded mirrors that would be orbiting the earth, ready to open up on computer command to reveal themselves as perfect large reflecting surfaces. These would change their orientation in split second after split second as they aimed the beams impinging on them either directly to their targets, or redirected them to other mirrors that would do the focusing.

Then there would be a computer network that would tie all the surveillance satellites, targeting devices, beam and ray weapons into a single system competent to deal not with one or a few enemy missiles but, if the space shield were to be truly impregnable, with hundreds, even thousands.

What all this means is that if it ever came to action, heaven would become hell within a few minutes, and, given a failure of the system, that hell would also break out on earth in less than an hour. What is more, even though the whole system would have to start reacting automatically at a moment's notice, somehow or other—no one has said how—there would have to be time for a human link in the chain of interacting processes. As a sop to the doubters, the proponents of SDI agree that the fate of mankind is not something that should be simply committed to a computer.

Teller, Lowell Wood and his whiz-kids, as well as their opposite numbers in Los Alamos and such supporters as they have in the Pentagon and the Department of Energy, believe that all this can be done, or at least that it is worth spending tens of billions of dollars to see whether it can be done. Little time passed, however, before it became clear that some members of Congress had doubts, and that the views of the space warriors were not shared by a number of scientists who know about these things, both within and outside government laboratories. Lowell Wood asserts that all the opposition emanates from a very few scientists. At a small international meeting, not mentioned by Mr. Broad in his fascinating book, Wood told his audience that the number of scientific skeptics could be counted on the fingers of one hand. Unfortunately he said on the fingers of a *maimed* hand, which rather shocked his audience and reduced the force of his argument.

3.

In fact, the situation is the reverse of what Lowell Wood believes. According to Dr. John Bardeen, twice a Nobel Prize winner in physics, there are few scientists either within or outside the administration who believe that President Reagan's dream could be realized in the foreseeable future. Dr. Bardeen was a member of the White House Science Council at the time of Mr. Reagan's SDI speech, about which both the council and Dr. George Keyworth, its chairman, were ignorant until five days before it was delivered.[11] Teller

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[7]Discovered independently by Charles Townes, an American, and two Russians, N.G. Basov and A.M. Prochorov, who in 1964 shared a Nobel Prize for their achievement.

[8]Ashton B. Carter, *Directed Energy Missile Defense in Space* (Congress of the United States, Office of Technology Assessment, April 1984).

[10]Hans A. Bethe, Jeffrey Boutwell, and Richard L. Garwin, "BMD Technologies and Concepts in the 1980s," *Daedalus* (Spring 1985), pp. 53–71.

[11]*Science* (December 13, 1985), pp. 1249–1250.

too does not share Lowell Wood's views about the number of scientific doubters. He told Mr. Broad that "a great many American scientists, perhaps the majority," are against SDI. The fact is that only a very few independent scientists have come forward to offer their support to the Livermore and Los Alamos enthusiasts. Of these, the quickest off the mark was Dr. Robert Jastrow, a well-known popularizer of science, and a professor of earth sciences at Dartmouth College. His unswerving loyalty to SDI shines out in *How to Make Nuclear Weapons Obsolete*.

Dr. Jastrow's short book begins with a number of fairly unassailable propositions. Defense, he tells us, is always a good thing; a policy of mutual nuclear deterrence is inhumane since it implies a willingness to destroy populations; if one side acquired an effective defense against ballistic missiles, it could attack the other with impunity; if both had a defense, nuclear arms would become useless; even an imperfect US defense that left some of its retaliatory nuclear weapons untouched would foreclose the possibility of a first strike by the USSR. Why the USSR should in any circumstances want to risk such a strike, knowing that the considerable submarine missile fleet of the United States would be immune to attack, Dr. Jastrow does not make clear. As former president Nixon has recently reminded us, the Soviet leaders are neither madmen nor fools.[12]

Dr. Jastrow then gives an account of the buildup of Soviet land-based missiles in the years since the signing of the SALT treaties, implying that doing so was contrary to what the treaties allowed. For Dr. Jastrow, the USSR has only one end in view, namely the destruction of the land-based components of the US nuclear arsenal in a first strike. Here Dr. Jastrow's echo of the conventional Pentagon view again clashes with the position of Nixon, who in his recent article in *Foreign Affairs* observes that the Russians have gained whatever "superiority" they have "in strategic land-based missiles not because of what *they* did in violation of arms control agreements but because of what *we* [the US] did *not* do within the limits allowed by those agreements."

Dr. Jastrow writes about the airborne and submarine elements of the US nuclear arsenal, including the Trident missile, in terms that rather belittle their value. He talks mysteriously of work going on which will make it possible to detect deeply submerged submarines. This is a possibility that has been continuously discussed and explored over the years, but so far with no results that would undermine the view that nuclear submarines are, and will continue to be, effectively invulnerable. The picture Jastrow paints seems to imply that America is wide open to attack by the more powerful armory of the USSR. The only real hope, therefore, is "a defense that shielded the American people." And despite what the critics say, that, he asserts, is already available. The new secret weapon is the 670-million-mph laser beam. With this introduction Dr. Jastrow takes us back to SDI.

