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LETTERS

SDI:LEVERAGE AND COUNTERMEASURES

I am writing concerning the article on SDI by Peter Zimmerman in the January issue of P & S. It was a thought-provoking article, as many are in your publication. However, it serves as an example of how a few seemingly innocuous assumptions can mislead the reader. This is not to say that there are significant errors in the article; nevertheless, an initial casual reading left me with some impressions that are not warranted by the arguments presented.

The catastrophic failure of the defense, described by the author, is an artifact caused by the absence of any excess capacity in the first defensive layer. Although layers two through four have generous fractional excess capacities, the absolute amounts are small. For example, the terminal stage has a fourfold excess capacity, but this represents the ability to destroy only 40 warheads. A 10% increase in the capacity of all stages produces essentially the same result as the large increases assumed by the author. In other words, the apparently generous margins in stages two through four are equivalent to a slim one in the all stages.

Perhaps a more realistic model would take this into account and provide adequate margins for the whole system. The objection may be raised that this would require the deployment of an absurdly large number of defensive systems. Although this may be true at current levels of offensive deployments, the defensive system could be a reasonable alternative if offensive forces were reduced. In any case, a defense only makes sense if it is able to succeed in the presence of more than the expected number of warheads. I'm certain that Peter Zimmerman and I could agree on this.

Gabriel G. Lombardi, 615 Garnet Street, Redondo Beach, CA 90277.

Response:

Gabriel Lombardi suggests that the catastrophic failure of the prototypical ABM system I used in my article is an artifact caused by an absence of excess capacity in the first layer. He is wrong: by definition there can be no excess capacity against a countermeasure which takes the defense by surprise. In that case even a system with a significant excess capacity against the expected threat must fail.

Even without surprise countermeasures to contend with, it is unlikely that the first layer of a multi-layered defense can have significant excess capacity, since the offense can surely build up to and beyond the capacity of the boost phase system. The absolute excess capacity of the terminal defense layer is actually quite high in my system: it must be capable of taking those 40 warheads anywhere and everywhere — including all on the same target. In order to be able to handle 40 warheads anywhere, it must be capable of handling 40 warheads at each of dozens (or perhaps hundreds) of defense sites.

Actually, however, it doesn't matter much what numbers are put in for excess capacities, including at the front end. Catastrophic failure of the system can merely be postponed but not prevented. In a system where the offense is constrained by arms control agreements the situation may be quite different. I believe, however, that no such limitations will ever be achieved in an environment where the defense is allowed to run free.

Mr. Lombardi and I can probably agree that a defense is worthwhile only if it meets all of the Nitze Criteria: effectiveness, survivability and cost-effectiveness at the margin. Unfortunately, the systems currently being proposed by the SDIO fail all three tests, in part because an unconstrained offense can always make a margin call.

Peter D. Zimmerman, Senior Associate, Carnegie Endowment for International Peace, 11 Dupont Circle, N.W., Washington, D.C. 20036.

ARTICLES

REDUCING THE HAZARDS OF NUCLEAR POWER: INSANITY IN ACTION

Bernard L. Cohen, University of Pittsburgh

How much money are we willing to spend to save a life? Some might say "Sky's the limit," but we don't act that way. We don't spend unlimited amounts on fire protection, highway and motor vehicle safety, health care, etc., although it is a simple calculation to convert such expenditure into a cost per life saved. In this paper we consider the question of how much our society is willing to spend to save a life in various contexts.

There are numerous opportunities for highly cost-effective life saving in under-developed countries. The World Health Organization (WHO) estimates[1] that over 5 million childhood deaths could be averted each year at a cost ranging from $50 per life saved from measles in Gambia and Cameroon to $210 per life saved by a combination of immunizations in Indonesia. These costs are for complete programs including providing qualified doctors and nurses, medical supplies, transportation, communication, etc. WHO also estimates[1] that about 3 million childhood deaths each year could be averted by oral rehydration therapy (ORT) for diarrhea. This consists of feeding a definite mixture of NaCl, KCl, $NaHCO_3$ and glucose with water on a definite schedule. The cost per life saved by complete programs range from $150 in Honduras to $500 in Egypt.

Other low cost approaches to life saving in the "Third World" include malaria control ($550/life saved), improved health care ($1930), improved water sanitation ($4030) and nutrition supplements to basic diets ($5300).

But charity begins at home. We next consider two fertile areas for relatively cost-effective life saving in the U.S.. Table 1 lists the cost per life saved by cancer screening programs,[2] including many situations where it is under $100,000. For example, only about 50% of sexually active American women get PAP tests for cervical cancer. In a few localities, there have been active programs, utilizing mail, telephone, and personal visits that have increased this fraction to over 90%. The cost of these programs[2] is about $50,000 per life saved.

Table 1. Cost per life saved for cancer screening and medical care programs in the United States. Costs are from Ref.2, but since they are given there in 1975 dollars, they have been doubled.

Item	$/life saved
Cervical cancer screening	$ 50,000
Breast cancer screening	160,000
Lung cancer screening	140,000
Colo-rectal cancer	
Fecal blood tests	20,000
Proctoscopic exams	60,000
Multiple screening	52,000
Hypertension control	150,000
Kidney dialysis	400,000
Mobile intensive care units in smaller towns	120,000

As another example,[2] a textile mill in North Carolina started a program of multiple cancer screening tests for their employees. After several years, they added up the cost of the program and the number of lives saved by early detection; dividing these gave $26,000 per life saved, or correcting for inflation, the $52,000 per life saved in Table 1.

Another fertile area is highway safety. Table 2 lists some measures covered in the 1984 Annual Report of the U.S. Department of Transportation, including the number of lives saved per year and the cost per life saved. Since these measures typically have a service life of about 10 years, these measures taken in a single year will eventually save several thousand lives at a cost in the neighborhood of $150,000 per life saved.

With this background, let us consider the price we are paying to save lives from radiation in the nuclear industry. Department of Energy documents give the cost per life saved in their radioactive waste management activities as $300 million in the Savannah River Plant[2] and $270 million at West Valley, New York.[3] But more important is our commercial high level waste management program which is supported by a 0.1 cent/kw-hr tax on nuclear electricity, or $8.8 million/GWe-yr (GWe=gigiwatt-electric). It is estimated that random burial with simple precautions would eventually cause 0.02 deaths/GWe-yr.[4] If half of the cost of the present program is to avert these deaths, the cost per life saved is ($4.4X10^6/.05=)$220 million, similar to the Savannah River and West Valley expenditures.

Table 2. Evaluation of recent projects undertaken to improve highway safety. From U.S. Department of Transportation, "The 1984 Annual Report on Highway Safety Improvement Programs," April 1984. It gives cost/fatal accident; we assume 1.1 deaths per fatal accident.

Improvements	Lives saved per year	$ per life saved
Improved traffic signs	79	$ 31,000
Improved lighting	13	80,000
Upgrade guard rails	119	101,000
Breakaway sign supports	2	125,000
Obstacle removal	8	160,000
Median barrier	28	163,000
Impact attenuators	6	167,000
Median strip	11	181,000
Bridge-guard rail transition	3	260,000
Channels; turn lanes	75	290,000
New flashing lights at railroad	11	295,000
Permanent grooving	6	320,000

There are some strange aspects to these large waste management expenditures. In the first place, the lives saved are those of people living many thousands of years in the future, who bear no closer relationship to us than those now living in under-developed countries whose lives we disdain to save at one-millionth of these costs. In the second place, there is an excellent chance that a cure for cancer will be found in the next few thousand years, in which case these deaths will never materialize and the money will be wasted. In the third place, if only a tiny fraction of this money were invested even at minimal interest, it could provide enormous benefits to these future potential victims, including the saving of tremendous numbers of lives. Equivalents of such an investment are spending the money on biomedical research, or simply using it to reduce the national debt and thereby making more money available to later generations to spend on themselves.

With any reasonable consideration of these matters, we are spending the equivalent of innumerable billions of dollars per life saved in our radioactive waste management programs.

