

# PHYSICS AND SOCIETY

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## LETTERS

### LAND-BASED MISSILES

The July 1988 "A Critical Look at Land-Based Missiles, Continued" was welcome and provokes the following comments.

Re P.D. Zimmerman: One should not count on the accuracy of a rail-mobile missile (or a submarine-based missile) being worse than that of a silo-based missile. In our article on SLBMs based in small submarines, Sidney Drell and I cited extensive studies using NAVSTAR for a ground-beacon system to aid boost-phase ICBM guidance, providing accuracy for mobile missiles no worse than that feasible for missiles based in silos.

One can hardly accept that "the track itself, together with the fiber-optics communication systems which parallel most of the U.S. rail network, virtually guarantee communications even under the conditions of a nuclear attack." *Cutting* such a communication system with a few well-placed craters from strategic warheads will destroy that contribution to communications.

Re Ruth Howes on terminal defenses: I am no supporter of densepack, which was to put silos so close together that they could not all be attacked simultaneously, but to conclude, "for example nuclear detonations near the surface in a defense that works by fratricide produce large quantities of lethal radioactive fallout which might cause a significant number of civilian casualties" misses the point. If the opponent's purpose is to exact civilian casualties, point defense of silos won't prevent that! And the enemy would not attack silos if he couldn't destroy them. Similarly, nuclear weapons buried 1 km north of each silo can be designed and emplaced in such a way that fallout is less than 1% of that from a ground-burst strategic weapon, *and* they would not have to be used if they were clearly effective defenses.

Preferential defense of silos can't contribute enduring survivability. By the use of "bombs that squeak" or other approaches, the attacker can promptly determine which of his warheads were intercepted and replace them in no more than an ICBM flight time. So preferential defense simply provides more time for launch under attack.

*Physics and Society* is doing a real service in publishing these preliminary papers on land-based missiles. Physicists should not forget the great unmentionable—that small, single-warhead missiles can be deployed in silos, where their confident destruction will require two attacking warheads for each one destroyed. I personally believe that the United States would never be confident that the location of *mobile* missiles was unknown to the other side, as is necessary for their survivability.

Richard L. Garwin  
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(Views not necessarily those of IBM)

### THE FRANKENSTEIN COMPLEX

As Abraham Maslow so aptly put it, "If the only tool you have is a hammer, you see every problem as a nail." Because, as educators, our tool is the classroom lecture, we see every problem as one requiring more, or better or different courses.

In your timely editorial (July 1988) you make the point that fear and mistrust of science is correlated with a lack of science courses that stress a social context because people are crying out to us that they "don't really understand what is going on" in our laboratories. If lack of understanding were indeed the root cause of "a vague and alarming mistrust of science," then such courses could be a legitimate response. Unfortunately, we are not convinced that this is the case. The very examples you use in your editorial, Chernobyl, TMI, Bhopal, Challenger, and ozone depletion, point out clearly that horrible things do happen, that they happen for unpredictable, even unimaginable reasons, and that some degree of fear or caution is both rational and warranted. After they occur, the reasons for these catastrophes are usually quite well understood, yet this understanding provides neither solace nor reassurance.

Even though both of us teach well enrolled courses that place science and technology in a social context, we do not see these courses as alleviating fears, nor do we teach them with that goal in mind. In fact, we are not convinced that fears should be alleviated, since very often it is precisely those fears that drive the policy making process.

We do, however, see two valid reasons for placing science and technology in a social context. First, science and technology are two of humankind's greatest endeavors and the more we understand them, the more we understand not just nature, but ourselves as well. Second, people must be made to realize that risk is inevitable in a technological society and that each risk must be weighed against the benefits of living in such a society. But to believe that by studying science and understanding even the most complex technologies we will allay fears of inevitable accidents and unimagined consequences, is to replace the image of Frankenstein by one of Pollyanna.

Morton Tavel  
Professor of Physics  
Director, Program in Science, Technology and Society  
Vassar College, and  
Judith Tavel  
Professor of Physical Science  
Head, Dept. of Physical Science, Math and Computer Science  
Dutchess Community College.

#### Response:

I enthusiastically agree! I had not meant to convey the impressions that all, or even most, fears will be allayed.

Art Hobson

## STAR WARS OR SDI?

After reading Art Hobson's Editorial "The Frankenstein Complex" (July 1988), with its plea "to devote more attention to understanding the full context of the scientific enterprise," I turned the page to Robert Park's Comment ("Is There a Science Advisor to the President?" July 1988) mentioning the "sad comedy of 'Star Wars'."

It is not a sad comedy but a veritable tragedy that a professor of physics and a prominent member of physics officialdom should stoop to the use of a comic-strip propaganda phrase that belittles a monumental effort to defend our country and our allies from nuclear attack, and represents it as war-like, when that effort represents but a small fraction of the resources devoted to it by the Soviets. The most recent assessment of Soviet military power includes the statement that "most of the advanced directed energy weapons concepts in vogue in the West were advanced by the Soviets at least a decade earlier" (*Soviet Military Power 1988*, US Department of Defense, p. 146).

The fact is that when we see such performances as Prof. Park's Comment in our own literature, and read his slashing attack on the "controversial Mr. Teller," we have only to learn that it appeared originally in *The Chronicle of Higher Education* to understand both popular distrust of the scientific community and the emergence of a Frankenstein complex in the popular mind.

NBC gave me time on its national news to deplore Tom Brokaw's use of the term "Star Wars," and he now refers consistently to the Strategic Defense Initiative, or SDI. But Prof. Park, *Physics and Society*, and *The Chronicle of Higher Education* still have to catch

up with Mr. Brokaw.

Lawrence Cranberg  
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Response:

Tom Brokaw reports the news. My commentary in the *Chronicle of Higher Education* was on the editorial page and clearly labeled "opinion." My opinion hasn't changed.

Robert Park

## STABILITY OF NUCLEAR FORCE STRUCTURES

I regret that I made two errors in our Tables (July 1988). First, the "Warhead Gain (or Loss)" under the START Treaty with some mobile missiles should have read 0.283 rather than 0.238. Second, Tables 1 and 2 are inconsistent: The outcome of a first strike with the 2000 warhead arsenal was calculated for Table 2 by assuming a force of 500 mobile missiles, while Table 1 assumes 600 mobile missiles. The numbers do not change significantly with that change. The ratio of destroyed warheads changes from 0.48 to 0.50, the warhead gain is -1046 rather than -1095, and the surviving warheads is 1046 rather than 1095.

Barbara Levi

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# ARTICLES

## HIGH TECH WINDOW COATINGS "SUPPLY" ENERGY SERVICES

Arthur H. Rosenfeld

Buildings account for over one third of all U.S. energy consumption. Energy policy has emphasized the development of new secure energy supply options such as off-shore oil. But advanced building technology that effectively reduces the need for current consumption can also be viewed as a supply option.

Consider the following two choices for "supplying" \$1 billion of energy services:

### Low-E window technology

Heat loss from windows is responsible for about 4% of total US energy consumption, or the equivalent of 1.4 million barrels of oil per day. Transparent low emissivity (low-E) coatings provide one third reductions in window heat loss.

This industrial low-E coater (See Recipe #1) can coat over 20 million square feet of glass for windows each year. Savings accumulate rapidly since each window continues to save energy

over its entire lifetime, at least 20 years.

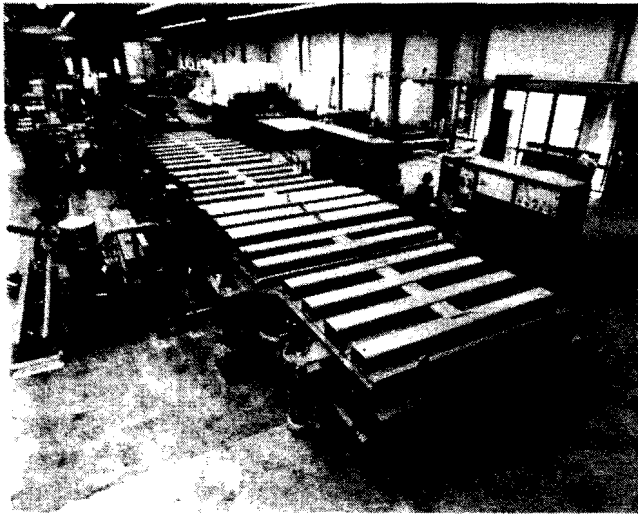
### Recipe #1

#### Low-E window technology

- Step 1: Invest \$8 million in a low-E coating system.
- Step 2: Coat 20 million square feet of windows per year for the 10 year nominal life of the coating system.
- Step 3: Accumulate energy savings over the 20 year life of the window.
- Step 4: RESULT: Savings of 36 million barrels of oil equivalent!

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The author is a physicist at the Center for Building Science, Lawrence Berkeley Laboratory, Berkeley, CA 94720



Glass coaters such as this high-rate sputtering system can coat large sheets of glass with sophisticated multilayer coatings for control of heat and light in buildings. (Photo courtesy of Airco Solar Products, Concord, CA.)