It turns out that he was so inspired by the President's speech of March 1983 that he immediately and publicly gave it his scientific imprimatur. He then became fortified in his faith by a talk given by Dr. Keyworth, until recently Mr. Reagan's science adviser who, Mr. Broad tells us, was recommended to the President by Teller. Dr. Keyworth is a former member of the staff of Los Alamos, outside which he was little known before, and is a friend of Teller. It would have been surprising if he had not been an ardent crusader for space defense.[13]

Much of the material for Dr. Jastrow's book was provided by Gregory Canavan of Los Alamos, and by Lowell Wood of Livermore, by General James A. Abrahamson, the head of the Pentagon's SDI office, and by a few other officials whom he names. The book contains no original analysis, which perhaps is not surprising since it would seem that Dr. Jastrow has not himself been involved in research either on nuclear weapons or on lasers, radars, or computers. He is a missionary for SDI.[14] What the reader therefore gets is a highly optimistic account of the same hypothetical space defensive system of which countless descriptions have already been published.

Can "inventive genius," Dr. Jastrow asks, find a device that can shield the American people? Of course it can. The invention is already there. "It is called the laser." And the way Dr. Jastrow writes makes it all but child's play to fit together the whole defensive complex. The US could deploy a Mark I system by the early 1990s[15] and all for a cost of $60 billion, for which could be bought one hundred satellites, each carrying 150 interceptor rockets, four early-warning satellites in geosynchronous orbits, lower altitude satellites for surveillance, acquisition, tracking, and terminal defense, all the necessary but as yet nonexistent computer networks and other accessories. Everything can be "easily" achieved. Terms such as "easy" and "not too difficult" characterize Dr. Jastrow's rosy picture.

His optimism is matched only by his breathtaking simplifications. War in space—that is to say, intercepting nuclear warheads with laser or particle beams or with pellets shot from electromagnetically driven rail-guns—is for him like an infantry battle. If the battle-management satellite loses touch with its weapons satellites, they can function autonomously—"like a machine-gunner cut off from his unit." It would, however, be better, so he writes, were they under the control of the master satellite which, like the general in charge of a land battle, can oversee the whole operation, moving his forces as required. The control function would be exercised by a master satellite—not, it should be noted, by the president of the United States in consultation with the heads of NATO governments—during the three to five minutes of the boost phase of the enemy missiles, whose targets this time would not be hostile soldiers, but defenseless cities with millions of inhabitants in peril of instant death. It reads like a film script. I suspect that were Dr. Jastrow's book to be made required reading for the leaders of America's NATO allies, what reluctant political support some of them have been prevailed upon to give to President Reagan's dream would vanish overnight.

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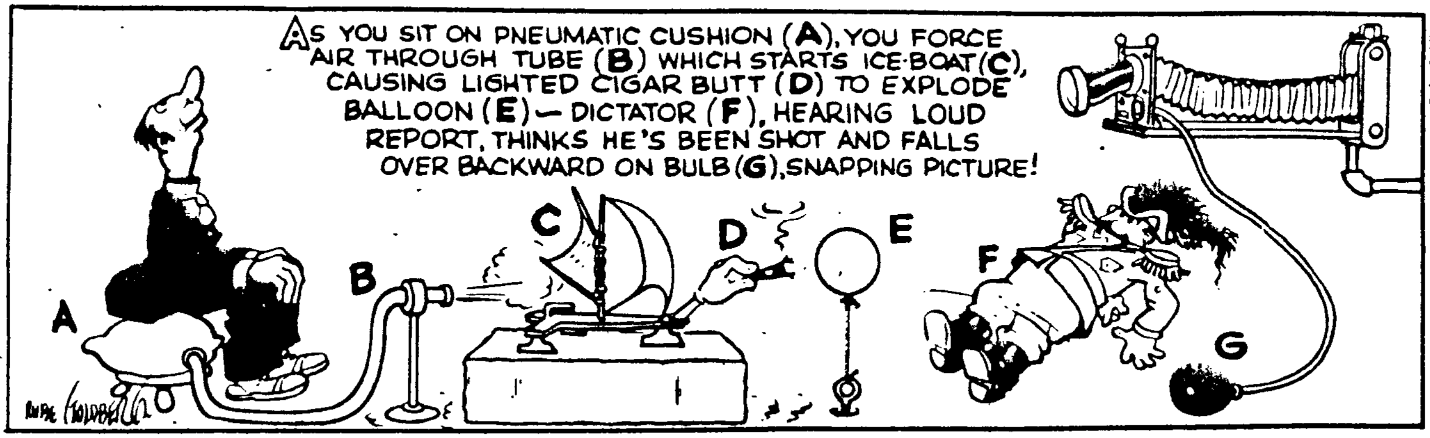
[12] Richard Nixon, "Superpower Summitry," *Foreign Affairs* (Autumn 1985).

[13] See, for example, George A. Keyworth II, *Security and Stability*, IGCC Policy Papers No. 1 (University of California, San Diego, 1985).

[14] In congressional testimony (April 22, 1985) Dr. Jastrow admitted that he had not carried out any analysis of SDI on his own, and that he had made it his business to translate into lay language the views of government scientists.

[15] Elsewhere in the book he claims that it would take only five years, which I presume means by 1990.