As another example from the nuclear industry, consider reactor safety. Since the mid-1970s, the Nuclear Regulatory Commission (NRC) has been tightening regulations to reduce the risks of reactor accidents. This program of "regulatory ratcheting" has increased the cost of a nuclear power plant by a factor of 4-5 over and above inflation, an increased cost per plant of well over $2 billion. How many lives does NRC hope to save at this cost? According to its own studies,[5] plants built prior to this regulatory ratcheting could be expected to cause an average of 0.8 deaths over their operating life. Thus, according to their own calculations, NRC is knowingly spending ($2 billion/0.8=)$2.5 billion per life saved.

An ironic aspect of these NRC reactor safety upgrading activities is that the cost increases they have caused have forced utilities to build coal burning power plants instead of nuclear plants. A typical estimate[6] is that the air pollution from 1 GWe of coal burning plants kills 25 people per year, or about 1000 people over its operating lifetime. Considering the fact that the nuclear plant is expected to kill 0.8 according to NRC[5] (or 100 according to the anti-nuclear activist organization, Union of Concerned Scientists[7]), that means that every time a coal burning plant is built instead of a nuclear plant, something like 1000 extra Americans are condemned to an early death.

As a result of this NRC program of regulatory ratcheting, about 100 GWe of coal burning plants will eventually be built instead of nuclear plants, causing about 100,000 needless deaths. The 60+ nuclear plants that will eventually be completed have cost an average of at least $1.6 billion extra, for a total cost of $100 billion in an effort to save these (60X0.8≅) 50 lives. If this money were spent, instead, on cancer sereening and highway safety measures, it could have saved something approaching a million lives.

There are additional indirect consequences of this NRC regulatory ratcheting. Essentially the same nuclear power plant costs about 2 1/2 times as much in the United States as in France and since projected costs for coal-burning electricity and nuclear electricity in the United States are about equal, this means that electricity will probably be twice as expensive in the United States as in Western Europe and Japan. This puts a direct bite on our standard of living. But more important, many economists believe that a large part of the reason for past U.S. economic success has been our relatively low cost of energy, so it is not unlikely that the reversal of that advantage will contribute substantially to our unemployment problems. It is estimated[8] that a 1% increase in unemployment in the United States causes an extra 37,000 deaths per year, including about 20,000 from cardiovascular failures, 900 suicides, 650 homicides, and 500 deaths from alcohol-related cirhossis of the liver. In addition to the deaths, it causes 4200 admissions to mental hospitals, and 3300 admissions to state prisons.

Returning to our principal theme, we see that our society is spending $\$2X10^9$/life saved from nuclear hazards while it could save a life for each $\$2X10^5$ spent on cancer screening or highway safety. This policy is clearly causing the needless loss of thousands of lives and the waste of billions of dollars every year. Why is this insanity taking place? It's easy to find out. Just ask the government officials who make these decisions. They tell you that the primary responsibility of a government official is to be responsive to public concern. In a democracy, that is the way it should be - we want our government to be responsive to our concerns. The problem is that public concern is driven by media coverage rather than by rational scientific analysis. The media have driven the public insane over the fear of radiation and of nuclear power accidents.

Why do the media do this? They are basically in the entertainment business. One point in the Nielsen rating for network evening news brings $11 million per year in increased advertising revenue. They must therefore do everything possible to attract an audience, and discussing hazards is much more useful for that purpose than discussing good, smooth, routine operation.

The entire problem can be viewed as one of natural selection, survival of those who adapt best to their environment. A TV producer who valued presenting problems in the proper perspective over emphasizing dangers to attract an audience would not survive, and a government official who valued doing what is right over being responsive to public conem would not survive. Laws of natural selection are hard to beat. But when the results lead to the needless deaths of many thousands of Americans every year, and to the impoverishment of our nation, we must do everything we can to try to beat them.

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THE NRDC/SOVIET ACADEMY OF SCIENCES JOINT NUCLEAR TEST BAN VERIFICATION PROJECT

Thomas B. Cochran, Natural Resources Defense Council, Inc.

[Thomas B. Cochran received the Forum's 1987 Leo Szilard Award for his role in the project described here. This article is the author's talk given at the Forum's Awards Session, 20 April 1987, at the Crystal City, VA, APS meeting. For more about the history and personnel of the project, and for the official text of the agreement, see *Physics and Society*, September 1987, pp.6-7.]

I am deeply honored to have been chosen to be the recipient of the 1987 Leo Szilard Award for my negotiation and implementation of a May 1986 Agreement with the Soviet Academy of Sciences for demonstration of in-country seismic verification of a nuclear test ban. I am, of course, very pleased to be now added to the list of great individual physicists who have received this award, but the credit for the NRDC/Soviet Academy project must be shared among the number of individuals who have played an important role in this historic initiative - the largest privately funded scientific exchange ever between the U.S. and the U.S.S.R..

On the Soviet side, Academician Evgeny P. Velikhov, Vice President of the Soviet Academy of Sciences and Academician M.A. Sadovsky, Director of the Institute of Physics of the Earth (IPE) agreed to the project in Moscow last May when I first formally presented the concept at an Academy-sponsored Workshop on Verification of a Comprehensive Test Ban. At what must have been considerable political risk, they showed great political courage in seeking and obtaining Soviet government approval for this unprecedented project. Professor Mikhail Gokhberg, Deputy Director of IPE, is responsible for the overall management of the Soviet component of the project and Dr. Igor Nersesov, Chief of Seismology at IPE, oversees the Soviet field team.

On the American side, Dr. Charles Archambeau of the University of Colorado has overall technical responsibility for seismic research and is Chairman of the NRDC Seismic Monitoring Advisory Committee. Dr. Jonathan Berger of Scripps Institution of Oceanography, University of California, San Diego and Professor Jim Brune of Scripps and who is also Director of the Seismological Laboratory at the University of Nevada, Reno are co-investigators responsible for the American field teams and the installation and operation of the seismic equipment.

The project represents the largest single program NRDC has ever undertaken in its 17-year history. Adrian DeWind, chairman of NRDC, participated in the Moscow Workshop, signed the agreement with the Soviet Academy on behalf of NRDC, and has played an active role in its implementation. John Adams, Executive Director of NRDC, has made a major contribution, including his tireless efforts to raise the funds for NRDC's participation in this exchange. My colleague S. Jacob Scherr, NRDC Staff Attorney, has worked closely with me on a day-to-day basis in the management of the project.

There are numerous other Americans and Soviets on what we think of as our Test Ban Verification Team, making this project a success. And finally, this effort would never have gotten off the ground without the very generous support from American foundations, individual funders, and the public.

The United States has sought a Comprehensive Test Ban Treaty (CTBT) since the mid-1950s - through every Administration from Eisenhower to Carter. From a U.S. perspective, at least up until the Reagan Administration, achieving adequate verification was the principal obstacle. Ultimately, negotiations toward a CTBT were broken off by the Carter Administration following the Soviet invasion of Afghanistan. Negotiations were not resumed during the Reagan Administration. Reagan is the only President to actively oppose a CTB.

General Secretary Gorbachev made clear his interest in a test ban when he unilaterally suspended Soviet testing in July 1985. He also announced that verification would not be an obstacle to a test ban. It is in this setting on May 22 of last year that NRDC proposed to the Soviet Academy of Sciences to establish and jointly staff seismic monitoring stations adjacent to each of the principal nuclear weapons testing sites in the two countries: in eastern Kazakhstan in the Soviet Union and the Nevada Test Site in the United States. As you know, seismology provides the main tools for detecting and discriminating underground nuclear tests and for accurate estimates of their yields. The objectives of the project as originally envisioned are:

- to demonstrate that in-country nuclear weapons test verification is not an obstacle to a comprehensive test ban (CTB) or a moratorium on testing;
- to demonstrate that scientists of the United States and the Soviet Union are prepared to cooperate to work toward a common goal of a CTB; and
- to obtain baseline seismic data that would be useful in designing and operating a seismic verification network.

We agreed that we need not wait until a treaty was negotiated but could place equipment in the field to demonstrate verification procedures and find out what problems might arise. By May 28, Velikhov had obtained Soviet government approval for the basic idea and the historic agreement was signed by Evgeny P. Velikhov on behalf of the Academy and by Adrian DeWind on behalf of NRDC.

In the past ten months, NRDC and the Academy have made substantial progress in implementing the NRDC/Academy agreement.