#### Offshore oil wells

Oil under the continental shelf is a secure, but environmentally fragile, costly, and depletable supply option. (See Recipe #2).

#### The economics of payback times

Thirty-six million barrels of oil equivalent saved by low-E is worth more than \$1 billion of home heating oil, natural gas, or

#### Recipe #2

##### Offshore oil wells

Step 1: Invest \$300 million in a 10 well offshore oil platform, producing 10,000 barrels per day.

Step 2: Pump oil for the 10 year nominal life of the oil field (don't spill a drop).

Step 3: RESULT: Supply of 36 million barrels of oil!

electric resistance heat.

The simplest economic measures of energy efficiency investments are simple payback time, or cost of conserved energy.

Low-E glass adds about \$2 per square foot cost to a new window, but pays back this investment in 2 to 6 years depending upon climate and energy costs. Coated glass cost may be reduced in the future, thereby further shortening the payback. The cost of energy conserved by a low-E window is 40 cents per therm of gas (current price, 60 cents per therm) or 54 cents per gallon of home heating oil (current price, 80 cents per gallon), or 2 cents per kilowatt for electric resistance heat (current price, 7.5 cents per kilowatt).

These energy conservation strategies are good investments for consumers, help strengthen US industry, and reduce our dependence on foreign oil.

For more information on the economics of energy conservation contact: American Council for an Energy-Efficient Economy, 1001 Connecticut Avenue NW, Suite 535, Washington, DC 20036, (202) 429-8873. For more information about low-E windows, contact your local building materials supplier, window manufacturer, or architect/builders.

## DOE DEFENSE PRODUCTION REACTORS: SAFETY ISSUES AND POSSIBLE FIXES

Theo G. Theofanous

Shortly after the April 1986 accident at the Chernobyl Nuclear Power Station in the Soviet Union, Secretary of Energy John S. Herrington requested that the National Academy of Sciences and the National Academy of Engineering provide an independent assessment of the safety of 11 of the Department of Energy's (DOE) larger reactors. In response, the Academies formed the Committee to Assess Safety and Technical Issues at DOE Reactors. The Committee began to work in August 1986. Its findings regarding the defense production reactors (4 of 11) were published in October 1987 (*Safety Issues at the Defense Production Reactors*, National Academy Press, Washington, D.C., 1987). A report on the group of research reactors (the remaining 7) is in preparation. The author is a member of this committee, and this presentation, which is focused on the production reactors, has drawn freely on the collective results. However, the author is solely responsible for its content.

The term "defense production" refers to the reactor's primary mission as suppliers of plutonium and tritium to the Department of Defense for use in nuclear weapons. They are also referred to as Class A reactors and include the K,L, and P reactors located at the Savannah River Plant (SRP) in South Carolina and the N reactor located on the Hanford Nuclear Reservation in Washington. The

K, L, and P reactors, all very similar, are heavy water moderated and cooled, low pressure systems. The N reactor is a graphite moderated, water cooled, high pressure system, with some superficial similarities to the Chernobyl reactor. A summary of relevant characteristics for each reactor is given in Tables 1 and 2. These reactors are all rather aged, the N reactor having operated over 25 years and the SPR reactors over 30 years. More importantly, their safety bases are also aged and have remained largely oblivious of the major technological advances made in the commercial nuclear power generation sector during the past 10-15 years. Thus, their re-examination, motivated by Chernobyl, resulted in the expression of significant safety concerns, which in turn led to the shutting down of the N reactor and to three successive deratings (power reductions) of the Savannah reactors.

This article and the succeeding article are based on invited talks given at the April 1988 meeting of the American Physical Society in Baltimore. Theo Theofanous is Professor of Engineering, and Director of the Center for Risk Studies and Safety, at the Department of Chemical and Nuclear Engineering, University of California, Santa Barbara, CA 93106.

The academy report, and this presentation, are focused on the problem areas identified. These must be viewed in the context of a good number of positive safety features and the over 25 years of operating experience without major incidents. On the other hand, it is important to emphasize that because of their unique design these plants do not enjoy the internationally synergistic feedback that over the past 10-15 years has sharpened the safety posture, and associated philosophy, of commercial nuclear power plants. Furthermore, the application of this technology to defense production reactors, again because of differences in design, is by no means a trivial task. If not handicaps, these are important disadvantages that will require the highest technological vigilance, on the part of reactor personnel at all levels, to meet the appropriate safety goals.

Indeed, most specific technical issues (Table 3) appear to have developed due to a failure to meet such high levels of technological vigilance. That is, in most cases difficulties arose because of lack of (or delayed) action rather than an inadequate quality of it. For example, probabilistic risk assessment has been recognized for over 10 years as an essential tool for identifying safety problems and prioritizing remedial action. Yet defense production reactors have only recently begun such studies. Consideration of severe (core melt) accident phenomena (Table 4), especially in relation to their effect on the confinement systems (i.e., hydrogen combustion/explosion, Table 5) employed in these reactors, are crucial to such assessments of risk, yet at this time only rudimentary treatments are available. In order to appreciate the impact on safety, these two broad areas of deficiency must be convoluted with acute aging phenomena (Table 6), inadequate plant maintenance practices, and concerns regarding human performance, liquid effluents, and emergency planning.

The issue of power limits (summarized in Table 7) provides an excellent illustration of the special needs for technological vigilance mentioned above. For normal operation maximum power limits are established by the requirement to avoid fuel melting in the unlikely event of a major break in the reactor coolant system (usually taken as the largest coolant pipe). Quite apart from its likelihood, such an event has been considered at the Savannah reactors (as in commercial plants) as the challenge against which the emergency core cooling system was designed. Technical considerations involve complex two-phase flow phenomena, including flow reversals, and counter-current steam-water flows within many parallel, narrow channels in the presence of boiling and condensation. Recent experiments at Savannah contradicted the ones originally used to set the power limits. As a consequence, power limits were reduced (by 20%), only to be reduced further later (to a new total reduction of 50%) based on the Committee's suggestion that available technical data were insufficient to assure emergency core cooling performance in the presence of boiling. Just recently another reduction (about 5%) became necessary to meet this objective, apparently due to an error in previous calculations. Meanwhile a fourth system for addition of emergency cooling water has been installed, and a comprehensive action plan has been put into effect to establish the bases for appropriate recoveries in power limits.

Work on all technical issues is pursued with high intensity. It is hoped that despite the rush technological vigilance will be established and maintained.

Table 1

<b>THE N REACTOR</b>
<ul style="list-style-type: none"> <li>• 4,000 MW<sub>th</sub></li> <li>• Graphite-Moderated, Water-Cooled</li> <li>• 1,003 Pressure Tubes (1,600 psi) - 54 ft.</li> <li>• 16 Fuel Elements/Tube</li> </ul>
Negative Void and Power Feedback Diverse Shutdown Reliable Activation of ECCS Graphite cooling System

Table 2

<b>SRP REACTORS</b>
<ul style="list-style-type: none"> <li>• 2,500 MW<sub>th</sub></li> <li>• D<sub>2</sub>O Moderated and Cooled (Low P)</li> <li>• 600 Aluminum Tubes (Vertical Lattice)</li> </ul>
Diverse Shutdown Negative Power and Void Feedback Reliably Activated ECCS

Table 3

<b>SUMMARY OF TECHNICAL ISSUES</b>		
missing: PRA/SAB		
<b>NORMAL OPER.</b>	<b>DBAs</b>	<b>SAAs</b>
<ul style="list-style-type: none"> <li>• Acute Aging</li> <li>• Maintenance</li> </ul>	<ul style="list-style-type: none"> <li>• Power Limits</li> </ul>	<ul style="list-style-type: none"> <li>• Hydrogen</li> <li>• Carmel Fuel</li> <li>• Confinement</li> <li>• Liquid Effluents</li> <li>• Emergency Planning</li> </ul>

Table 4

<b>SEVERE ACCIDENT EVALUATIONS</b>
<ul style="list-style-type: none"> <li>• Thermal Hydraulics</li> <li>• Thermal Shock</li> <li>• Radionuclide Releases and Transport</li> <li>• Fuel Damage Progression</li> <li>• Hydrogen Generation and Transport</li> <li>• Behavior of Core Debris</li> <li>• Confinement Loads</li> </ul>

Table 5

<b>HYDROGEN</b>	
<b>ISSUES:</b>	<ul style="list-style-type: none"> <li>• Generation, Mixing, Accumulation</li> </ul>
<b>FIXES:</b>	<ul style="list-style-type: none"> <li>• Mixing   Inerting   Monitoring System (N)</li> <li>• Improved Understanding of Core Degradation</li> <li>• Improved Mixing analyses</li> </ul>

Table 6

<b>ACUTE AGING PHENOMENA</b>	
<ul style="list-style-type: none"> <li>• Savannah River Reactors               <ul style="list-style-type: none"> <li>- Corrosion Cracking (Leak - before - break)</li> </ul> </li> </ul>	
<ul style="list-style-type: none"> <li>• N-Reactor               <ul style="list-style-type: none"> <li>- Graphite Expansion</li> <li>- Pressure Tube Embrittlement (Growth Monitoring, Flow detection, Flux Flattening)</li> </ul> </li> </ul>	

Table 7

<b>POWER OPERATING LIMITS</b>	
<b>ISSUES:</b>	<ul style="list-style-type: none"> <li>• Inadequate Documented Understanding of LOCAs</li> <li>• Effectiveness of ECCS Questioned (SRP)</li> </ul>
<b>FIXES:</b>	<ul style="list-style-type: none"> <li>• Extensive New Analyses</li> <li>• New Experiments</li> <li>• Derating (SRP)</li> <li>• Increased ECC Water Supply (SRP)</li> </ul>

## DOE DEFENSE PRODUCTION REACTORS: INSTITUTIONAL ASPECTS OF SAFETY

Herbert Kouts

Following the Chernobyl accident, the Secretary of Energy asked the National Academy of Sciences and the National Academy of Engineering to form a committee to conduct an independent review of the Department's larger nuclear reactors, and to provide an independent assessment of their safe operation in the light of that accident.

