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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

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!

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

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

Table 2

SRP REACTORS
<ul style="list-style-type: none"> • 2,500 MW_{th} • D₂O Moderated and Cooled (Low P) • 600 Aluminum Tubes (Vertical Lattice)
Diverse Shutdown Negative Power and Void Feedback Reliably Activated ECCS

Table 3

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

Table 4

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

Table 5

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

Table 6

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

Table 7

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

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.