Under the Agreement, we had a single month in which to launch the project. In just three weeks, NRDC raised about $1 million. Dr. Archambeau persuaded Drs. Berger and Brune at Scripps to agree on extremely short notice to equip and send a team seismologists to the Soviet Union. In a little more than a week, e were able to obtain the necessary export license.

The U.S. team of seismologists arrived in Moscow on July 4. Vith IPE, we established the first station at Karkaralinsk on July 9 f last year. By the end of August the U.S. and Soviet teams had stablished three stations around the Kazakh test site about 200 kilometers distant. The stations were located at Karkaralinsk, Bayanaul and Karasu in the Kazakh Republic.

It was decided to equip the stations in two phases. The stations were initially equipped (Phase I) with short period (Teledyne Geotech S-13) and intermediate period (Kinemetrics S-1) surface seismometers and battery operated portable digital recorders. Most of this equipment was loaned by Scripps. Over the last ten months rotating teams of two seismologists from Scripps and the University of Nevada have joined with their IPE counterparts in operating this Phase I equipment.

In late July, Scripps also began the procurement of over $600,000 worth of state-of-the-art seismic and computer data recording equipment for Phase II. This included high frequency down-hole seismometers which had to be custom manufactured by Teledyne Geotech.

Construction of facilities to house the Phase II equipment were completed by the Soviets by early November 1986. The sites at Karkaralinsk, Bayanaul and Karasu, are all located in granite massifs that rise several hundred meters above the surrounding Kazakh steppe. In order to reduce the surface noise, boreholes with 20 cm diameters, which would eventually house the high frequency seismometers, were drilled to depths of 70 to 100 meters, cased, and sealed. Wellhead vaults were set in the surrounding rock, just below the earth's surface. The interiors of these vaults measure approximately 3X4 meters with a 1X2 meter pier situated next to the borehole. At each site a large trailer was situated approximately 300 meters from the vault to house recording instruments. One or two additional trailers at each site provide accommodations for Soviet and American personnel. High-voltage power lines were installed
at each site along with backup diesel generators.

During the past two months the two teams have been installing and calibrating the instruments at the three Kazakh stations. At each station there are three component high-frequency accelerometers (Teledyne Geotech 54100) in the borehole, augmented by six surface seismometers on the pier, three component short period instruments (Teledyne GS-13) and three component intermediate period instruments (Kinemetrics S-1). There are also plans to install three broadband seismometers (Streckeison STS-VBB). When fully equipped these stations will each cover a frequency band from 100 Hertz down to a period of about 3000 seconds. The seismic signals are to be recorded locally on magnetic tape. The data recording system (designed and assembled by Scripps) at each station in cludes signal digitizers and a PDP 11/73 computer.

Ths Soviet Union ended its nineteen-month unilaterial testing moratorium on February 26, 1987. At the insistence of the Soviet Government, the Kazakh stations are required to be turned off for a short period surrounding each of their tests. A military official flies into each station a few days prior to a test, and a protocol is followed to shut down and seal the instruments. The day after the test an official returns and the stations can be turned on. During the first few tests thus far, this procedure has not worked well due to the difficulty of transporting our team to each of the stations to turn them back on. Since February 26, the stations have been down about 50 percent of the time. Provided we can reduce the delay in restarting our stations, the scientific objectives of the project should not be compromised by the inability to record Soviet tests. The primary purpose of the project is to demonstrate technology to verify the absence of clandestine, or unannounced, tests. In the past Soviet tests were not announced, either before or after the shot. NRDC is now in the unprecedented position of receiving formal advanced notice of Soviet tests.

While operating, the Kazakh stations will continue to collect seismic data from U.S. nuclear tests in Nevada,teleseismic and regional earthquakes, and industrial explosions in the region, as well as background noise. Our best scientific results, associated with verification of test limitations or bans, will come from the anlayses of these data.

The ambient ground noise level is being recorded and its frequency dependence measured. The noise levels obviously control the magnitude of events that can be detected and the accuracy with which signals can be characterized by any given station configuration.

Analysis of regional earthquakes and explosions (out to 2000 km) can be used to study the source properties and transmission efficiencies of various seismic wave types, which are usually termed seismic "phases," in the Kazakh area and thereby reduce uncertainties in the quantitative description of seismic wave propagation characteristics. Numerous studies of this kind have been conducted in Nevada, but this provides the first opportunity for U.S. seismologists to study the Kazakh test site area. These studies will be particularly useful in reducing the uncertainties of important parameters of models used to estimate the capability of in-country seismic stations to verify a low threshold test ban treaty.

Evernden, Archambeau and Cranswic (*Review of Geophysics* 24, May 1986, pp. 143-215), for example, argue that 40 high-frequency stations, including 25 in-country stations in the Soviet Union of the type being operated under the NRDC/Soviet Academy project, would be sufficient to verify a 1 kiloton threshold test ban. A similar number would be required to monitor the U.S. They assume the possibility of evasion by fully decoupling the underground explosion, that is, they assume attempts might be made to muffle the seismic signal from the explosion by exploding the nuclear device in a large underground cavity. Their model assumes sufficiently quiet sites can be found in the Soviet Union and efficient transmission of high-frequency (30 to 40 Hz) seismic compression and shear waves at regional distances in stable continental shield areas. Preliminary analysis of the data from our Kazakh stations is consistent with these assumptions.

The velocity and attenuation of compression and shear waves depend on the temperature and composition of the medium. It is now well known that the upper mantle attentuation below the Kazakh test site is low compared to the attentuation below the Nevada test site. Thus, for the same yield, the amplitude of the compression body wave (the so-called P-wave) recorded at a distant station from a nuclear test in Nevada is smaller than for a test in Kazakh. Consequently, if no correction is made for these differences, the explosion in Kazakh will appear larger than the equivalent explosion in Nevada.

Failure to properly correct for the m_b bias for P-waves leaving the Nevada and Kazakh test sites, in years past, has led to over-estimates of Soviet test yields and has resulted in U.S. Government claims that the Soviets have violated the 150 kiloton limit under the Threshold Test Ban Treaty. As reviewed by Sykes ("Underground Nuclear Explosions: Verifying Limits on Underground Testing, Yield Estimates and Public Policy," in Press, U.S. Report to IUGG, 1987), more exhaustive analyses in recent years indicate that the m_b bias is higher than that previously assumed by the U.S. Government, and the evidence for Soviet non-compliance with the 150 kt limit has evaporated.

Some of the best data for reducing the uncertainty in the m_b bias, and thus for determining the m_b versus yield relationship for the Kazakh test site, will come from seismic measurements of Nevada nuclear tests by our stations near the Kazakh test site. This is accomplished by comparing the m_b as measured near the Kazakh test site with the values from well calibrated recording stations elsewhere in the world. Specifically, the attenuation of a body wave (i.e., the direct compressional P-wave) traveling from Nevada to Kazakh is the same as that for a signal traveling in the reverse direction. Since the yield of U.S. tests are known to the U.S. Government, the P-wave amplitudes for Nevada tests recorded at our Kazakh stations gives a direct measure of the attenuation and this in turn can be used to normalize Soviet tests recorded at stations in Nevada.

The bias can also be measured, albeit not as accurately, by comparing the P-wave amplitude of teleseismic earthquakes simultaneously recorded at our Kazakh stations and at our Nevada stations. The Soviets can of course use these same proceudres to improve their estimates of the yields of U.S. tests. Hopefully, we can put to rest the issue of whether the Soviets have violated the 150 kiloton limit. Preliminary analysis of our data, incidently, is consistent with Soviet compliance.

We have been delayed in establishing the Nevada station and our Soviet colleagues have been unable to staff them due to successful efforts by the Reagan Administration to obstruct our joint research program. In September 1986 we invited five Soviet seismologists to come to the United States to assist in selecting locations for the three seismic monitoring stations around the Nevada Test Site (NTS). The Reagan Administration first delayed action of the visa request until after their scheduled departure and then placed restrictions on their visas. The Soviets were told that they would not be permitted to visit the proposed sites without first going to the Nevada Test Site and witnessing a nuclear explosion and a demonstration of CORRTEX. CORRTEX, the acronym for "continuous reflectometry for radius versus time," is a device for indirectly measuring the yield of an explosion by measuring the speed of the shock wave in a narrow radial distance range at the edge of the hydrodynamic zone. For tamped explosions in the 75 to 150 kiloton range, this range is a few tens of meters away from the explosion source. President Reagan had previously invited the Soviet Government to send their experts to Nevada for such a demonstration in response to General Secretary Gorbachev's Administration's strategy has been to deflect Congressional interest in a nuclear test ban or moratorium by insisting that the Soviets have probably violated the Threshold Test Ban Treaty and that better verification methods are required before the Treaty is ratified. The extension of the Soviet test moratorium last April. The Reagan Reagan Administration wants the Soviets to agree that each side be permitted to measure, using the CORRTEX technique, the yield of all nuclear tests above 75 kilotons conducted by the other side. (CORRTEX does not work well at lower yields because the distance range for the measurement of the shock speed is too close to the source.)