Rube Goldberg

Dr. Jastrow fully realizes that a large number of highly reputable American scientists regard the entire idea as technical and strategic nonsense. Yet almost the only point of criticism on which he concentrates relates, first, to an erroneous early estimate, in a report by scientists opposed to SDI, of the number of surveillance satellites that would have to orbit the earth in order to keep the Soviet missile fields constantly in view, and, second, to an estimate of the considerable weight of a satellite that would be demanded by a particle-beam weapon. Dr. Jastrow did not himself spot the errors. He says he learned about them when they were rumored by "professionals in the field." In fact the authors of the report in question,[16] which included such distinguished scientists as Hans Bethe, Richard Garwin, Victor Weisskopf, Kurt Gottfried, and Henry Kendall, themselves drew public attention to the two errors five weeks after their report was issued, and before anyone else had done so.[17]

They also made quite sure that their subsequent publications were free of computational errors, at the same time emphasizing that estimates of the numbers of surveillance and laser satellites that a defensive system might call for depended on a varying number of assumptions. Dr. Garwin has subsequently published what seems to be the most complete and unchallenged set of estimates, given several different assumptions.[18] At any rate it is judged as such by Edward T. Gerry,[19] the chairman of the relevant panel of the Pentagon's Fletcher study team,[20] which the administration set up in 1983 to advise whether the pursuit of a space-based defensive system was technically justifiable.

In reality the two computational errors did not affect any substantive judgment about the feasibility of a space-based defense, as emerged clearly from a vigorous and lengthy exchange of letters published in *Commentary* in March 1985. Dr. Jastrow, who took part in the exchange, nonetheless again hammered away at the errors in an article published later in the summer,[21] in which he went so far as to imply that the views of his critics about the efficacy of Soviet countermeasures should not be "accepted"—by which I sense he means they should be disregarded. (It should be noted that his present book appeared a year after the corrections had been made by Dr. Garwin in his testimony to the Senate Armed Services Committee, and that Jastrow makes no mention of that testimony.) Someone not competent to follow the technical nuances of the debate could be forgiven were he to assume that Dr. Jastrow's apparent obsession with the long-corrected computational errors reflects a determination to discredit his critics personally.

Dr. Ashton Carter, the author of the first report on SDI to be prepared for Congress's Office of Technology Assessment (OTA), is also the target of Dr. Jastrow's criticisms. He too has pointed out[22] that Dr. Jastrow has never provided his own analysis of the problem. It would be unfortunate if the analysis included such meaningless statements as Jastrow's observation, on page 95 of his book, that one molecule of oxygen always consists of two oxygen molecules bound together. In truth, the precision of Dr. Jastrow's style, as manifested in his book, compares poorly with the appearance of scientific exactitude of the papers in which he attacks his critics, and in which he quotes extensively from documents provided him by proponents of SDI at Los Alamos and Livermore. While the voice, like that of Jacob, is obviously Dr. Jastrow's, his papers often read as though the hands of more than one Esau had helped steer his pen.

Dr. Carter's report of April 1984 considered the technical ideas that were discussed by the Fletcher study team as possible ways for attacking enemy ballistic missiles during their brief boost phase. In preparing it, he was helped by every official organization that was concerned, including Los Alamos and Livermore, as well as the CIA. But the conclusions that he drew were his alone, and the main one was that

> the prospect that emerging "Star Wars" technologies, when further developed, will provide a perfect or near-perfect defensive system...is so remote that it should not serve as the basis of public expectation or national policy about ballistic missile defense.

Not surprisingly, he was immediately set upon by the proponents of SDI in Los Alamos, Livermore, and the Defense Department—not to mention Dr. Jastrow.

Dr. Carter's study had been commissioned by OTA at the request of the House Armed Services Committee and the Senate Foreign Relations Committee. In view of the debate that his report stimulated, OTA then undertook an even more extensive study under the scrutiny of an advisory panel, which included among its twenty-one members Michael May, associate director-at-large of Livermore; Robert Clem, the director of systems sciences of the Sandia National Laboratories; senior representatives of several of the major defense contractor companies who are, or who would be, involved in SDI work; General David Jones, the former chairman of the Joint Chiefs of Staff; Robert McNamara, former defense secretary; Gerard Smith, the chief negotiator of the 1972 ABM and the SALT treaties; Major General John Toomay, who had served on the Fletcher study team; as well as Richard Garwin, Sidney Drell, and Ashton Carter, three who have criticized SDI on technical grounds. It would be difficult to conceive of a more distinguished or better balanced group. They advised a project staff which, in addition to writers of the studies they commissioned and an administrative staff, included nine researchers.

So far as I can judge, the new and lengthy OTA report, *Ballistic Missile Defense Technologies*, and the summary report accompanying it, touch on every aspect of SDI that has been publicly debated, and they set out both sides of every point at issue. The authors and the advisory panel acknowledge that the USSR is "vigorously developing advanced technologies potentially applicable to BMD." But at the same time, and contrary to the somewhat equivocal views put forward by the proponents of SDI in order to encourage public support, the OTA report does not consider that the Soviet Union has any lead over the US "in any of the 20 basic technologies that have the greatest potential for significantly improving military capabilities in the next 10 to 20 years." (These were the technologies which were recently reported on in the annual report to Congress of the under-secretary of defense for research and engineering in the Pentagon.)[23]

The OTA report reviews the requirements that an effective BMD system would have to meet in the face of the obvious Soviet countermeasures. The reader is also warned that it is essential to consider more than just the feasibility of a host of separate technical ideas. What matters is operational feasibility—could the developed technical components be combined into an "integrated, reliable system that could operate effectively and maintain that effectiveness over time as new countermeasures appeared." The report reaches the same general conclusion that Ashton Carter did in his earlier appraisal—"assured survival of the US population appears impossible to achieve if the Soviets are determined to deny it to us."