This review consists of two parts. The first is a review of issues at the defense production reactors at the Hanford site in the state of Washington, and the Savannah River site in South Carolina. A report has been written containing the results of this part of the review, and it is primarily these which I will discuss. The second part is a review of issues attached to five research and test reactors. This review is still underway, and since its results are still not in final form, they are not discussed here.

The Hanford site was at one time the location of nine nuclear plants devoted to production of materials for nuclear weapons. Eight of these have now been decommissioned, and the only one remaining at the time of the review in question was the so-called "N" reactor, which was used simultaneously to produce weapons material and to generate electricity for the Washington Public Power System.

The Savannah River site was at one time the location of five reactors used primarily for producing materials for nuclear weapons. Two of these have been decommissioned. Only the "K", "L", and "P" reactors remain in operation, and these were the subjects of the review that was made there.

The Chernobyl accident had aspects that were related to the physical design of that facility, and others that were associated with

safety practices at that facility and were found also to be more widespread. The review of safety at the Department of Energy's reactors paid special attention to these. A number of observations, conclusions, and recommendations have been made in technical areas, and these are discussed by Dr. Theofanous (see the preceding article). Others are of a more institutional form, and are associated with the methods used by the operating contractors to ensure and assess safety, and the systems of review and provision of guidance in safety used by the Department of Energy. I shall discuss these institutional aspects.

Several factors have helped to shape the circumstances behind the Academy committee's comments, conclusions, and recommendations on institutional topics. The first is the replacement in 1974 of the Atomic Energy Commission (AEC) by the two successor agencies, the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA), which was in turn later replaced by the Department of Energy (DOE).

I will describe the practices that were used in monitoring safety of the AEC's reactors, before that agency was divided.

The Advisory Committee on Reactor Safeguards (ACRS) came into existence in an early form in 1948, to conduct a review of the safety of the plutonium production reactors at the Hanford, Washington site. Over the following years, this Committee continued in the broader role of reviewing the safety of all of the nuclear reactors built for the AEC, and provided its comments directly to the

This article and the preceding article are based on invited talks given at the April 1988 meeting of the American Physical Society in Baltimore. Herbert Kouts is with Brookhaven National Laboratory.

Chairman of the Commission along with conclusions and recommendations.

In 1956, the ACRS became a statutory committee, with functions assigned to it by Congress, for reporting to the Chairman of the AEC on proposals to build and operate commercial nuclear power plants and other facilities of the so-called production and utilization type in the civilian sector. This did not displace the ACRS's responsibilities for watching over the safety of DOE's reactors; it supplemented that activity.

The ACRS continued to monitor the safety of DOE's reactors throughout the period of AEC's existence. It reviewed initial analyses of safety, preparations for startup, operating plans and limitations, unusual occurrences, proposals for modifications, and so on, and issued numerous letters to the Chairman containing comments and recommendations. These reviews had a sizeable impact on the design, construction, and operation of the facilities. As time went on, the safety features of the defense-related facilities, which originally were not characteristic of the later nuclear plants in the commercial sector, were modified to resemble corresponding features of the commercial sector more and more. They still deviated from commercial practice in ways that continued to be justified on the basis of need for national defense, but the ACRS made it clear that it saw the approach of an end to the double standard. The ACRS recommendations had led to a number of modifications to Hanford and Savannah River reactors to enhance safety, including addition of emergency cooling systems, provision of capability to confine fission products in event of an accident, and limitations to neutronic performance in the interest of safety.

Parallel to the system of monitoring by the ACRS, the AEC maintained an in-house activity which watched over nuclear facility safety. This was accomplished through a separate Division of Operational Safety, which maintained a presence in the field offices that were the channels for contractual management of facilities, and that reported to the General Manager of the Commission. This Division of Operational Safety included a technically competent staff that provided a nearly real-time view of the status of safety of reactor operation.

In 1974, the Energy Reorganization Act was passed, terminating the AEC in what the then-Chairman, Dixy Lee Ray, said was "a bad idea whose time has come." There is little doubt but that the effects were harmful to the methods used to provide independent oversight of the safety of the nuclear reactors inherited by the new ERDA. The continuing monitoring by the ACRS was ended; though the Secretary of Energy was later given the right to request advice on any matter from the ACRS, it was clear that this was to be an exceptional exercise, and I know of no record of its being done by a Secretary of Energy for a production reactor.

The responsibilities formerly under the Division of Operational Safety were assigned to the organization reporting to the Assistant Administrator for Health and the Environment, and in my judgment the safety tracking was badly weakened in the process.

Starting in about 1974, the safety of the reactors operated by ERDA (and later DOE) contractors became almost exclusively the province of the contractors and the associated field offices. This was the state of the system as it was reviewed by the Academies' committee.

Another related factor has affected DOE reactor safety assurance. The Undersecretary is the DOE's operational manager. The various program Assistant Secretaries report to him, as do almost all of the other Washington offices. The operations of the Department are for the most part conducted by contractors who operate the various DOE facilities. These include the production facilities at Hanford

and Savannah River. The contracting offices for these operations are the field offices, in these cases field offices at Savannah River and at Richland, Washington. The contracting office provides the interface between the contractor and DOE. The field office managers report independently to the Undersecretary.

The Assistant Secretary for Environment, Safety, and Health has been assigned a responsibility for oversight of the safety, quality assurance, and environmental performance of both the DOE line management and the contractors. The lines of communication for exercise of this responsibility are long, flowing through the Undersecretary, and the resources of the office of the Assistant Secretary have not been extensive, though they have been strengthened in the past year or two. The responsibility for safety achievement and monitoring has been almost entirely with the contractors for a number of years. It has not been possible to retain skilled reactor safety staff in the field office positions, which are generally marked by routine and by lack of substantial ability to affect the course of events.

The contractors themselves have continued to provide large staffs responsible for reactor operation, engineering, safety, and environmental protection, among other functions. The staffs are experienced and (in the words of the Academy committee's report) reasonably technically sophisticated, with senior managers who typically have long-standing familiarity with the reactors. Each site also has the benefit of an associated support laboratory of national repute.

Yet the diversity of missions and designs of DOE's reactors, the independence of the field offices, and the lack of a strong central safety function such as was once provided by the ACRS and the Division of Operational Safety, have led to a fragmenting of safety concepts and methodologies among the separate reactor facilities. An almost total disappearance of interaction with the commercial reactor safety field contributed to an isolation of DOE facilities from nuclear safety trends and concepts being developed elsewhere. There was even an isolation of the two production sites from each other, with different safety concepts and methods used at them.

A complicating problem was that the budgets for operations and for safety were merged into a single budget which was prepared within the offices of the Assistant Secretary for Defense Programs, and obtained as a unit through the administrative and legislative budgetary process. This introduced a conflict that in general was surely more apparent than real, but the committee did find that in some cases the contractor sought budgetary support for changes for safety purposes that were not implemented because of lack of funds made available.

These were the major institutional problems contributing to the committee's conclusions and recommendations. The conclusions were the basis for recommendations for institutional change, and were concentrated in areas of internal DOE management and provision of external, independent surveillance. In effect, they called for restoration of practices comparable to those previously followed by the AEC.

The *first conclusion* was:

- The Department of Energy's management approach copes with the mix of production and safety responsibilities faced by the Department, but falls short of reasonable expectation.

The *related recommendations* were directed toward strengthening those Environment, Safety, and Health (ES&H) functions related to DOE production reactors:

- DOE should expand its capability to sponsor research, conduct and review safety analyses, evaluate operations, analyze trends, and assess proposed plant upgrades.

- ES&H should have a permanent and significant onsite presence with a formal reporting relationship between onsite personnel and headquarters staff.
- ES&H should have more direct access to and involvement in the resolution of key safety issues on a timely and effective basis.
- ES&H should be centrally involved in the Department's internal budgetary processes so as to help assure adequate funding for safety improvements.