The Soviet position is that while the CORRTEX method is useful for measuring the yield of one's own tests, it is not a practical method of monitoring the yields of tests by a second party, since confidence in yield estimates would be low because of uncertainties in the reliability of information required to properly emplace the CORRTEX system and interpret the recorded data. For example, the uncertainty in the yield estimate could be a factor of two or more at the 95 percent confidence level if the emplacement geometry, and the local rock properties, were not well known. Thus, CORRTEX is unworkable under a scenario which assumes cheating. The Soviets, moreover, do not wish to establish the precedent of renegotiating a treaty which both countries have signed, as a precondition to ratification. The Soviets, rightfully I believe, also see CORRTEX as yet another attempt by Administration officials, who are actually opposed to arms control, to foster the impression of movement in discussions with the Soviet Union.

Presumably for all of these reasons, the Soviets have refused to permit the seismologists associated with the NRDC/Academy project to participate in a CORRTEX demonstration at the Nevada Test Site. Without visiting the test site the Soviet seismologists were permitted to stay in the U.S. only seven days. We were permitted to take them to LaJolla, California , where the two teams, relying on slides, rock samples and geologic maps, selected the three station sites around the Nevada Test Site.

In February, a team from the Seismological Laboratory at the University of Nevada, Reno, established temporary surface seismometers at these three locations and began recording data. We invited three Soviet seismologists to the U.S. to work for two months with our seismologists at Scripps and the University of Nevada and to assist in the construction and installation of the Phase II stations. Again, the Reagan Administration placed the same restrictions on their visas. Their stay in the U.S. would be limited to seven days and they could not go to our stations in Nevada or California unless they first went to NTS and witnessed a test and CORRTEX demonstration.

In an effort to break the visa impasse, Academician Velikhov convened a workshop on Nuclear Test Yield Estimation in Moscow on February 12, 1987. This workshop was attended by over two dozen scientists from eight countries. Two methods of yield estimation were considered: the CORRTEX method and several new seismic techniques. Soviet experts from the Academy presented technical papers on CORRTEX. Velikhov invited U.S. Government experts on CORRTEX from Los Alamos National Laboratory and experts on seismic techniques from Lawrence Livermore National Laboratory. They did not attend. Following the workshop Velikhov telexed the U.S. weapons laboratories offering to continue the discussions to identify the best method that can be employed for yield estimation. He asked whether the Los Alamos and Livermore experts could participate in such a workshop and, if so, what would be a convenient time and place for a meeting.

Upon returning from Moscow, we brought these new developments to the attention of the State Department pointing out that the Academy has agreed to have its CORRTEX experts participate in technical discussions at a time and place of U.S. choosing, and that no useful purpose can be served by forcing the young seismologists associated with the NRDC/Academy project to go to the Nevada Test Site to witness an explosion and a demonstration of CORRTEX about which they have no expertise. Moreover, assuming the Administration was interested in resolving technical issues surrounding CORRTEX, an opportunity existed to host the Soviet Academy's experts.

Despite these efforts by the Soviet Academy, the Reagan Administration continues to refuse to lift the visa restrictions of our Soviet colleagues. To continue to prohibit the Soviet seismologists from visiting our joint seismic monitoring stations without first witnessing a CORRTEX demonstration about which they have no expertise makes it clear the Administration is only using them for its own propaganda purposes.

We have all been taught the virtues of living in a free society. It is appalling to find that our American scientists have more freedom to travel and conduct scientific research in the Soviet Union, than our Soviet colleagues have in the United States. American physicists are not free to engage in privately funded, unclassified research where it is seen by the Executive Branch as threatening to its own policy preferences.

The Reagan Administration seems to be afraid of scientific truth. The Administration stands in fear of a research program designed to demonstrate verification of a comprehensive test ban; a program which in fact improves its own capabilities to verify the existing Threshold Test Ban Treaty.

SDI PROGRESS

Gerold Yonas, President Titan Technologies, San Diego, California

[The author was formerly Chief Scientist of the SDI Organization. This paper was originally presented at the Arms Control and Verification Technology Symposium in Albuquerque, New Mexico, on 14 April 1987.]

In spite of the rhetoric, the SDI is a research and technology program to provide the basis for a future deployment decision, although it is not a deployment program. A decision-driven program is very different from a deployment program where well-defined goals, schedules and budgets can be turned over to a program manager. To such a program manager, innovation will be the enemy, in SDI it is still an ally. Within the SDI there still is flexibility, as well there should be. In the decision process one has to not only deal with defined technical requirements, but we must also understand the possibility that as time proceeds, the Soviets can anticipate our future capabilities and we must cope with a changing set of requirements. For this reason, managing a decision-driven program places severe demands on planning and communicating the nature of the program to the public.

One of the most frequently posed questions to the SDI is to its state of progress. The most extensive advances have been in rocket-launched, maneuvering exoatmospheric interceptors with precision homing that can destroy targets by direct collision. The progress is a result of miniaturized sensors, computers, and propulsion. There has been a series of very impressive intercept experiments beginning with the HOE program in 1984 that demonstrated interception and destruction of an RV in outer space, the development and successful testing in 1985 of a much smaller antisatellite weapon launched from an aircraft, and then most recently in September 1986 the Delta 180 experiment in which two space test platforms tracked and observed each other giving an extensive amount of tracking and homing information. The Delta 180 experiment emphasized the appearance or optical signature of rocket powered flight as needed to define the sensor requirements for boost-or post-boost-phase intercept.

Substantial progress has also been made with endoatmospheric interceptors. Recent demonstrations of small, agile, homing missiles offer the possibility of developing an ability to intercept and destroy, by direct collision, high velocity attacking mi ssiles within the atmosphere.

The second vital area of progress is in our ability to track and discriminate re-entry vehicles above the earth's atmosphere far from their intended targets. The most likely near-term approach to accomplish this intercept is with sensors and missiles launched from the ground, and carrying out their surveillance, tracking, and intercepts in the late mid-course part of the flight. In order to succeed with this kind of intercept in the face of a responsive threat where we must expect chaff, decoys, and anti-simulation, we have to find a solution to the problem of discriminating the heavy objects. Here there has been progress using passive, active, and interactive techniques to acquire, track, and interrogate this complex threat cloud and provide defined tracks for interception of the real RV's. Many years of prior investment in long wave infra-red sensors and recent advances in laser radars are beginning to pay dividends.

The third area is the survivability of our predeployed assets in and surveillance capabilities that must survive a determined attack. We have greatly improved our understanding of the components and tactics of a survivable system, although we realize that in an attack we would certainly lose many important assets. The issue here is to define a system concept that continues to function and never presents an attractive target to an attacker. In this area we are faced with the task of defining the threat and predicting its evolution, and our activities have been greatly accelerated. Studies thus far show that with substantial investments in maneuver, hardening, deception, and self-defense, that our pre-deployed space assets can survive or extract an unacceptable price from the offense. Clearly survivability and cost-effectiveness will be at odds with one another however. Great advances in lowering the cost of space transportation are necessary to solving this question favorably for the defense.

The fourth subject is one of great controversy, namely software. Very large software programs are being designed and written both within and outside the SDI program. Techniques for creating, maintaining, and upgrading these large flexible software systems are being developed and progress is being made, although, admittedly, not necessarily just because of the SDI, but because of the increasing demands of software in many conventional military and civilian applications. Fully realizing the vital nature of the software requirements, the program has rapidly accelerated the emphasis and investment in this element. It is now generally believed that the definition of the battle management should precede the definition of the other system features, rather than the other way around.