Press reports suggest that the Pentagon's reaction to OTA's new assessment has been less hostile than it was to Ashton Carter's, and that the defense authorities agree that during the years that it would take to move to a defensive strategy, new risks of nuclear conflict might well arise. On the other hand, the head SDI office in Washington believes that even a partial defense would increase the USSR's uncertainties were it ever to contemplate a first strike against the US, and would therefore enhance deterrence.[24]

But while administration and congressional leaders, as well as many press commentators, accept the OTA report as a nonpartisan review, which is the way it certainly reads, some die-hards have condemned it. What I find surprising is that they have now been joined by Dr. Frederick Seitz, the chairman of the Pentagon's Defense Science Board. He and Dr. Jastrow recently proclaimed at a meeting of the conservative Heritage Foundation that all the members of the OTA advisory panel except Dr. Seitz, as well as its staff, were strongly prejudiced *ab initio* against SDI. Dr. Seitz is also disturbed that the advisory panel did not vote on the report.[25] This, one might suppose, would have been a waste of time, since the vote would surely have gone against SDI in view of his assertion that the majority of those on the panel were in the anti-SDI camp.

General Daniel Graham of High Frontier withdrew from OTA's advisory panel because he anticipated that he would not like the conclusions which were being reached by the study team. He, at least, appears to be committed to SDI whatever the scientific judgment about the program's technical feasibility.[26] It is an entirely different matter when a scholar of Dr. Seitz's eminence[27]—he took General Graham's place on the panel—disavows the report for such reasons as he has so far made public. These reasons add up to

[16] Union of Concerned Scientists, *Space Based Missile Defense* (March 1984).

[17] Union of Concerned Scientists, *The Fallacy of Star Wars* (October 1984).

[18] See Richard L. Garwin's testimony to the Senate Armed Services Committee (April 24, 1984) and his "How many orbiting lasers for broad-phased intercept," *Nature* (May 23, 1985), pp. 184–290.

[19] Richard L. Garwin and Edward T. Gerry, "Fifteen Agreed Propositions on SDI," publicly presented at Dartmouth College, May 23, 1985.

[20] Department of Defense, *The Strategic Defense Initiative Defensive Technologies Study* (March 1984).

[21] Robert Jastrow, *Journal of International Affairs* (Summer 1985), pp. 45, 55.

[22] *Commentary* (March 1985).

[23] *The Fiscal Year 1986 Department of Defense Program for Research, Development and Acquisition*, Ninety-ninth Congress (1985).

[24] *International Herald Tribune* (September 27, 1985).

[25] *Nature* (November 7, 1985).

[26] *Nature* (March 7, 1985), p. 7.

[27] Dr. Seitz is a former president of the National Academy of Sciences and of Rockefeller University. He also served a term as chairman of the NATO Science Committee.

a blunt denial of what has been said by critics of SDI about the ability of enemy space mines to destroy battle stations, the ability of "spoof launches" to confuse space sensors, and so on. Surely the issue of the technological feasibility of the SDI concept has become far too important to the world at large for it to be argued about by accusations of prejudice, whatever the quarter from which they come, rather than by cogent analyses.

If one were to imagine that the President's dream will one day be given substance, far-reaching political and strategic issues will have to be debated, and debated internationally, in a world in which the 1972 ABM Treaty would have become a dead letter, and which in the meantime would undoubtedly have been transformed by major political events. But that could be decades away. Scientific judgments must come first, and they are an entirely different matter. Regardless of whatever political views he may now entertain (he is on record as having declared that the US should be able to make a first strike against the USSR), Dr. Seitz should be expected to argue his case before those of his scientific peers who have reached judgments on the facts—some of them in the field of basic science—that are contrary to his.

Dr. Jastrow bluntly says that the views of "professionals," who work full time in the "defense science community," should be given greater weight than those of their scientific critics, however distinguished they may be, and whatever their previous experiences of defense science. Lowell Wood is, not surprisingly, in full agreement. He tells us that Hans Bethe, Richard Garwin, and others who have dared criticize SDI "have fared uniformly poorly in technical debate in the classified surroundings required by government regulations," and that it is because of their failures in secret conclave that they carry the debate to the public "immune from the criticism of those who know better."[28]

This contemptuous dismissal by Lowell Wood of his critics harmonizes well with his claim that all the technological criticisms of SDI emanate from a few physicists who could be numbered on the fingers of a maimed hand. In any circle where the rules of scientific discourse prevail, both remarks would be dismissed with an equal measure of contempt. Unfortunately laymen who write in favor of SDI and who presume to make judgments on scientific matters about which they have little or no understanding tend to cite any scientific claim—for example Lowell Wood's—that reinforces the entrenched views in which they have a vested interest, be it political or financial. It is highly regrettable, therefore, that many of the most influential and ardent proponents of SDI are politicians and officials such as Richard Perle who have so far displayed surprisingly little critical understanding of the difficulties that the R&D program entails. It is surely absurd that matters which obviously first need to be strictly judged on their scientific and technological merits, and which are of such profound importance to the future of life on earth, should be pronounced upon by laymen lacking either a scientific background or any experience in the management of major R&D projects—or both. The technical feasibility of a space-based BMD system is not a matter that will be resolved either by a show of hands, or by a slanging match in which the pro-SDI side on occasion goes so far as to suggest that its critics are soft on communism. The laws of physics and judgments about what is technologically feasible are not yardsticks for the measurement of political attitudes, any more than Galileo's discoveries were disposed of by the conventional dogma of the Church.

4.