The *second conclusion* of the committee was

- DOE's safety oversight of production reactors is ingrown and largely outside the scrutiny of the public. Weaknesses in management of the defense production reactors have led to a loose-knit system of largely self-regulated contractors operating within budgetary constraints imposed by and on DOE.

There were two *related recommendations*:

- An independent external safety oversight committee, advisory to the Secretary of Energy, should be established. The com-

mittee should: be of recognized stature with expertise covering the full range of relevant disciplines relevant to reactor safety; include individuals from outside the DOE community; set its own agenda; review both the product and the process of DOE and contractor efforts, including review of design, safety analysis, operations, management, inspection, and enforcement; have a full-time and technically qualified staff and a budget adequate to obtain external technical assistance as required; conduct the bulk of its work outside of classified channels; and make its work available to the public.

- The Department of Energy should encourage each contractor to establish a permanent visiting committee of outside experts to review and assess the implementation of safety initiatives and to report to contractor management at the site and at corporate headquarters. These committees should be free to set their own agendas.

## A STUDY OF INTERACTIVE DISCRIMINATION IN THE MIDCOURSE PHASE

Guy Letterer

The current research and development programs of the Strategic Defense Initiative have provided limitations on the basic framework for the near-term deployment of a variety of ballistic missile defense schemes. Among these, the use of neutral particle beams (NPBs) as interactive, midcourse-phase discrimination devices has been described as "the cornerstone of a cost-effective BMD system" (1). The basic problem entails the identification of massive nuclear warheads amidst lightweight decoys by detecting characteristic nuclear radiation which is induced due to interactions between the nuclei in the warheads and the incident beam of particles. Since the fraction of the beam that is stopped by the target is proportional to the area of the target illuminated by the beam, the total energy (in the form of particles and/or radiation) emitted is proportional to the mass of the target. Thus, by using a particle beam to illuminate briefly each object within a swarm of attacking nuclear warheads (e.g., mylar balloons) and then by detecting any re-emitted flux of particles or radiation, one can conceivably "weight" each object consecutively, and identify the massive ones (ignoring the empty decoys) for subsequent interception (2). Recent work (3,4) has yielded pertinent information on the gamma ray signals that are induced by proton beams on various targets. Such results emulate the use of neutral hydrogen beams as midcourse discriminators. Although the neutron signal would certainly be detected and employed in this discrimination process, this article will focus solely on the gamma rays that are involved.

Typical NPB prototypes under study at the Los Alamos National Laboratory (1) call for 50-100 MeV and 0.1-1 ampere hydrogen beams with an angle of divergence (due to the emittance of the accelerator) of approximately  $\alpha = 3 \mu$  radians. An additional divergence of the beam at the target is given by the beam due to the neutralization of the accelerated  $H^-$  ions must be included as an independent source (i.e., quadratically). This quantity has a minimum value of approximately  $\beta = 6 \mu$  radians (5). Suppose the accelerator is orbiting a distance  $X$  from the target and the detection platform is a distance  $Y$  from the target (at a right angle to the accelerator/target distance). The diameter of the beam at the target

is given by:

$$B^2(X) = B^2(0) + (\alpha_n X)^2 + (\alpha_n X)^2 \quad (1)$$

In Eq. (1),  $B(X)$  is the diameter of the beam at the target and  $B(0)$  is the diameter of the beam as it leaves the accelerator (approximately 0.30 m) (1).

Suppose the target is taken to be a fission-fusion-fission weapon with a cylindrical shape, outer jackets of uranium and iron, and an approximate length of  $L = 0.50$  m. The diameter of the beam at the target will be assumed larger than the target. The APS study on directed energy weapons (6) considers the case where the beam is smaller than the target and arrives at results consistent with this calculation.

The significant quantity that determines the effectiveness of the discrimination process is the gamma ray detection rate,  $\phi$ , given by:

$$\Phi(E, \theta) = \frac{fI}{e} n \epsilon(E) F G \Delta\Omega(\theta) \frac{d\sigma}{d\Omega}(E, \theta) \quad (2)$$

In Eq. (2),  $E$  = energy of the detected gamma ray,  $\theta$  = angle of the detector ( $90^\circ$  in this case),  $I$  = current of the hydrogen beam,  $f$  = efficiency of the neutralization of the  $H^-$  ions,  $e$  = charge of a proton,  $n$  = number of nuclei/cm<sup>2</sup> traversed by the beam,  $\epsilon(E)$  = efficiency of the detector for gamma rays of energy  $E$ ,  $F$  = beam loss factor due to the fact that the beam is larger than the target =  $L^2/B^2(X)$ ,  $G$  = attenuation factor due to the passage of gamma rays through the outer jackets of iron and uranium (see below),  $\Delta\Omega(\theta)$  = solid angle of the detector as seen from the target = (area of detector)/ $Y^2$ , and  $d\sigma(E, \theta)/d\Omega$  = the  $(p, x, \gamma)$  differential cross section for gamma ray energy  $E$  and detector angle  $\theta$  (in cm<sup>2</sup>/ster).

The attenuation factor  $G$  is due to the passage of gamma rays through the outer layers of the uranium and iron jackets once they

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are produced. If the proton beam penetrates a distance of 8.80 g/cm<sup>2</sup> (the approximate range of 67.5 MeV protons in uranium) and the iron jacket is taken to be 7.87 g/cm<sup>2</sup> thick, the attenuation factor is found to be G = 0.432 (3).

The measurement of the differential cross section was accomplished at the Crocker Nuclear Laboratory with a 67.5 MeV proton beam (produced with an isochronous cyclotron) illuminating a stationary target of uranium (of thickness 48.4 mg/cm<sup>2</sup>). A Ge(Li) detector was positioned at 90° (relative to the proton beam) in order to detect the gamma rays. Gamma rays of several different energies were deemed to be characteristic "fingerprints" of uranium and could be used collectively to identify the presence of a nuclear warhead in the midcourse phase. However, for the sake of simplicity, only one gamma ray energy will be used here. The differential cross section for the 0.9308 MeV gamma ray (which emanates from a transition from the 10th excited state to the ground state in a nucleus of <sup>238</sup>U) was measured to be 1.45 x 10<sup>-26</sup> cm<sup>2</sup>/ster<sup>3</sup>.

In regard to Eq. (2), it will be assumed that I = 0.1 A, f = 0.5, ε = 1.0, the area of the detector = 1.m<sup>2</sup>, and n = 2.22 x 10<sup>22</sup> nuclei/cm<sup>2</sup> (this corresponds to the above distance of 8.80 g/cm<sup>2</sup>). With these, one finds:

$$\Phi = \frac{1.085 \times 10^{13}}{Y^2 (0.090 + 4.50 \times 10^{-11} X^2)} \quad (3)$$

For the case where X = Y = 1000 km, one finds φ = 0.241 cps. Since the cosmic background is about 1 cps (6), such a detection rate is insufficient for discrimination purposes. If X = Y = 100 km, then φ = 200 cps and discrimination appears quite possible.

Based on the results of the (p,x,γ) experiment, a gamma ray event total of 100 counts gives an uncertainty of about 10%. With this assumption, one must achieve φ = 100 cps for 1 second, or 1000 cps for 0.1 seconds, etc. As a conservative estimate, the former will be assumed. Table I lists several values of X and Y (the accelerator/target distance and the detector/target distance) that result from Eq. (3).

As Table I clearly shows, the trade-off between accelerator/target distance (X) and detector/target distance (Y) is such that the orbiting platforms would need to be prohibitively close (< 250 km) to the swarm of nuclear warheads in order to sort through the decoys and isolate the warheads for subsequent interception. Typical distances of 1000 km are required in order to facilitate most midcourse BMD schemes due to geometrical constraints on the absentee factors for satellite orbits. In a time period of 20 minutes, if one assumes one second for identification and one second for re-aiming to a new target, each station could identify no more than 1200/2 = 600 objects. In a scenario where there are 10,000 objects requiring discrimination, it would be necessary to orbit 167 accelerator/detector pairs. Allowing for an absentee factor of 5%, this value increases to over 3000 accelerator and detector stations in orbit. For the case where 0.1 seconds time intervals are assumed, this figure becomes about 300 accelerators and detectors in orbit. Such analysis indicates the harsh realities that any defense against ballistic missiles in the

midcourse phase must overcome in order to have even a remote chance of success.

Of course, one must consider the collective effects of several different gamma rays and the secondary neutrons which are involved in this process. Both of these effects would tend to enhance the discrimination capabilities of such a device. However, calculations which include these have been performed and do not change the above conclusions by more than a factor of 10 or so. Also, the use of countermeasures and "second generation" penetration aids undermines the inclusion of these additional factors (especially the neutron signal) (3).

The findings of this study on the use of secondary gamma ray signals produced by neutral particle beams in interactive discrimination devices indicate that the problems of midcourse discrimination remain an unsolved challenge for SDI researchers. At the very least, the need for further study prior to near-term deployment of any component of a space-based BMD is warranted.