Fifth, I think progress is being made in lethality: understanding the requirements to actually destroy a missile in its boosted flight, a post-boost vehicle, or a re-entry vehicle. Here progress is being made in realistic, large-scale computer simulation and laboratory tests to validate those calculations. Because we cannot test every hypothetical Soviet threat, we must understand the phenomena inherent in lethality and realistically test postulated lethality levels using simulations that have been bench-marked against selected test environments.

A major obstacle faced by the program is evaluation of the threat posed by the Soviets. The aspect of the responsive threat that is so difficult to understand and to predict is that of countermeasures. The problem is to evaluate, to anticipate, and to understand realistic countermeasures in order to be able to provide technologies that can respond flexibly and ahead of Soviet moves. Examples of postulated countermeasures are space mines, ground-based lasers, fast-burn boosters and the techniques of antisimulation. All of these possibly realistic and potential countermeasures have to be fully understood and evaluated by the U.S. in order to understand what is not just possible but what we might expect and when. We must learn how to "think red". That may be one of our biggest challenges. We don't fully understand the Soviet's technological capabilities and planning strategies, but we have no choice if we are to make an informed decision about deployment. None of these countermeasures are cheap and easy; they would take time, cost money, and create uncertainty for the attacker, but we must quantify that statement.

There are other kinds of tactics that the Soviets may employ and these are on the diplomatic front. Are the Soviets really prepared to go forward with substantial strategic arms reduction space. For all of these defensive concepts, we require early-warning agreements? Are the Soviets willing to substantially reduce offensive ballistic missiles under any circumstances that permit needed verification? Can we or should we plan on any kinds of agreements in proceeding with the technology program, and can we proceed without at least considering the impacts of agreements on investment strategies?

Another problem is lack of an institutional framework within this country for defense. This country has built its strategic capability on offense, on retaliation. We don't have the institutions, the experience, the large-scale facilities to really act on, let alone prepare for defense, and it takes time to gain those capabilities. The Soviets, on the other hand, have an operational system at a single site. They are training people, they are making mistakes, learning, and modifying their system. When we start to consider all of the practical system issues, the so-called "ilities", realiability, productability, maintainability, etc., we realize it takes years to resolve such issues, even after you know exactly what you want to do. Just being in the business of defense, in the evolutionary way of the Soviets, gives them a lead, but not because we couldn't cover that same territory if we tried. By not being in the business of defense we are faced with an inevitable delay.

The last issue is "spinoff" raised by proponents, and "opportunity cost" raised by the opponents. The spinoff issue is a red herring if one uses civilian spinoff to justify any military program. Spinoff to the commercial sector is extremely difficult because of many economic factors involving capital and investment risk. On other other hand, it is only good management, having invested in one technology, to see how you can benefit from that investment in other related areas. In that sense, the most apparent application of SDI technologies appears to be to the problems of identifying, locating, and tracking targets on the conventional battlefield, communicating that information to the decision maker, and then providing smart precision-guided weapons. The combination of sensors, battle management, automated decision-making, and smart weapons will change our notion of the conventional battlefield, and SDI technology is at the heart of the matter. Rapid advances in aircraft, ground-based, and space-based sensors, and in real time data processing, represent technology that was progressive anyway, but SDI has accelerated and focused these technologies allowing increased emphasis that should provide rapid benefits.

As for "opportunity cost", I find it hard to believe that the technical community is over-committed and can't provide the personnel or material resources to carry out this program. This program is now funded at less than 2% of the defense budget. Many relevant corporations have much larger programs that completely dominate their defense investment strategies independent of the SDI. Admitedly there are a few areas where there have been requirements for additional people, such as in software, but those requirements are there anyway and having a source of funding and a program where "the action is" usually attracts capable individuals trained in other fields who see the excitement and the support and move over to new areas. When the challenges aren't there for our technical community, when they don't have the focus, or worse when they are unemployed, our technology languishes. Clearly, we are far from the limits of our resources needed to pursue these programs. There are also many of our allies who would love to work on these programs and are now being given a chance. They too have much to offer and much to benefit in terms of their own defense. I see more of an opportunity in the SDI than an opportunity cost.

Some questions are easily answered but many more remain including the most difficult issues of evaluating the threat. Possibly the words of Sun Tzu written over 2500 years ago gives us some insight: "To secure ourselves against defeat lies in our own hands, but the opportunity of defeating the enemy is provided by the enemy himself." I suspect the Soviets apply this logic to their own defensive and offensive investments. It is ncessary that we prepare ourselves through understanding and not leave our destiny to others.

THE STRATEGIC DEFENSE INITIATIVE: PROGRESS AND PROSPECTS

Louis C. Marquet, Deputy for Technology, Strategic Defense Initiative Organization, Department of Defense, Washington, D.C.

[This article is a summary of the author's talk given at an invited session on the SDI, at the APS/AAPT meeting in San Francisco, on 30 January 1987.]

Good Morning. I've been asked to speak on the subject of "SDI: Progress and Prospects." I've chosen to approach these topics by reversing their order, to more clearly show why we in the Strategic Defense Initiative Organization (SDIO) are optimistic about the prospects for a successful program. I'd like to begin by describing what we believe these prospects to be and what measures have been used to arrive at that assessment, and then to illustrate those measures with examples of recent significant progress.

To refresh your memory, the stated objective of the Strategic Defense Initiative (SDI) is to conduct a focused program of vigorous research and technology advancement. We seek to exploit emerging technologies to provide strategic defense options that can significantly devalue Soviet offensive ballistic missiles. By devaluation I mean reduction of the military utility of such missiles in terms of the confidence level a Soviet mission planner would have in being able to accomplish a given mission. More specifically, we are concerned about those missiles that are most capable of supporting a disarming first strike. By dramatically reducing the confidence level that such a mission could be successful, we can provide a better basis for deterring aggression, strengthening strategic stability, and increasing the security of the United States and our Allies. The SDI technology and systems programs are pursuing research on strategic defense options that could form the basis for an informed decision on whether to develop and deploy a defense of the U.S. and our Allies against ballistic missiles. In addition to these goals, SDI is also essential in light of the continuing progress of the Soviet Union in modernizing their strategic offensive and defensive forces. Their progress, if permitted to continue unchecked over the long term, could undermine the military balance which is essential to an effective and enduring deterrence.

In order to achieve all of our objectives, it is obvious that we will require sufficient resources. Our budget requests have been established to provide funds for validating the technical feasibility of the widest possible selection of defense options. However, substantial budget reductions by Congress for the past three years have made it impossible to pursue the program with the scope orginally planned by the Flectcher Study. Establishing program continuity has been especially challenging, creating a more difficult environment for a responsbile research program. The number of promising technologies being pursued in parallel has been reduced, and the risk in realizing solutions to specific technical issues has increased. Further reductions made to our fiscal year 1987 budget have now placed us in a position where simply scaling back alternatives is no longer viable. We are faced with either delaying our planned decision date or eliminating some potentially promising technology efforts com pletely, thereby reducing the number of defense options we can support at that decision and increasing the risk in achieving our goals.

In this fiscally limited climate, a dilemma has arisen which further complicates the task of directing a focused and stable program. On the one hand there are those who believe that the more mature technologies should be emphasized. They want not only to see some tangible results in the near term, but also to maintain a hedge against potential Soviet BMD breakout by ensuring that the most mature technologies are available to be developed and deployed without significant delay. On the other side of this dilemma are those who would prefer to forego less capable technologies in favor of working on longer-term efforts to defeat the most responsive threat. They stress that the U.S. should not simply respond to an existing threat but should leverage our innovative science and engineering capabilities vis-a-vis the Soviet threat.

The answer to this dilemma between alternative approaches is that a balanced program, involving a combination of short-term and longer-term options, remains essential. Not only must validation of the more mature and promising technologies be completed to facilitate making an informed development and deployment decision, but we must also aggressively pursue a technology base research effort to establish the feasibility of our most advanced defense concepts. This is the only way we can take full advantage of the opportunity to anticipate increased Soviet offensive and defensive capabilities, and provide the needed strong incentive to "build down" our mutual reliance on offensive deterrence systems.

Balancing these competing needs within current fiscal constraints is one of the most difficult challenges the SDIO faces. We have, nonetheless, received support from the American public and are optimistic about the prospects for a well-supported and successful technical program—one with well-defined objectives that will allow us to carry out the mission assigned to us by the President. Let me now turn to a brief description of the recent progress that has fostered our optimism.