The resolution of the technical argument will depend on the clear formulation of a few basic questions and, following that, on those competent to express a view providing the wisest answers that can be put before the administration, Congress, and the people of the world. For example, a fundamental premise, given that a space-based ABM system could be devised, is that beam weapons can be aimed from space at a ballistic missile before it ejects its payload of warheads and penetration aids, that is to say, they can be aimed at a single target and not have to contend with tens and tens of separate targets. If, as Dr. Garwin and others have argued, and as the Russians claim, the separation of warheads from the missile can be made to occur within, say, the first hundred kilometers of the atmosphere, then X-ray lasers and particle beams fired from satellites would be relatively useless since they lose their effectiveness when they enter the upper layers of the atmosphere.

The primary question, therefore, is whether a ballistic rocket can be fueled and programmed to eject its warheads before reaching that height. The recent OTA report, as well as that of Ashton Carter, gave a positive answer to this question, which was what the Fletcher study team also implied the Russians could do, given time. If this is the consensus of those best able to judge, and if the USSR were to seek to achieve the necessary countermeasures over the next decade (if indeed it has not already done so),[29] the complexion of the entire problem of a space-defense system changes completely.[30] One critical part of the SDI concept would evaporate overnight.

Take another question—the enormous number of targets which a space-defense system should be able to engage almost simultaneously. A ship-defense system known as Aegis, which was designed to track two hundred incoming cruise missiles, and to engage sixteen of them at the same time, has not yet been shown to be able to manage two or three.[31] Have the contractors and engineers who have been

[28]*Commentary* (March 1985). Not surprisingly, Wood's assertion has been denied by Garwin and others who have participated in secret debates with Livermore scientists. It is interesting too that at a Congressional hearing in 1985 Teller cited Hans Bethe's opinion in support of an optimistic statement he was making about the X-ray lasers. He said that having discussed the matter with Livermore scientists, Bethe now agreed with him, which Bethe subsequently denied. Ironically, one of Teller's well-known public themes—ploy might be a better word—is to decry the evils of secrecy, beyond the veils of which he is not unknown to vanish when challenged.

[29]See *Space-Strike Arms and International Security*, Report of the Committee of Soviet Scientists for Peace Against the Nuclear Threat (Moscow, October 1985).

[30]Ashton Carter's views were strongly supported by Major General John C. Toomay, a member of Dr. Fletcher's study team, in his rejoinder (June 22, 1984) to the Department of Defense's criticisms of the Carter report.

[31]"Star Wars: SDI, The Grand Experiment," *Spectrum*, the Journal of the American Institute of Electrical and Electronic Engineers (September 1985).

working for years on airborne and ship defensive systems given their views in public about the engagement pattern that is presumed to be possible in the SDI concept—the destruction every second of between ten and twenty ballistic missiles in a salvo of more than a thousand?

Towering above all such technical issues is the question whether it could ever be possible to design the computer links that would be needed for a BMD system to function as a whole. This matter, too, is discussed in detail in several reviews, with generally pessimistic conclusions. Dr. David Parnas, a consultant of the Office of Naval Research, and an experienced professor of computer science, spelled out in detail his reasons for resigning from the official SDI panel that is dealing with the computer problems of a space-based ABM system.[32] They make formidable reading, adding up as they do to the general conclusion that the job of designing the necessary computer network is an impossible one. In the letter of resignation that covered his detailed submissions, Dr. Parnas wrote that he was aware that there were software experts who would disagree with him, and for whom

> the project offers a source of funding, funding which will enrich some personally.... During the first sittings of our panel I could see the dollar figures dazzling everyone involved. Almost everyone that I know within the military industrial complex sees in the SDI a new "pot of gold" just waiting to be tapped.

Dr. Parnas is fully supported in his view by the computer specialists who have recently founded an organization called Computer Professionals for Social Responsibility. British computer experts have also expressed their skepticism about what has been proposed,[33] and even more recently Herbert Lin of MIT has ended a review of the entire problem by stating that "no software-engineering technology can be anticipated that will support the goal of a comprehensive ballistic missile defense."[34] All this is in line with the conclusions of the recently published OTA assessment. The fact that Dr. Solomon Buchsbaum of the Bell Laboratories and Dr. Danny Cohen of the University of Southern California have publicly expressed more optimistic views, even if they do not claim that error-proof or tested software for the SDI concept could be devised, does not dispose of the criticisms. What is more, it is difficult to imagine the political uproar that would result were the public to become aware that in addition to having its destiny entrusted to a computer network, it was one not free from errors in software. I doubt if SDI could ever surmount this obstacle. It would be worse than having nuclear antimissiles in one's back yard.

The OTA report undoubtedly reinforced the views about the strategic shortcomings of the SDI concept which have been so powerfully expressed by James Schlesinger, Dr. Harold Brown, and Robert McNamara, three former secretaries of defense; by General Brent Scowcroft, whom the President had earlier put in charge of the preparation of a major report on the strategic forces of the United States; by Gerard Smith; by at least five of the holders of the office of director of defense research and engineering since it was established in the late Fifties, all of whom know from bitter experience, as I do, how easy it is to waste hundreds and thousands of millions of dollars in the pursuit of a technological will-o'-the-wisp; and by a number of other prominent men who have held public office in the field of national security. There may have been some members of Congress who also found it odd when the Canadian government decided that it wanted no part of the SDI program, even though any hypothetical space-based defensive system for the United States would automatically provide a shield over Canadian territory. In view of all the doubts, it is no wonder that Congress has now reduced the SDI budget for the coming fiscal year.