Table I. Accelerator/target distances (X) and detector/target distances (Y) for the gamma ray detection rate (φ) of 100 cps in Eq. 3.

X (km)	Y (km)
50	732
100	448
219	219
500	97.8
1000	49.1

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## DO WE NEED LAND-BASED MISSILES AT ALL?

Gerald E. Marsh

There would be no need to ask whether we need land-based missiles if there weren't some liability associated with their current role. What is wrong with these missiles is that they are vulnerable to Soviet attack. The history of how they got that way is interesting: it all goes back to the decision made in 1969 by the Nixon admin-

istration to proceed with the deployment of Multiple Independently-targetable Reentry Vehicles (MIRV) (1). This decision was

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made in spite of the fact that then national security advisor Henry Kissinger was repeatedly warned by a distinguished group headed by Paul Doty (which included Jack Ruina, George Rathjens, Carl Kaysen, Sid Drell, Wolfgang Panofsky and Dick Garwin) that if testing of MIRV continued, the land-based missile force would eventually have to be abandoned.

Jack Ruina and George Rathjens recommended at that time a unilateral cessation of testing, so long as the Soviets would also stop; many others, including Gerard Smith, Elliot Richardson and William P. Rogers, also proposed MIRV flight test bans. Their advice was ignored, and as a result we find ourselves today proposing one scheme after another to deploy land-based missiles in a survivable mode.

The concern for survivability derives from the fact that as the missiles become more vulnerable to Soviet attack, there is a growing incentive to launch them on warning. Although Donald Lathan, Assistant Secretary of Defense for C<sup>3</sup>I, told Congress in the Spring of 1986 that "our policy is not one of launch on warning, absolutely not," General Charles A. Gabriel testified in February 1985 when he was Air Force Chief of Staff that

"There are options that I won't go into. Obviously, if (the enemy) were going for our missile silos, there will be a period of time when we can see his weapons coming. We have sensors that tell us that. There are options that obviously do not make them sitting ducks."

In September of 1985, General Robert T. Herres, then Commander and Chief of the North American Aerospace Defense Command (NORAD), told the House Committee on Government Operations that

"We in the military would like to provide the national command authority with the flexibility to be able to ride out at least some portion of a nuclear attack if that should be necessary." Unfortunately, he added, "[we] have been able to keep up with the capability to launch on warning, but to go beyond that takes quite a bit of investment" (2).

What is clear from these statements is that the U.S. now preserves the *capability* to launch under attack as a stated doctrine — but does not necessarily rely on such a posture.

Some people have advocated simply declaring a launch-under-attack policy thereby solving the vulnerability problem. The deployment of MX missiles in Minuteman silos, the "new wine in old wineskins" approach to missile basing, is tantamount to doing just that. Although such a policy has minimal risks during a period of detente, the danger of error increases as tensions rise. And, unfortunately, U.S. leaders tend to use the alert level of strategic forces to send political messages — a very dangerous practice indeed.

There are a number of things wrong with a launch-under-attack posture:

- It might not work. The National Command Authorities may be unwilling or unable to make the decision to launch within the 5 to 10 minutes available if there is an SLBM attack against Washington and communication facilities.
- Because of this possibility it may be necessary to pre-delegate launch authority to the Airborne National Command Posts or otherwise "wire-in" the response to an attack, especially if weapon effectiveness as measured by accuracy, time-on-target control, and the like are to be preserved.
- The ability to control escalation, if one believes it is possible to do this, would be severely degraded.
- And last, but by no means least, there is the possibility of error. These are, in my opinion, unacceptable risks.

There are two principal reasons advanced for preserving the land-based missile leg of the strategic triad: First, the belief that diverse basing gives greater assurance that strategic forces can weather any future technological breakthrough that might increase the vulnerability of one leg of the triad; and second, that there are special missions requiring the combination of high yield and accuracy attributed to the land-based missiles.

Because of the concern over the land-based missiles, many in the defense community have been embracing, with a sense of relief, attempts to refocus SDI toward defending them. They believe that such a redirection would rescue SDI in a way that would enhance stability. This argument is fallacious: Although point protection of silos is technically more feasible now than it was in the 1960s, such a system can still be overcome with the combination of an offensive buildup and the deployment of tracking and discrimination countermeasures. For this reason limited ABM defenses contribute to arms-race instability, nor do they decrease the incentive to launch the land-based missiles on warning of an attack: Soviet preemptive capability should be judged not only by the number of US warheads destroyed, but also by the ability to prevent the land-based missile force from carrying out its intended mission. In this context, Soviet preemptive capability could only be eroded by a highly effective defense.

Another approach to increasing survivability is to make the land-based force mobile. Unfortunately, we have been unable to find an acceptable and survivable basing mode for either the MX or the proposed Midgetman because of operational constraints dictated by social and political circumstances. These are unlikely to change in the future. Whatever the potential of mobile missiles, elimination of fixed land-based missiles would be an enormous contribution to crisis stability.

The argument that the land-based missiles are required for special missions because of their combination of yield and accuracy is no longer compelling. The Navy's new Trident II missile, deployed and supported to its fullest potential, could perform the same missions as the land-based force.

The Trident II's capabilities could allow the United States to move toward a more stable strategic balance based on a diad of survivable nuclear forces: Strategic missile submarines and a bomber force that, armed with long-range cruise missiles, need not penetrate Soviet air space to carry out most of their missions. Land-based ICBMs need not be eliminated immediately, but could be allowed to "age gracefully."

Once one gets over the initial shock of this heresy, it can be seen that the evolution to a diad would offer a number of advantages:

- Because the Trident II's mission would be identical to that of the land-based missiles, the vulnerability of land-based missiles would no longer be a concern.
- Since land-based ICBMs would no longer have special status, and currently carry only about 25 percent of US warheads, there would be much less incentive to launch them on warning.
- Money would not have to be spent to upgrade the aging infrastructure supporting land-based missiles — a cost often overlooked by Congress when considering deploying the MX in Minuteman silos.
- The decision to evolve toward a diad would not require reciprocal action from the Soviet Union.

Many have expressed the concern that ballistic missile submarines suffer from irremediable command, control and communications deficiencies and vulnerabilities. These issues have been vastly overblown. Even a so-called decapitating strike by the Soviet Union would be incapable of preventing the ballistic missile sub-

marines from receiving their launch orders. Concern with submarine communications is centered on the ability of the various communications systems to endure throughout an extended nuclear war, not on the ability to respond to an attack on the United States.

Evolving toward a diad, however, would mean giving priority to strategic considerations in determining U.S. force structure and in funding defense programs. Unfortunately, as Robert Komer, a former undersecretary of defense for policy, noted in a Foreign Affairs article in the summer of 1982, "The professional body to which the Administration would logically turn for advice, the Joint Chiefs of Staff, is far less able to reassess strategy than to clamor for

more resources." The U.S. force posture, he continues, "tends to be dictated by service parochialism and such domestic considerations as which defense contracts get what."

This is not a very positive note with which to conclude. But it is unfortunately where we stand today.

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## REVIEWS

### ARMS AND ARTIFICIAL INTELLIGENCE: WEAPONS AND ARMS CONTROL APPLI- CATIONS OF ADVANCED COMPUTING, edited by Allan M. Din

Oxford University Press, New York, N.Y., 1987, 256 pages

Currently, artificial intelligence (AI) is *hot*. A decade ago, AI existed mainly in elite academic and industrial institutions supported by the Defense Advanced Research Projects Agency (DARPA), where researchers pursued the science fiction fantasies of their SF author/heroes: Asimov, Heinlein, Dick, *et al.* Nascent industrial applications, such as robotics and expert systems, bolstered by the Japanese fifth generation "challenge," increased the scope of applications, institutions involved, and monetary support. Recently, the spate of controversial US military programs, such as "Star Wars," autonomous weapons, and "smart" to "brilliant" weapons, has focused attention on AI realities and hallucinations as the enabling technology for these programs.

This book represents the efforts of attendees at a Stockholm International Peace Research Institute (SIPRI) conference, organized by the editor, Allan Din, to bring together "the knowledge and experience of experts from six different countries" in order to begin an assessment of AI in "key areas of importance to international security, command and control, strategic defense and verification." As a map to current and projected military and arms control applications of AI and other advanced computing technologies, this book is useful. As a well-grounded critique for potentials, realities, and consequences, the book barely skims the surface.

The opening two sections include an overview, background from computer scientists on AI and its computer hardware requirements, and a thought piece on differences between human and machine intelligence in the context of conflict.