First, in a system architecture sense, we have greatly increased our confidence in the prospects for achieving a flexible, effective, multifaceted boost-phase intercept capability. Second, we are encouraged by enhanced prospects for success in achieving midcourse interactive discrimination. Third, we expect to capitalize upon the advantageous defense levereage of multiple engagements of an attack throughout its flight to the target.

A further measure of our prospects for achieving a successful program is the progress we are making in several key technologies that would facilitate the achievement of the system capabilities I just mentioned. Let me briefly summarize these technologies.

Kinetic energy weapons (KEW) are a logical extension of current weapon systems and therefore represent the most mature weapons approach for near-term SDI missions. The KEW Office carried out two major experiments in FY 1986, involving proof-of-principle demonstrations designed to support full-scale engineering development decisions in the early 1990s time frame. Both experiments yielded much-needed data. In the first experiment (Flexible Lightweight Agile Guided Experiment, or FLAGE), the U.S. Army demonstrated a number of successful direct impact homing intercepts of low radar cross-section targets at low altitude, the last of which involved an actual air-launched reentry vehicle simulator traveling at a velocity of about 2 km/sec.

The second experiment, Delta 180, was successfully launched on 5 September 1986. In this experiment, critical space observation data was obtained, and an actual dynamic space intercept was conducted. This extremely complex experiment explored and verified, in spectacular detail, several previously problematic aspects of the SDI mission, and also revealed a number of new phenomena which will require further study.

A second technology which is important to a successful enduring defensive capability is the development of directed energy weapons. In this field we have advanced about an order of magnitude in brightness every two to three years since the early 1970s. This achievement has come as a result of a combination of higher laser power, better beam quality, shorter wavelengths, and increased aperture diameter. This progress shows every sign of continuing since there is now the potential for several more orders of magnitude increase in brightness over current capability by the early 1990s. Major achievements in chemical lasers include megawatt-class experiments that yielded the brightest laser outputs in the free world. Precision optics fabrication processes for very large, segmented mirrors (4 meters or larger in diameter) have been developed. These advances plus new proof-of-principle results in phase-locking chemical laser outputs and in optical phased arrays have provided substantial new evidence of the potential feasibility of achieving space-based lasers of very high brightness.

For ground-based lasers, advances in free electron lasers (FEL's) have led SDI to initiate a more aggressive technical program to achieve high performance levels. One major accomplishment so far has been in bringing down the capital cost of laser power from a few thousand dollars per watt to a few hundreds of dollars. SDI's goal is to bring this cost down by another factor of ten. These and other accomplishments, specifically the demonstration of FEL efficiency of about 40% by Lawrence Livermore National Laboratory plus atmospheric compensation successes achieved by MIT Lincoln Laboratory at Maui, have encouraged us to initiate a program with the goal of a ground-based station in the early 1990s capable of multi-megawatt experiments in beam generation and atmospheric compensation.

To support reliable, responsive and survivable battle management, command, control and communications (BM/C3) for strategic defense, we are pursuing technology advances in algorithms, computers, communications systems, and in software engineering. The issue of the feasibility of developing software for SDI has received a lot of attention in the press and in our studies. These studies have shown that if we are careful about the overall architecture design and minimize the amount of coordination required among system elements, the task of developing software and a reliable, fault-tolerant SDI system can be made tractable. In addition, we are taking advantage of major advances in computational capability, computing speed, and size reduction of computer hardware to simplify software development.

I could contiue this impressive list of examples of recent technological progress, but in the interest of time, let me just touch on one more category. That is experimental research and analysis addressing the survivability of our potential defenses against a robust Soviet defense suppression threat. The SDIO Survivability Project is designed to identify promising approaches, including technologies and tactics, and to evaluate their effects on system survivability.

During this past year, we have initiated numerous experiments to determine the hardness levels required of satellites and other elements of a defensive system. We have made good progress in the areas of hardening against nuclear and laser effects and are continuing to pursue techniques to protect our systems against these and other threats (e.g. kinetic energy weapons, microwaves, etc.). Our data base in this area is growing, and we are learning more and mroe each day about how we might protect our systems.

One other example of progress in survivability is the first quantitative analysis of the synergistic advantages offered by multiple survivability options. Recent findings have verified that the first order simulations performed to date by many analysists may have reached results far less favorable to the defense than are now emerging. When trades are performed between multiple survivability options such as hardening, shootback, electronic warfare, maneuver, and decoys, the resulting probability of survival is much higher than when two options are traded. We are greatly encouraged by these findings and will be generating detailed trades this year from specific architectures.

The last item I wish to discuss is the Innovative Science and Technology (IS&T) Program. Through the IS&T office, the SDIO has sought to fund novel approaches to strategic defense through innovative research in science and engineering. Realizing that ultimate, long-term solutions to many of the technological problems yet to be solved in a viable strategic defense are still in the minds of this nation's scientists, the SDI is providing about $100M in fiscal year 1987 to sponsor them in seeking these solutions. Although only two years old, the IS&T program has helped produce many new advances: epitaxial layers of monocrystalline diamond suitable for the next generation of semiconductors, new ultra-short-wavelength laboratory lasers for lithography and x-ray laser studies, opitcally bistable switches for applications in sixth generation optical computers, and new highly refractory composite materials which can withstand high temperatures for long periods of time.

The fact that the SDI program has already yielded dividends which have met or exceeded our expectations in key program areas is testimony to the skill and enthusiasm of both American and Allied researchers, and, I believe, well justifies continued investment in this program.

THE SWORD OF JEHOVAH

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11:55 p.m., July 26, 1965. Delta group is on patrol in the vicinity of a small village a little west of Hue in Viet Nam. They are under bombardment from a Viet Cong morter brigade about one mile north. They know the location, but have no weapons able to reach it. A radio call for air support brings forth a helicopter gunship, which drops some ordinance near the Viet Cong emplacement, but doesn't stop the attack. The Viet Cong is getting close - they must have an observer nearby. There is no way to identify where. Losses mount.

Thousands of the soldiers honored at the imposing black granite Viet Nam Memorial next to the Lincoln Memorial in Washington lost their lives in situations much like this.

Today the Department of Defense is developing a technology which will offer a completely new approach to this kind of military problem. It's a part of Star Wars, the Strategic Defense Initiative. The SDI technologies are not frequently discussed as a means of projecting American power in conventional conflicts. If implemented they will prove revolutionary. To understand what SDI laser technology could mean, imagine it had existed during the Viet Nam war.

A sergeant whispers to a private wearing an electronics-filled backpack. The private looks at some dials, and reads back his location: 107° 54' 75.39" W, 16° 20' 18.73" N. The NAVSTAR navigation system is accurate to within a few feet. Another private has meanwhile determined the enemy emplacement's location relative to the patrol team

The private punches the "enter" button on his control panel. For a fraction of a second a burst of high frequency signal propagates from his backpack to a geostationary communications satellite. A high gain directional antenna makes it virtually impossible for the enemy to detect the signal. Moments later the request is relayed to SAC command headquarters in Cheyenne Mountain, Colorado. A technician punches up a map of the area. On a giant screen, familiar to everyone from the movie "War Games", there appears a blow-up map of the area.

The commanding officer reads the request from the display: Enemy gun emplacement 1549 yards from US platoon, relative coordinates as shown. Enemy emplacement location uncertainty +/-2 yards. Required kill diameter 5 meters.

"Attack authorized".

Electronic signals leave Cheyenne Mountain at the speed of light. An authorization code is sent to a command post in Northern California. A steereable mirror in low earth orbit above California is redirected to point toward a relay mirror (fighting mirror) over Asia.

One thousand megawatts of mechanical power is extracted from a spinning flywheel, converted to electricity, and fed to a pulsed free electron laser atop Mount Hamilton.

A few hundred microseconds later the Viet Namese sky glows for a moment as Sword of Jehovah strikes. 10,000 joules of energy are deposited in a spot 5 yards in diameter. The pulse lasts for one second. Perhaps long enough for a soldier in the target zone to suspect what is happening. Far too fast for him to get out of the way.