[32]David L. Parnas, "Software Aspects of Strategic Defense Systems," *American Scientist*, Vol. 73 (1985), pp. 432–440.

[33]*New Scientist* (October 31, 1985).

[34]"The Development of Software for Ballistic Missile Defense," *Scientific American* (December 1985), pp. 32–39.

In consequence we are told that next year's SDI R&D program will focus mainly on land-based systems. On the other hand, it should not be expected that the setback to the program will put an end to the work being done in Livermore on nuclear-bomb-pumped X-ray lasers, or at Los Alamos on excimer lasers powered by electron beams. As I have said, both laboratories had embarked on their pet laser and particle-beam projects well before the President spoke in March 1983, and they did so without being disturbed by any thought that the 1972 ABM Treaty barred the development of space-based defense systems, or by the fear that long before any such system could even be devised, the testing of its components would almost certainly constitute an abrogation of the treaty.

There is also no reason to suppose that the men who are working on a supercomputer and software for a space defense system are likely to bring their work to a halt because authoritative computer specialists have declared that it will never be possible to devise an acceptable network which could transform the separate components of a space-based BMD into a workable BMD system. The theatrical dream that was the background of the President's challenge to the scientists of America should in retrospect be seen as a proclamation to the world that work on particle beams and high-power lasers was already in progress. In no sense did it set that work in motion. It would be equally sensible and prudent to suppose that research and development work on lasers and particle beams that is going on in the USSR was not halted by the announcement of the American SDI program.

5.

One consequence of the criticisms of the SDI program has been the reduction of the SDI budget. Another is that many of the explanations that are now given by the administration for the need for the program to continue differ from the President's original vision and from his view that a defense against ballistic missiles constitutes a higher category of morality than the maintenance of security through the threat of mutual annihilation. One major justification continues to be heard: that the Russians are engaged on work that corresponds to different elements of the SDI program, and that in many ways they are ahead of the United States. We have also been told that some Russian actions have already breached the terms of the 1972 ABM Treaty. Specific violations are spelled out in impressive brochures.[35]

The Russians counter by pointing to American actions which in their view are breaches of the treaty. They have even offered to suspend work on the much spoken of, and highly vulnerable, vast phased-array radar system which they are building at Krasnoyarsk if the United States abandons its program to modernize the radar complexes which it has at Fylingdales in the United Kingdom and Thule in Greenland. Their spokesmen argue that these modernization plans, and particularly the rebuilding of Fylingdales as what is rumored to be a 360-degree phased-array radar complex, is far more questionable than what the USSR is doing at Krasnoyarsk.

A further accusation by the administration is that the USSR has committed "a far greater investment of plant space, capital, and manpower" to advanced BMD technologies than the US has.[36] This extravagant claim is not borne out by a CIA document about Soviet efforts which

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was presented to the Armed Services Committee of the Senate on June 26, 1985.[37] Indeed, the document expresses doubt about the applicability of even a network of Krasnoyarsk systems—regarded as the most serious breach of the 1972 treaty—for widespread ABM deployment. Dr. Garwin, in a follow-up to testimony presented to a congressional study group on October 10, 1985, has also pointed out that the better part of the large Soviet program on strategic defense is devoted to the upgrading of its anti-aircraft defense system.[38]

But whatever the truth about Krasnoyarsk, it can hardly be a justification for the US deliberately interpreting the 1972 treaty so widely that the Russians are given cause to say that the US is proposing to contravene the treaty in a much more specific way, or ways, in order to gain the "advantage" of being able to launch a first strike against the USSR without fear of significant retaliation.

[35]*Soviet Directed Energy Weapons Perspectives on Strategic Defenses*, CIA (March 1985); *Soviet Acquisition of Military Significant Western Technology: An Update* (September 1985); *Soviet Strategic Defense Programs*, Department of Defense and Department of State (October 1985); Richard Perle, "The Soviet Record on Arms Control," *The National Interest* (Fall 1985).

[36]*Soviet Strategic Defense Programs* (Department of Defense and Department of State, October 1985), p. 12.

[37]Robert M. Gates and Lawrence K. Gershwin, "Soviet Strategic Force Developments."

[38]In a submission to Congressman Mrazek (October 10, 1985), in which he also pointed out that the Stanford University Workshop of Strategic Missile Defense, of which he was a member, recommended (April 1985) that the United States should fund an adequate program of work on offensive countermeasures to Soviet SDI, including work on powerful lasers.

It was therefore unfortunate that immediately before the Geneva summit, Robert McFarlane, then the head of the National Security Council, declared that no aspect of the development of space-based BMD components is prohibited by the 1972 ABM Treaty, and that what was intended about testing and development merely implied a shift from the technology that was available at the beginning of the 1970s to what can be undertaken today. This statement could be taken as reflecting the hard fact that major vested interests are now involved in the SDI program—not only the men in the laboratories who started the whole thing and the authorities in the Defense Department who encouraged them, but also the industrialists who see in the SDI program a bonanza that they cannot afford to disregard. Unfortunately the statement also clearly implied an intended breach of the treaty. Indeed, Gerard Smith has pointed out that what McFarlane implied was not just a breach, but a *new version* of the treaty.[39] That the statement was publicly played down before the President met Mr. Gorbachev was therefore only to be expected.