Articles in the third section detail US and NATO plans for AI in military and strategic arenas, and a background article by Soviet researchers. Leading this section, Akersten describes the objectives and initial five-year "achievements" of DARPA's Strategic Computing Program (SCP). Although detailed, Akersten glosses over the technical hurdles toward developing the three projects, corresponding to the three military services: the Autonomous Land Vehicle (Army), a Pilot's Associate (Air Force), and a Battle Management System for a Carrier Battle Group (Navy). SCP has fostered considerable controversy within academic and professional circles, particularly from Computer Professionals for Social Responsibility, because of the implied change in DARPA's support for basic computer science research. Akersten suggests that this

change in DARPA's role towards scientific R&D - from support for pure and applied R&D to including advanced technical implementation previously done by industry and the military services - was inevitable.

Other critics of the SCP and of similar programs have focussed explicitly on changes in tactical warfare and military doctrine. In the next paper, "Artificial intelligence and the automated tactical battlefield," Nikutta argues that "these technologies are revolutionary in their effect because they automate the battlefield and further radically dehumanize the course of war." Nikutta traces the aims of automated battlefield programs, such as the SCP, and new operational concepts such as Airland Battle and Follow-on-Forces-Attack, back to the electronic weaponry developed and tested during the Vietnam War. Nikutta's concerns arise over crisis stability and civilian political control. He argues that automated systems leave little time for decisions, thus decreasing the involvement of humans outside the battlefield and increasing the pressure for immediate if not automatic action in response to data which cannot be verified by humans. The decreasing response time follows from increasing integration at all levels.

In "Software and systems issues in strategic defense," Lin argues that software requirements for ballistic missile defense (BMD) make population defense infeasible. Others have argued this elsewhere, but Lin pushes further in that confidence in any BMD system, for partial population defense or for defense of military assets, is misplaced when considering the complexities of software reliability, testing, and maintenance. The major conclusion from Lin's discussion is that regardless of the time, money and human resources a nation commits to BMD, an effective ability to retaliate must be preserved because we cannot have confidence in the effectiveness of those systems.

Closing the third section, in "Artificial intelligence and disarmament" Soviet researchers Averchev, Kochetkov, and Sergeev review technological advances which have changed warfare historically and portend that new information technologies, including AI, "will result in drastic changes in the possible modes of war-fighting." They focus on the oversold potential of these advanced weapons systems and admonish "Western politicians" who act as if the potential was actual capability. They ask the scientific community to clarify the impact of AI on "weapon capabilities and on the world military-political situation."

The fourth and final section focuses on AI in arms control and verification. In "Computer applications in monitoring and verification technologies," Orhaug presents imaging techniques, analyzes the advances necessary for automatic scene and object recognition, and concludes that for the near future, verification must still be done

by human experts in photo-interpretation. In "Verification and stability: a game-theoretic analysis," Brams and Kilgour present a formal analysis of the "verification game." The analysis suggests that if the probability of detecting violations is not high, verification will fail because the "rational" strategy of players is to violate and challenge. Therefore, from a formal (or even common sense) viewpoint, verification should aim to increase detection capabilities.

The final two papers present AI systems for war game simulation and arms control. In "Knowledge-based simulation of nuclear strategy," Davis presents an overview of a war-game simulation developed at RAND "for studying three issues in nuclear strategy: deterrence, escalation control, and war termination." He argues that the simplicity of game-theoretic models can hinder real decision-making, and that AI techniques can help close the gap between real human decision-making regarding issues of nuclear war and game-theoretic principles. In "ARMCO-I: An expert system for nuclear arms control," Din follows a rhetorical AI tradition by arguing for the development of superior technology by contrast to the inferiority of "the average human mind."

AI is a new technology, and in a world driven to technical fixes many try to fit AI to our most pressing dilemmas. Perhaps incorporation of AI into weapons systems and arms control initiatives is "inevitable." However, as with other technical fixes, this does not address the underlying, difficult issues of values and choices.

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## THE ARMS RACE AND NUCLEAR WAR by David P. Barash

Wadsworth Publishing Company, Belmont, CA 1987, 365 pages,  
paper \$23

This is a comprehensive 350-page paperbound text, written at a level suitable for a general college audience. It is well illustrated and pedagogically well structured. Study questions and a bibliography are provided for each chapter. Key terms are printed in boldface and listed at the end of the chapter in which they are introduced, though not defined in a glossary. The book is densely packed with information yet highly readable.

The author, a biologist, needs help with his physics. He confuses atomic weight with atomic mass number, the strong force with binding energy, and geodetic anomalies with geomagnetic ones. He suggests that all radioactivity is caused by a surplus of neutrons, that nucleons are "smaller" when they are inside a nucleus than when they are free, that the short range of alpha particles is due to their being "large," and that a neutron must have high energy to induce nuclear fission. And so on. Fortunately, these problems are mostly limited to the first chapter and can be rectified in the lectures.

Aside from the physics, some other errors are worth mentioning. In table 2.2, the yields listed for the Minuteman III and MX warheads are ten times too large. The Soviet SS-13 is missing from Figure 9.8. Table 12.2 gives the first operational year for the Trident II missile as 1969 rather than 1989. The statement on page 66, that "rad" and "rem" are used interchangeably for most purposes, is unwarranted because neutrons and alpha particles cannot be ignored. The statement on page 280, that military spending is a larger fraction of GNP now than during the Vietnam War, is contra-

dicted by Figure 12.3 on the same page. There is also no consistency in units of measure; for example, feet, meters, miles, and kilometers are all used on pages 74-75!

Despite his strongly dovish views, Barash has attempted to make *The Arms Race and Nuclear War* a balanced textbook. In that, he has failed. Mock debates, intended to illustrate both sides of the issues, too often consist of anemic straw-man hawks being picked apart by dovish ripostes. The author's viewpoint is built into the very way he defines the issues and the opposing sides. Why, for example, do we have so many weapons? The motivating factor for U.S. policy makers since World War II is certainly clear: the Soviet Union, with its brutal disregard for human rights, its ideologically driven imperialism and its obsession with military power, threatens free peoples. It is in response to that threat that we maintain enormous military capabilities, including a variety of nuclear weapons, in order to deny the Soviets credible military options against the West. What Barash does is to assign that view of things, along with Dwight Eisenhower, whom he quotes on page 200, to the political "far right." He then places on an equal footing a "far-left" view that the U.S. is to blame for the arms race. Between those "extremes," the middle ground is a purely dovish proposition, that the Soviet-American military confrontation is some sort of crazy game being played out by morally equivalent adversaries.

Moral equivalence is promoted by numerous passages that refer abstractly to "Side A" and "Side B," "one side" and "the other," and by excuses continually offered for the Soviets' first-strike-oriented strategic forces, their massive, offense-oriented conventional forces in Europe, and their behavior generally. Readers are discouraged from thinking too much about the wide range of military challenges the West might face, or about less-than-total nuclear war. Such considerations fall into the category of "nuclear war-fighting," a morally questionable game for morally equivalent adversaries to be playing. Frequent reference to the views of "peace groups" suggests that we who disagree with those views must belong to "war groups." Civil defense gets only a few pages, but a whole chapter is devoted to "nuclear psychology" (missiles as phallic symbols and all that). Thus, an ostensibly even-handed presentation in fact delivers a one-sided message—not intentionally, I'm sure, but simply because the competition between opposing views takes place on one side's home turf.

What good is a biased book like this? Well, I use it as the text for a half-semester on nuclear war in my Science, Technology, and Society course. Students get one view from Barash, a very different view from me. The result is more balanced and, I believe, more thought-provoking than either of us could have provided alone. On the other hand dovish-left faculty who care about balance won't get it from this book. Robert Ehrlich's excellent *Waging Nuclear Peace* might be a more appropriate choice for them.

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## SEISMIC VERIFICATION OF NUCLEAR TESTING TREATIES, by the Office of Tech- nology Assessment

US Congress, Washington, DC, 1988, 139 pages, \$7

Over the past 15 years, the Congressional Office of Technology Assessment (OTA) has been able to avoid politicization of technical

issues, presenting the consensus view of professional scientists and engineers on issues that affect public policy. By obtaining competent panels representing wide opinions, OTA has produced many landmark reports on these large issues. The recent OTA report on Seismic Verification of Nuclear Testing Treaties continues this level of honest competence.