Virtually instantly five Viet Cong operating the gun emplacement, every bit of living matter, shrubbery, ants, and a few small animals are incinerated. The shooting stops. The platoon sees a smoking black circle on the hilltop from which they were only moments ago attacked. There is no sign of life.

Fantasy? Today, yes. But what about 1995? The technology I've described is being developed. It's development is a part of the United States Strategic Defense Initiative for defending the nation against Soviet intercontinental ballistic missiles.[1,2,3] Directed energy weapons (DEWs), which are the focus of most of the discussion here, have recently been reviewed in a detailed study by the American Physical Society[4]. The most promising directed energy weapons for ground basing are the free electron laser, and Deuterium-Fluorine excimer lasers operating in a frequency regime where the earth's atmosphere is transparent.[4] A critical review of the SDI program may be found in ref #5.

If Soviet ICBMs are to be prevented from reaching US soil, they must be attacked at every stage of their path, first during boost phase while the booster rockets are burning, then during ballistic flight over the North pole. Any surviving rockets must be destroyed during their final terminal phase of entry into the US atmosphere.

Boost phase intercept is the most important and also the most difficult part of ICBM defense. During boost phase the rockets have not yet deployed their multiple warheads, so there are far fewer targets to attack than later on. Also, during boost phase the booster rockets emit bright flames which make them easy to detect. The boosters are very vulnerable, particularly when measured relative to the warheads, which are armored with ablation shields so they can reenter the atmosphere without burning up. The requirements to kill Soviet ICBMs during boost phases are formidable. A technology capable of boost phase kill will automatically have remarkable non-nuclear war-fighting capability.

ICBM boosters are enormous eggs shells containing rocket fuel. The Soviet SS-18 stands over 100 feet high, and is 6 feet in diameter. The booster shell walls are a few millimeters thick. Typical analysis shows that 10-20 kilojoules per square cemtimeter deposited in a few seconds can burn a hole through the booster shell.[6]

People are killed by far less energy. It only takes 50 joules per square centimeter to inflict third degree burns on a person. 245 joules/square centimeter will cause newspaper to burst into flame. 120 joules per square cemtimeter will cause plywood to burst into flames. Silicacous sand will explode in a "popcorning" effect when exposed to 80 joule per square centimeter.[7] Energy depositon of only one percent of that needed to destroy a missile will kill people.

Typical SDI designs call for deploying a capability to destroy 1400 Soviet ICBMs during a simultaneous launch phase, within two minutes.[8] Such a system must be able to deliver at least 1400 pulses to virtually any point on the globe,[9,10] with only a few seconds warning time, and within a few minutes.

I've explored here only one aspect of the military capabilities of SDI technology. There are many more. The laser technology being developed could be used to incinerate a political leader standing in front of his capital. It might be used instead of aircraft for the attacks on unpopular politcal leaders, such as the one against Libya's Colonel Ghadaffe. Cities or forests could be incinerated through the creation of firestorms.[11] Oil refineries could be set on fire. Low level radiation at critical times (e.g. during germination) could destroy crops, possibly in such a way that detection would be difficult. The possibilities seem endless.

Presently US policy calls for the ability to project power rapidly to virtually any point on the globe. Implementation of this policy results in a major fraction of current US military expenditures of about $300 billion per year (the equivalent of one Mercedes 300SD automobile every three seconds). SDI technology will contribute substantially to this capability.

SDI is being promoted as a counter to Soviet ICBMs. Other uses of a deployed SDI technology must also be considered. The political and military implications of these uses are considerable.

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NEWS

APS DIRECTED ENERGY WEAPONS STUDY RELEASED

As all Forum members are surely aware, the APS recently released its DEW Study. The Study Group found that:

- The development of an effective ballistic missile defense utilizing DEW would require performance levels that vastly exceed current capabilities.
- There is insufficient information to decide whether the required performance levels can be achieved.
- A decade or more of intensive research would be required to provide the technical knowledge needed for an informed decision about the potential effectiveness and survivbility of directed energy weapon systems.
- The important issues of system integration and effectiveness depend critically on information that does not now exist.

Following release of the Study Group's report, the APS Council released a statement expressing the belief that "—it has a public responsibility to express concerns about the Strategic Defense Initiative that go beyond the issues of DEW covered in the Study." The Council's statement concludes that, "In view of the large gap between current technology and the advanced levels required for an effective missile defense—It is the judgement of the Council of the American Physical Society that there should be no early committment to the deployment of an SDI system."

The Executive Summary of the DEW Study has been published in the May issue of *Physics Today.* The complete report will be published soon in *Reviews of Modern Physics.* Reprints may be ordered from APS.

A NEW FORUM STUDY BEGINS

The Forum on Physics is establishing a group to work on the topic "What should the United States Be Doing to Prepare for the Next Energy Crisis?" The study will examine three broad areas: (1) When can we expect the next energy crisis and what are our current energy resources? (2) What research programs are needed and what is the current status of research in such energy-related areas as photovoltaics, nuclear fusion, breeder reactors or energy-efficient buildings? (These are only examples of interest areas and are not meant to be limiting. Ideas are very welcome!) (3) What educational measures can be taken to increase public awareness of energy issues?

Forum studies are carried out by individuals interested in the topic and working on their own. In the past, it has been possible for study groups to meet very cheaply to have expert briefings on the topic in question after the completion of preliminary drafts of portions of the study and again to finish the final version of the study. Study groups are open to all members of the Forum who are interested in applying their knowledge of physics to the topic in question and are willing to work actively at research for the study. Forum studies emphasize the technical rather than the political issues of a problem and strive to present a balanced picture of the topic in question. If you are intersted, please write to one of the Energy Study organizers outlining your area of interest. Organizers are: Ruth Howes, Department of Physics and Astronomy, Ball State University, Muncie, IN 47306 and Tony Fainberg, Office of Technology Assessment, Washington, D.C. 20003.

CALL FOR FORUM AWARD NOMINATIONS

The forum is now accepting nominations for its two annual awards, to be presented in the Spring of 1988. The Szilard Award is given to an individual or group who has applied physics in the public interest. The APS Forum Award is given to an individual or group who has promoted the public understanding of the relation of physics to society. In 1987, Thomas B. Cochran of the Natural Resources Defense Council received the Szilard Award for negotiating and implementing a private seismic measurement agreement with the Soviet Union, and Richard Scribner of the American Association for the Advancement of Science received the Forum Award for developing and implementing the AAAS Program on Arms Control and National Security.

Nominations, with supporting material, should be sent to the awards committee chairperson, Ruth Howes, Physics Department, Ball State University, Muncie, IN 47306, (317) 285-8860.

OPPORTUNITIES IN PHYSICS

"Integrity in Physics" has been actively discussed by the Committee on Opportunities in Physics (COP) for over two years, considering whether there should be APS action in the light of much press coverage on scientific fraud. Your reporter represented APS/COP at a two-day AAAS Workshop on Professional Societies and Professional Ethics in May 1986. This activity culminated in the adoption by the APS Council on April 24 of an integrity-in-physics resolution developed by COP. You'll be seeing it soon in the *Bulletin of the APS* and/or *Physics Today*. In addition, new members will automatically receive a copy. The timing of this action was excellent, since it coincided with the publication of an interview with Frank Press (President of the National Academy of Sciences) in the April 1987 *Physics Today* (pp. 47-52). He exhorts the scientific community to "come up with standards, a reaffirmation of ethics in the scientific method, and instill this in the next generation."

Workforce concerns relating to physics as a career dominated the recent meeting of COP in April. We are picking up where the POPA ad-hoc Workforce Panel Report of October 1986 left off. They observed that there is a "tightening" market of physics personnel — with some spot shortages — in universities. There is reason for eventual concern in the industrial market because future industrial scientists are trained in these institutions. The POPA Panel conducted a poll of department chairs in Ph.D.-granting insitutitions on the availability of new physics faculty, achieving a remarkable 76% response. Considered by subfields, the results suggest an oversupply of particle theorists and shortages of condensed matter experimentalists. COP, in cooperation with the AIP Statistics Division, will assume continuing sponsorship of this Questionnaire on Faculty Workforce to run on a biennial basis, giving APS a running assessment of this important factor.