But it remains highly regrettable that the myriad and diverse arguments about SDI have now induced what might well be described as a state of schizophrenia among America's European allies. All of them recognize that the coherence of NATO is a vital consideration, and one that makes it necessary for the United States, as the keystone of the alliance, to be supported in its policies whenever possible. But at the same time there is considerable skepticism in Europe about some of those policies, and particularly about America's nuclear policies, including the SDI program, which is widely regarded as a threat to the 1972 ABM Treaty and as a spur to the nuclear arms race. The arguments about the deployment of cruise and Pershing II missiles on European territory caused considerable political trauma and their echoes have not yet died.[40] It would therefore be a major error of political judgment to treat lightly the fact that vast numbers of Europeans are fearful of any moves that might lead to a further buildup of nuclear armaments, or to assume that any deterioration in the relations between the US and the USSR as a result of SDI would not produce a new wave of antinuclear, and indeed of anti-American, protest in Europe.

The agonizing that is now going on about the US invitation to engage in SDI work is already a practical sign of the disquiet and suspicion which are entertained about the President's initiative. Some NATO governments have declined because they dislike the entire idea on political and strategic grounds. The British government agreed to participate

[39]*The New York Times* (October 23, 1985).

[40]For example, on December 3, 1985, the Netherlands government declared that having finally agreed to the stationing of the complement of cruise missiles assigned to it, as compensation it was going to abandon two other nuclear roles which had for long been its responsibility in the NATO strategic plan.

in the knowledge that if it refused to provide a formal blessing SDI scouts were already in the field seeking to entice European specialists with particular skills to work in the United States. Since the 1972 ABM Treaty bars the United States from sharing with others any technology that relates to strategic ballistic missile defense systems, cooperation will do little to help either the economies or the military defenses of European countries that formally bless collaboration on R&D, except insofar as such SDI R&D contracts as may be won in probably costly competition with American companies could provide employment for some European scientists and engineers in what may well turn out to be no more than a sharecropping exercise.

Europeans who concern themselves with these matters appreciate that even if the nuclear arsenals of both sides were cut by 50 percent—as has now been proposed by both the US and the USSR—more than enough destructive power would still remain, whatever way the cuts were made, to devastate not only the European mainland but also the United States and the western USSR. The concept of nuclear superiority has become meaningless. It belongs, in the language of Lord Carrington, NATO's present secretary general, to the unreal world of "nuclear accountancy."[41] And Europeans no more believe that their countries could be defended by a space-based BMD than they imagine that the USSR would ever risk a first strike either in Europe or against the US. Many suspect that the picture of a layered space-defense system was fabricated in order to confuse the innocent into supposing that a space-based BMD would operate in a measured sequence, a proportion of the offending missiles or warheads being destroyed as they traversed the layers in turn. The greater the number of layers postulated, the more missiles would be destroyed, until in theory—and on paper—almost all were eliminated. But, as I have said, it is the first layer defense that is both decisive and regarded as unfeasible by independent scientists. There are also many European officials who, being concerned with real military security, wonder what SDI has to do with Europe. They know that while it is just conceivable that the Russians might one day attack across the Iron Curtain, their purpose would be to occupy territory—not radioactive territory that had been devastated by nuclear weapons.

The President and Mr. Gorbachev now seem to be locked into their respective positions. Time and time again the Russians have declared that if the US continues in its search for a space-based defense system, it will embark upon its own countermeasures, including the further buildup of its offensive forces. This is surely not propaganda. In the Weinberger letter to the President that was leaked just before the Geneva summit, the defense secretary warned that "even a probable territorial defense [by the USSR] would require us to increase the number of our offensive forces and their ability to penetrate Soviet defenses to assure that our operational plans could be executed."[42] That is precisely what the Russians also say they will do if the US continues to seek, through SDI, to develop a "territorial defense." And, as Mr. Nixon warned in his recent article in *Foreign Affairs*, it would be easy for the Russians to triple in little time the number of warheads that are carried on their giant SS18s, a simple multiplication which in theory would by itself increase the threat that US missile silos face from an SS18 first strike from three thousand to nine thousand MIRVed warheads.

Richard Nixon and Henry Kissinger gave their support to SDI because they saw in it both a means whereby the Russians could be induced to return to Geneva, and a "bargaining chip" in arms control negotiations. But if one were to regard SDI as a bargaining chip, one would also have to accept that the US will gain only if it throws it away. If the SDI R&D program continues, the Russians will respond. Even were SDI to confound its critics and succeed in the sense that its separate components could be fitted together in a working system, the United States and the West as a whole would still lose, not only because the USSR would have devised measures for defeating a space-based BMD, but because there are ways other than land-based ICBMs, for example long range low-flying cruise missiles, whereby the US could be threatened with nuclear devastation.

President Reagan still speaks as though nothing has changed his original dream. But it has been changed. He himself changed it when he declared after the Geneva summit that what the United States was embarking upon was a *non-nuclear* space defensive system. That declaration, if acted upon, would be the death knell of the nuclear-pumped X-ray laser, the kernel of the scenario of a defensive astrodome first painted for him by Edward Teller.

Paul Robinson, the principal associate director for national security programs at Los Alamos, has been recently quoted as saying that the X-ray laser is in any event flawed because "it might inadvertently wreak havoc on other SDI components in space," while his colleague, Steven Rockwood, the Los Alamos director of SDI research, asks whether an orbiting device containing a powerful nuclear bomb could ever be politically acceptable.