Over a decade ago the US and the Soviet Union signed the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET) which limit nuclear explosions to under 150 kilotons. The US has not yet ratified these treaties, but will do so when the standard of verification has been improved from the original standard of  $F=2$ , which means that 95% (2 sigma) of the explosions at 150 kilotons would be measured between 300 kt ( $2 \times 150$ ), and 75 kt ( $150/2$ ). In order to proceed with ratification, Executive Branch has required that CORRTEX be used at the Soviet site in order to improve  $F$  to a value of about 1.3. After ratification of the TTBT and PNET, both sides would then begin negotiating on either a lower threshold than 150 kt, or a Comprehensive Test Ban Treaty (CTBT). OTA was requested by the House Committee on Foreign Affairs and by the two intelligence committees to examine the technical facts, and lay out the options for Congress. OTA was instructed to consider the progress that has been made on seismic methods in the past decade: (1) Remote, unattended seismic stations have been operated. (2) The Soviets have allowed the NRDC to operate seismographs in the Soviet Union. (3) The unified seismic method, which uses the  $L$  wave, reduces random errors by 30%. (4) By monitoring several shots with CORRTEX, it is possible to reduce systematic errors considerably. (5) Small arrays of seismographs, such as the Noreass array in Norway, can easily detect very small explosions. Some of OTA's conclusions are as follows:

*How low can we go?* Noreass has obtained a 10-to-1 signal-to-noise ratio on explosions of 0.25 kt, however the issue of identification at these lower levels is greatly exacerbated because of other small seismic signals from small earthquakes and chemical explosions. OTA states that "From a monitoring standpoint, stations within the Soviet Union are more important for improving *identification* capabilities than for further reduction of the already low detection threshold." OTA concludes that "The structure of any treaty or agreement should be approached through a combination of seismic methods, treaty constraints, and inspections that will reduce the uncertainties and difficulties of applying seismic monitoring methods to every conceivable test situation." OTA considers four different treaty regimes:

*Above 10 kt:* "Readily monitored" with external seismographs and National Technical Means. "For accurate monitoring of a 10 kt threshold treaty it would be desirable to have stations within the Soviet Union—."

*1-2 to 10 kt:* "Monitoring network must demonstrate a capability to defeat evasion scenarios. —Demonstrating a capability to defeat

credible evasion attempts would require seismic stations throughout the Soviet Union (especially in areas of salt deposits), negotiated provisions within the treaty to handle chemical explosions, and stringent testing restrictions to limit decoupling opportunities. If such restrictions could be negotiated, most experts believe that a high-quality, well run network of internal stations could monitor a threshold of about 5 kt. Expert opinion about the lowest yield that could reliably be monitored ranges from 1 kt to 10 kt."

*Below 1-2 kt:* "Additional work in identification capability will be required before it can be determined whether such small decoupled explosions could be reliably differentiated from the background of many small earthquakes and routine chemical explosions of comparable magnitude." However, "There remains—a lack of consensus on the extent to which the use of higher frequency data will actually improve monitoring capabilities."

*CTB:* "There will always be some threshold below which seismic monitoring cannot be accomplished with high certainty. A comprehensive test ban treaty could, however, still be considered verifiable if it were determined that the advantages of such a treaty would outweigh the significance of any undetected clandestine testing (should it occur) below the monitoring threshold."

*Estimating the yield of nuclear explosions:* "Most of the systematic error associated with estimating the yields of Soviet nuclear explosions is due to geological differences between the US and Soviet test sites and in the coupling of the explosion to the Earth. Therefore, the single most important thing that can be done to reduce the uncertainty in yield estimation is to calibrate the test sites." The first stages of such a calibration have just taken place with the use of CORRTEX in the Joint Verification Experiments at the Nevada and Soviet test sites during the summer of 1988. OTA estimates that once the calibration procedures are completed, seismic methods will be sufficient for the TTBT, by stating "It is estimated that through such measures the uncertainty in seismically measuring Soviet tests could be reduced to a level comparable to the uncertainty in seismically measuring US tests. An uncertainty factor of 1.3 is the current capability that seismic methods are able to achieve for estimating yields at the Nevada test site." In other words, CORRTEX and calibrated seismic methods (using  $L$ ) have about the same  $F$  factor.

*Soviet compliance:* "All of the estimates of Soviet and US tests are within the 90 percent confidence level that one would expect if the yields were 150 kt or less." This conclusion disagrees with the charge of "likely violation" of the TTBT.

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## NEWS

### COMING FORUM SESSIONS: JOINT MEETING OF APS, AAPT, AAAS IN SAN FRANCISCO, 15-19 JANUARY 1989

ENERGY RESEARCH AND FUNDING IN THE 1990S:  
STATUS AND FUTURE DIRECTIONS

Ruth Howes, Ball State University, presiding.  
Probable time: Sunday evening 15 January.

- William F. Martin, Washington Policy Analysis, "Overview of energy research and funding plans"
- Robert Budnitz, President, Future Resources Associates, Inc., "Is there a future for fission electric power?"
- Arthur Rosenfeld, Director, Center for Building Science, Lawrence Berkeley Laboratory, "Energy efficient buildings: problems and promise"
- H. M. Hubbard, Director, Solar Energy Research Institute, Department of Energy, "Solar energy today and tomorrow"

## THE UNIVERSITY OF CALIFORNIA, NATIONAL WEAPONS LABORATORIES, AND ARMS CONTROL

Paul Craig, University of California-Davis, presiding.

- Karl Hufbauer, Associate Professor of History, University of California-Irvine, "A historian's perspective on science, arms control and the management of the national laboratories"
- Jose Fulco, Chairman, Department of Physics, University of California-Santa Barbara, "The bases for concerns about the University of California connection to the weapons laboratories"
- John Nuckolls, Director, Lawrence Livermore National Laboratory, "Livermore Laboratory in the 1990s"
- Speaker to be announced, "Improving the role of the national laboratories in contributing to arms control"
- Deborah Blum, Reporter, *Sacramento Bee*, "Public perspectives on the University of California/National Weapons Laboratory relationship"

## SPACE NUCLEAR POWER AND ARMS CONTROL

Co-sponsored by AAAS and the APS Forum on Physics and Society  
David Hafemeister, California Polytechnic University, presiding.

- Daniel Hirsch, Director of the Stevenson Program on Nuclear Policy, University of California-Santa Cruz, and Joel Primack, Professor of Physics, University of California-Santa Cruz, "Why orbiting reactors should be banned"
- Roald Sagdeev, Director, Space Research Institute of the Soviet Academy of Sciences, USSR, "A joint proposal to ban nuclear power in earth orbit"
- Joseph G. Gavin, Chairman, NAS Study on Advanced Power Sources for Space Missions, "Advanced power sources for space missions"
- George M. Hess, Director, Survivability, Lethality and Key Technologies Division, SDIO, "SDI's nuclear power programs"

ALSO look for the following AAAS sessions:

- SDI testing and the ABM Treaty (Carter)
- Negotiated force reduction in Europe (Dean)
- Implementation of major arms control agreements (Graybeal)
- National security implications of commercial satellites (Krepon)
- Implications of a global weapons convention (Messelson)
- Biological and toxin weapons (Zalinskas)
- Environmental concerns affecting national defense and security (Carnes)
- Technology for fissile material detection (DeVolpi)
- Implication of Soviet new thinking about international security (Duffy)
- Limitations to nuclear testing (Fetter)
- National security implications of high technology trade with the USSR (Hecht)
- Arms control without negotiations: the role of unilateral initiatives (Ramberg)
- Physics of the Atmosphere (Beasley)

## CURRENT FORUM OFFICERS

Two additions need to be made to the list of current Forum officers published in the July newsletter. We are sorry that these were omitted from the previous list:

Secretary-Treasurer: Henry H. Barschall.

Representative to the Forum from the APS Council: Richard Freeman (in addition to Francis Perkins).

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## THE BUENOS AIRES OATH

The idea of a Hippocratic oath for scientists has been mentioned for many years, but G. Lemarchand, an astrophysics student at the University of Buenos Aires, has decided to do something more than mention it. For over a year, Lemarchand has been refining the concept and pushing for the implementation of the oath. With the support of UNESCO, the University of Buenos Aires, the national government, and other universities, Lemarchand was instrumental in organizing the international symposium, "Scientists, Peace and Disarmament", held in Buenos Aires. During the week-long meeting, a committee of panelists met to consider the working and objectives of the oath. This was a difficult task because different delegates had different concepts of the purposes and implementation of the oath. In several countries of South America, students actually swear an oath when they receive their diplomas, and the oath was thought of as a method of committing scientists to work only on peaceful research. In North America, it is not customary to swear an oath to anybody for anything so this oath was perceived to be a method of increasing social awareness. Since they believed that most US scientists would never sign a pacifist oath, participants felt it was better to have them morally committed to consider the purposes and effects of their research. The final wording signed by most of the panelists avoided specific promises and in essence is a moral statement:

"Aware that, in the absence of ethical control, science and its products can damage human society and its future, I pledge that my own scientific capabilities will never be employed merely for remuneration or prestige, or on instruction of employers or political leaders alone, but only on my personal belief and social responsibility - based on my own knowledge and on consideration of the circumstances - that the scientific or technical research I undertake is truly in the best interests of society and peace."

The participants agreed that this would be the suggested wording, although individual universities (in the case of South America) or professional organizations in various countries could alter the actual text to fit their specific needs. Letters describing the oath are being sent to a commission of the USSR Academy of Sciences.  
[Reprinted from *Astronomers and the Arms Race*, May 1988, with permission.]

## SAVE THE NEWSLETTER!

More precisely, ask your library to save it. We have found that many, perhaps most, libraries routinely toss anything that is labeled "newsletter," as soon as the next issue arrives. "Journals" are kept, and indexed in the card files, but newsletters are seldom even kept. Although many libraries will not want to index Physics and Society in their files, because indexing is expensive, it should be possible for them to simply keep the back issues instead of tossing them.