A COP subcommittee is working actively on a workforce and membership profile focused on the APS membership itself. The AIP Statistics Division staff is again indispensable in this project, both for data and for professional expertise. We hope to obtain useful insights into the composition of the Society from many facets. Some examples are: professional self-identification, type of employer, age profiles (academic and industry separately), employer type by year of Ph.D., and for dropped members, their professional self-identification and type of employer. Many of these questions have been "answered" in the past by anecdote or intuition, while others were only inferred from overall AIP statistics. We are quite excited about sharpening the focus on this snapshot of APS, and on the evolving trends. There is also an awareness in COP that substantial numbers in the physics workforce have learned physics in and hold degrees from university departments other than physics. Ultimately, the workforce statistics will have to account for this fact.

COP is also interested in tutorial presentations that might be called "special topics for the non-specialist." These could be in the form of symposia at meetings, or in the short-course (pre-meeting) format. Some examples suggested are chaos and also high-temperature superconductors. Discussions on this concept are still evolving and we'd like your comments and suggestions on the idea, the format, and possible topics of interest. Please write Israel Jacobs, General Electric Corporate Research and Development, P.O. Box 8, Schenectady, NY 12301.

AWARDS FOR WORK ON INTERNATIONAL SECURITY

The Social Science Research Council has announced 10 MacArthur Foundation Fellowships — totaling $510,000 — to postdoctoral and advanced predoctoral researchers from seven countries in the Americas, Europe, and Africa, representing five disciplines in the social and physical sciences.

These research and training fellowships strengthen the ability of the researchers to examine the basic assumptions of current thinking on international security. Some of the researchers receiving support seek to ask conventional questions in an unconventional way. Others seek to expand current conceptions of international security by examining nonmilitary threats to the security of states and their citizens. All of the fellows will engage in periods of training to add skills needed to carry out their research projects. Some will receive this training in formal courses at universities around the world. Others will take up internships or apprenticeships with governmental and nongovernmental agencies.

The council particularly welcomes proposals for training and research from people working outside the mainstream of security studies, such as those working on nonmilitary conceptions of security and those working in world order studies. Applications are also particularly sought from researchers outside the United States and from individuals who have worked on issues of peace and security in nonacademic settings.

For further information and application forms, contact the Program in International Peace and Security Studies, Social Science Research Council, 605 Third Avenue, New York, NY, 10158,(212) 661-0280.

CONFERENCE ON NUCLEAR WAR AND PEACE EDUCATION

This second annual conference will be held 29-31 October 1987 at George Mason University in Fairfax, Virginia (near Washington, DC). It is intended primarily for college faculty interested in courses and programs relating to nuclear war and peace. In addition to short contributed papers by participants, the conference will feature talks by nationally prominent persons, films, a poster session, a book display, and informal discussions. Persons planning to attend may submit 50-word abstracts of papers they wish to present. The abstract deadline is 9 September 1987, and the conference registration deadline is 1 October 1987. Participants from outside the Washington, DC, metropolitan area whose abstracts are accepted will receive a $150 stipend to help defray travel costs. The conference is made possible by a grant from the Alfred P. Sloan Foundation, New York. For further information contact Robert Ehrlich, Physics Department, George Mason University, Fairfax, VA 22030, (703) 323-2303.

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If you are an APS member it is easy, and free, to join the Forum and receive our newsletter. Just complete and mail (to the editor) the following form, or mail us a letter containing this information:

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COMMENT

EDITORIAL: PHYSICS AND EVOLUTION

Being originally educated in music and then, upon discovering that I didn't really have the "right stuff" to be a successful jazz musician, moving to physics, I have always been fascinated by the interactions between physics and the larger society. One important interaction site is the college classroom, specifically the introductory courses in physics, physical science, and astronomy. Thus I am happy to note that the American Association for the Advancement of Science (AAAS) is initiating a 2-year study of the role of liberal education in our science/technology-dominated society. The AAAS Project on Liberal Education and the Sciences, funded by the Carnegie Corporation of New York, will design model programs to achieve the scientific and technological literacy needed for our times.

As a contribution to the AAAS goals, I would like to devote occasional editorial space to descriptions of a few of the physics-related interdisciplinary topics covered in the liberal-arts physics course "Physics and Human Affairs" on our campus. Today's topic is physics and evolution.

Evolution, in the broad sense of long-term natural change as well as in the specific sense of mutation- and survival-driven alteration of biological species, is one of the underlying themes of the course. It appears in at least four different contexts.

In the introductory "why you should take this course" lecture, we attempt to justify the science for non-scientists courses such as this one by appealing to long-term trends in the natural world. In the beginning, some 10-20 X 10^9 years ago, there were elementary particles and photons. Then H and He. Then stars produced the periodic table. The elements connected to form organic molecules which, in some places such as here, organized themselves in such a way as to feed and reproduce and thus developed a survival-based need to be aware of their environment. The trend toward connections and awareness continued until, a few brief millions of years ago, structures developed that were aware not only of their immediate environment, but of distant reaches in space and time and, even more remarkable, learned an awareness of their own detailed structure. The human brain could be described as "self-aware molecules": molecules that know they are molecules. Thus an ever-increasing awareness of the natural environment is a fundamental trend (some might say "purpose") of the universe. In studying fundamental science, we are furthering this universal purpose.

Throughout most of the USA, and especially here in Arkansas, the evolution/creationism controversy is very hot. It behooves scientists, including physicists, to be involved in this controversy, lest anti-scientific arguments carry the day. The controversy itself may not be as unfortunate as it seems, for it encourages fundamental re-thinking of science, religion, and their relation. It is probably still true that, as Alfred North Whitehead remarked earlier in our century, "When we consider what religion is for mankind and what science is, it is no exaggeration to say that the future course of history depends upon the decision of this generation as to the relations between them."

Biological evolution relates to physics through the second law of thermodynamics and through radioactive dating, and it relates to astronomy through the question of extra-terrestrial life. In connection with the second law, our course reflects on the seeming violation of nature's principle of increasing microscopic disorganization by life processes such as the growth of a leaf, as well as by long-term historical processes such as the development of life on earth. The resolution, that neither the leaf nor the earth is a closed system, is important in two senses: it replies to the oft-repeated anti-scientific argument that evolution conflicts with the second law, and it highlights the fundamental fact that our very unusual low-entropy biological structure depends on energy exchanges with our environment and particularly with our star.

We devote a lecture to the search for, probability of, and implications of, extraterrestrial life. We discuss, in very general terms, the mechanisms and energy sources that might have given rise to life on earth and speculate on the probability that similar processes might have occurred on planetary systems around other stars in this or other galaxies. Class discussion usually reveals that nearly everybody believes there is life out there, and even that our planet has actually been visited. Most scientists do not accept this latter proposition, and we usually spend some time discussing why it is improbable that we have been visited, and debating it.

Radioactive dating is one of the important applications of nuclear physics, and we spend one or two lectures on the details and implications. Carbon-14 dating is an especially nice example, as C-14 in the atmosphere depends on the continued impact of cosmic rays and these rays originate in such high-energy astronomical phenomena as supernova explosions. We list a few of the major conclusions of radioactive (and other) dating methods: a 4.5 X 10^9 year old earth, 3 X 10^9 year old life forms, 3 X 10^6 year old hominids (human-like creatures), etc. For perspective, we use the well-worn analogy of a 12 hour noon-to-midnight time scale. On this scale, life begins at 4 pm, hominids at -30 s before midnight (!), *Homo sapiens* at -1 s, human culture at -0.1 s, and the "scientific age" (Copernicus) at -0.003s! The lesson, that a lot has happened very recently, is worth knowing.

This all leads into an open-ended class discussion of similarities and differences between the biblical and scientific accounts of origins. Every effort is made to refrain from anti-religious attitudes and from stepping on student' beliefs, while at the same time encouraging students to examine any ambiguities or contradictions in their own beliefs. The class consensus is usually that Genesis portrays deep religious and psychological truths, and that it may in fact be demeaning to such a spiritual work to demand that it also portray strict scientific or historical truth.

Your thoughts about liberal arts and science/technology education are solicited by the AAAS project, and by *Physics and Society*. For the AAAS project, write to the director, Audrey B. Champagne, Office of Science and Technology Education, AAAS, 1333 H Street, NW, Washington, DC 20005. For *Physics and Society*, write us a letter!

Art Hobson