But, one now has to ask, did an effective X-ray laser ever exist, or could it be made to exist? Whatever the President's motives in insisting in recent weeks that his SDI proposal implied a non-nuclear BMD, his protestations, no doubt inadvertently, coincided with a growing volume of informed comment, based on recently published statements by Livermore itself, to the effect that the claim that an effective nuclear-bomb X-ray laser has been devised was not only premature, but also based upon an unwarranted reading of measurements made in critical tests.[43]

What is more, some directors of SDI research at Livermore have publicly expressed concern because the success of the research for which they are responsible has been exaggerated by Pentagon officials. Dr. George Miller, head of defense programs at the Livermore laboratory, has been reported as saying that the public "is losing sight of how difficult the job is," while his colleague Dr. Cornelius F. Coll III, who is director of "Star Wars" systems studies at Livermore, declared that "overstatements by Pentagon officials were imperiling the pro-

[41] Alastair Buchan Memorial Lecture, given at the Institute for Strategic Studies, London, April 1983.

[42] *Boston Sunday Globe* (November 24, 1985).

[43] For the above statements by Robinson, Rockwood, and Livermore, see R. Jeffrey Smith, *Science*, Vol. 230 (November 8, 1985), pp. 646–648 and (November 29, 1985), p. 1023; *Los Angeles Times* (November 12, 1985).

gram.... This job is difficult enough without having to defend hyperbole and exaggeration." It is even reported that a recent demonstration which was laid on to impress a selected audience about the effectiveness of the electromagnetic rail-gun was a spoof. The demonstration pretended to show that a mock-up of a Soviet SS18 missile could be destroyed by the rail-gun. In fact, General Abrahamson is reported by *The New York Times* as having later revealed "that the damage had not actually been done by an electromagnetic rail-gun but by a hardened projectile fired from an air-gun"—a weapon whose antiquity goes back to the early eighteenth century!*

Surely the President must now appreciate, possibly even from what Gorbachev told him, what the arguments against SDI are. Surely he realizes that the nuclear arms race is different in kind from the competition which takes place in the field of conventional arms; that the idea that the US, the USSR, and Europe could ever by subjected to a nuclear conflict is total madness; and that such a conflict could solve nothing. In the forty years since Hiroshima and Nagasaki, increasing numbers of nuclear warheads and delivery systems, not to mention presumed defensive measures, have not provided greater security to any party—not to the United States, not to the USSR, and not to Europe. What they have done is reduce security for all.

We often hear the homely term "leaky" in the course of the SDI debate, as though if a perfect BMD defense proves impossible, a "leaky" one would still be worth having. It is yet another of those words which helps to lull the senses, so that we fail to realize the hideous reality—that the fraction of warheads that would "leak" through would today be enough to cause what once used to be euphemistically called "unacceptable damage." We continue to talk about numbers of warheads and megatons as though they were numbers of tanks and bomber aircraft. The brutal fact which our minds seem incapable of taking in is that were the explosion to occur over New York or Washington, London or Moscow, one megaton would be equivalent to a million instantaneous deaths (what matter if the figure were 100,000 or 200,000 more or less?).

The President may protest that his SDI dream implies a protection of people and not of silos. But however many times he does so, the fact is that were the "unthinkable" ever to occur, a future American president would probaby never know how his enemy had behaved. He could well have disappeared in the nuclear Armageddon. If the SDI program ends up only in protecting America's land-based missiles, no president could be sure that given a nuclear outbreak, the Russians would necessarily confine their fire to the American missile fields and not also aim at centers of population, any more than the Russians can be relied upon to believe that the United States would spare their cities. A "point defense" or SDI II, as some now call it, would, in short, take us back to square one—to the same argument that revealed the futility of missile defenses and which ended in the 1972 ABM Treaty.

Adhering to the strictest interpretation of that treaty has therefore become a vital consideration for all of us—not some so-called liberal intepretation of the way its terms were drafted, however legally argued, not some new version, as Gerard Smith has put it, but the treaty in the sense in which it was negotiated by the two sides. Were some demonstration test of a novel BMD component by either side to result in a unilateral breach, it would be but a short step to the abrogation of the few other treaties that have been so painfully negotiated in order to try to stem the spread of nuclear weapons.

A conflict in which nuclear weapons were used would not help solve any of the political disputes that now divide the two superpowers. It would certainly make it impossible for either to help solve the multitude of territorial and racial disputes and problems of social and economic development which now torment the nations of the world, and in the resolution of many of which both have a common interest. Both leaders should therefore remind themselves of the critical difference between the BMD of the Sixties and what is being discussed now. Twenty years ago, active defenses against missile attack were being devised by both sides in response to a formulated operational requirement which it was incorrectly assumed could be technically satisfied. Today SDI is a concept that is "technology led" by the belief that new technological wonders can be fitted together in order to create an effective operational defense system. No one, not even the President, believes that this could ever happen before the turn of the century, if indeed it ever proves possible. He also knows that in the interval there could be military conflict.

The two leaders should therefore keep on reminding each other that were the prevailing state of nuclear deterrence to break down, the result could be a catastrophe unparalleled in the history of warfare, and one which would make even the worst natural disaster of which history tells us seem like a gust of wind. Let us therefore hope that when President Reagan and Mr. Gorbachev next meet, even if they do not discuss technicalities, their visions of the dangers which they face in the years ahead will move them closer than they appear to have been in Geneva. □

*For the statements by Miller, Coll, and Abrahamson, see William J. Broad, *The New York Times* (December 16, 1985).

LIPSTICK, 1935

At Aunt Pearl's kiss the pointed head
Extruded glistening pale red
From the jet sheath where it was housed
Looked like our Labrador, aroused.

—James Merrill