## JOIN THE FORUM! GET THE NEWSLETTER!

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. (Nonmembers: see the masthead, on p.2).

I am an APS member who wishes to join the Forum and receive the newsletter:

NAME(print) \_\_\_\_\_

ADDRESS \_\_\_\_\_  
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# COMMENT

## TO EDWARD TELLER, ON INDEPENDENCE DAY, 1988

Every responsible friend of western civilization should join in extending good wishes and highest regards to Professor Edward Teller this year, in which he celebrates his eightieth birthday.

This writer first saw Teller in action at the weekly meetings of staff members of the Los Alamos Scientific Laboratory, on joining the staff as a newly minted Ph.D. in April, 1950. It was a momentous time. President Truman had ordered a crash program to build the H-Bomb, the project which Teller had long advocated under the name "Super". The Lab was on a six-day-a-week basis, and had become a Mecca for the leading scientific talents of the country.

But it was crystal clear at every one of the staff meetings, even when they were attended by such notables as Enrico Fermi, Hans Bethe, Lothar Nordheim, etc., that at every phase of discussion, whether it related to technical matters or administrative decisions necessary to achieve quick success, Teller was by all odds the dominant figure. His quick, penetrating analyses of complex questions, always getting to the very heart of the matter, made an unforgettable impression on this attentive observer.

When Teller left Los Alamos a few years later, to found and direct Lawrence Livermore Laboratory, I felt that we had been left behind, and that the center of future action would be elsewhere.

In later years as Teller sought to develop industrial uses for his Ploughshare inventions, for example to use nuclear explosions for gas recovery or for earth removal, and still later as he led in developing defenses against nuclear weapons, it became clear beyond all doubt that he is not only a superb scientist, but a scientific statesman who has no equal in history.

Many scientists in the past, starting perhaps with Archimedes, have lent their talents to the defense of the societies they admired. Thanks to the weapons devised by Archimedes in the third century B.C., for example, the Romans were held at bay for three years in their assault on his native Syracuse. But none even remotely approaches Teller in the magnitude and effects of their contributions.

Given the fact that we were being counseled by respected figures in the scientific community that "if we don't build an H-bomb, the Soviets won't either", absent Teller, a refugee from Hungary in the twenties, the West today might very well be a vassal and tributary of the Soviet empire.

Few observers would argue fundamentally with the foregoing facts about Teller and his historic role. It is therefore most remarkable that he is often characterized by the media and certain of his colleagues in negative terms as "controversial", and despite his vehement distaste for the term, "father of the H-bomb," thereby feeding the mills of Soviet Agit-prop that we are warm-mongers and giving color to vulgar, slanderous distortions of scientists as "mad" and irresponsible.

Time and again this observer has noticed that the same media and individuals who typically refer to Teller as "father of the H-bomb" also refer to our Strategic Defense Initiative by the belittling, warlike term "Star Wars," as though there were a coordinated effort to misrepresent our every attempt to defend ourselves from aggression as itself an act of aggression. For this state of affairs we have to thank not only the vulgarization and popular distortion of the media, both spontaneous and Soviet-motivated, but also those in the ranks of the physics community who are among his habitual detractors, whose own achievements can never hope to hold a candle to those of Professor Teller.

But achievement such as Teller's has never come without a price. And it may come as a consolation to him on his eightieth birthday that among his many accomplishments is his inadvertent role as a stalking horse who brings to the surface otherwise hidden or unconscious enemies of the West.

On this Fourth of July, let us remember that Edward Teller is one of those few men without whom our independence might now be merely a past episode. He should be thought of and remembered not as father of the H-bomb, but as the twentieth-century savior of western democracy and independence, and on a par with the greatest founders of our country.

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## EDITORIAL: THE GREENHOUSE, THE OZONE, AND THE NARROWNESS OF PHYSICS

"Predicted changes during the next few decades could far exceed natural climate variations in historical times. —warming can reach 5 K during the next century. —it has been suggested that the carbon dioxide variations themselves may help explain the glacial interglacial cycles" (V. Ramanathan, in *Science*, 15 April 1988).

"Atmospheric ozone has been depleted not only over Antarctica but globally. —between 1979 and 1986 ozone declined globally about 5%" (Kenneth Bowman, in *Science*, 1 January 1988).

Would all those physics teachers who devote significant class time to the global greenhouse or ozone problems please raise their hands? Better yet, send a letter to *Physics and Society*.

Do we teach these topics regularly, in any physics course, at any level? Judging from the introductory general college physics texts I have seen, and from discussions with college and public school faculty and students, I would guess that the answer is an overwhelming "no." To be sure, there are—there must be—a few instructors willing to spend time on global atmospheric problems. But it is a small fraction of our students, out of even that small fraction of US students who ever enroll in physics (that's a small fraction squared!), who will ever hear about greenhouse gases or ozone as part of a physics course.

"We've no history of the earth with the levels of carbon dioxide we're about to put into the atmosphere. We can't say what's too little or too much" (William Jenkins, quoted in *USA Today*, 29 July 1988).

"It is my belief that the level of ozone depletion observed in 1987 is already unsafe for the health of the global atmosphere, and an agreement permitting a rising chlorine concentration—is neither soon enough nor stringent enough; a full ban within the decade is needed" (F. S. Rowland, Letter to *Issues in Science and Technology*, Summer 1988).

But is it physics?

Global atmospheric problems involve electromagnetic radiation, the solar spectrum, infrared and ultraviolet radiation, atmospheric trace gases, emission and absorption spectra, energy conservation, energy transformations, etc. etc. If this isn't physics, then what is?

Judging again by textbooks and discussions, most general physics courses are about 80% Newtonian ("classical") and 20% post-Newtonian. Applications tend toward blocks sliding down inclined planes and point charges in vacuum. If it is well taught, such a course can be interesting, even exciting. But only the vanishingly-small fraction of students who are already planning a career in physics are likely to emerge thinking that physics has anything to do with their lives.

Physicists are purists by nature. In our teaching and our research, we strip away everything that is not "pure physics" and hand it over to some other discipline or, more likely, to oblivion. Thus engineering gets nuclear power, philosophy gets the interpretation of quantum theory, chemistry gets the global atmosphere, and the physics student gets stuck with blocks sliding down inclined planes.

"It is time to stop waffling and say that the evidence is pretty strong that the greenhouse effect is here. —four of the hottest years on record occurred in the 1980s" (James Hansen, quoted in the *New York Times*, 24 June 1988).

"Sharp seasonal thinning of the ultraviolet-filtering ozone layer over the South Pole threatens to wipe out plankton, the food on which fish, penguins, winged birds, seals and whales depend for their food. —Any substantial decrease in the production of plankton will have serious ecological reverberations throughout the entire Antarctic marine ecosystem" (Sherwood Rowland, quoted in the *Arkansas Gazette*, 30 March 1988).

Why are we so intent on being irrelevant? The physicists I know are interested in broader questions of science, culture, politics, etc. Why then are we so professionally inhibited about interdisciplinary connections?

The answer probably lies in the specialization that is so encouraged by our academic departmental structures, our granting institutions, our professional organizations and publications, and, indeed, by the highly technical and detailed nature of science itself. It is a central problem of the scientific age: Knowledge has fractured, and there are few rewards and many dangers in trying to put the pieces together. We fear to tread professionally on unfamiliar ground. We might make a mistake. We might be asked a question we can't answer. In a recent article, Stephen Schneider of the National Center for Atmospheric Research makes this point insofar as it applies to the problem of interdisciplinary research ("The Whole Earth Dialogue," *Issues in Science and Technology*, Spring 1988). It applies as well to the problem of interdisciplinary teaching.

"Sea levels are rising and are likely to keep rising throughout the next century. Unless global warming is checked, most of what coastal wetlands remain today will be gone by the year 2100" (*World Watch*, March/April 1988).

"Now comes the first evidence that ozone-destroying forms of chlorine also form over the Arctic during the winter" (*Science*, 27 May 1988).

Is it practical to introduce global atmospheric problems into general physics courses? I have found that it is in courses that are flexible enough to permit new topics. It is easy to find reliable information on the atmosphere: *Science* and *Science News* are useful, and in fact during the recent long hot summer the popular press has become a useful source. In my non-mathematical liberal-arts physics course, I devote one lecture/discussion to the greenhouse and ozone problems right after two lectures about electromagnetic waves. It works very well with students, much better than inclined planes. Similarly, it should be easy to work these topics into high school courses. But I have been unable to give these problems more than passing mention in the more technical general courses for engineering and science students, because these courses are so full of mandatory technical topics that there is no time for trivial practical matters such as the destruction of our atmosphere.

Global atmospheric problems have been described as "the most significant economic, political, environmental and human problem facing the 21st century" (Senator Timothy Wirth, chief author of proposed legislation to deal with greenhouse warming). Because of these problems, "we will all be environmentalists soon," predicts James Gustave Speth, president of the World Resources Institute.

Can physicists find a way to be relevant?

Art Hobson