ELECTION BALLOT

PHYSICS AND SOCIETY

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LETTERS

PHYSICS AND EVOLUTION

As scientists we must evaluate how much of our personal bias goes into our teaching.

A case in point is the recent *Physics and Society* editorial (July 1987) about teaching evolution at the university level. It is so common to hear the theory of evolution taught as fact. Evolution is not fact, no matter how much any scientist might want it to be.

The old rule of science is that facts are facts when they are conclusively proved by data. Thus far, data supporting evolution (or for that matter, creation) is good but not conclusive. There are incomplete data and conflicting data. Because of that, there is no way we can find a reason to call evolution fact. And when we teach evolution as the definitive answer to the beginnings of the universe, we are declaring evolution is fact.

If we are to be scientists true to our profession, we need to encourage people to enter into the investigation of the theories of evolution and creation. The goal of the investigation is the same: an answer. We cannot look only for data to support one view, ignoring other evidences. Pure science does not allow for that sort of investigation. Pure science is objective; the data conclusive.

The program at the University of Arkansas sounds like it teaches evolution as fact, while trying not to destroy students' beliefs. It is not right to teach one theory and not the other. I see nothing wrong with teaching evolution as long as it is presented as the theory that it is. If we are to be honest, and true scientists, we also need to present the possibility of creation by a Creator. As unlikely as creation sounds, it is quite possible. There are unsettling parallels between the "Genesis account" and evolution's early chronology. And at the very least, a catastrophic creation cannot be disproven

Giving equal time to a religious view is not the issue. The issue is whether we are making the public an informed public by showing them evidences thus far obtained for both theories. As scientists, we must look for solutions to the problems data present, rather than finding data to support problematic solutions. And the only way to produce objective results is to be unbiased. Even in our view of the beginnings of the universe.

Chris S. Orr, Physicist/Meteorologist, Minneapolis, Minnesota.

REDUCING THE HAZARDS OF NUCLEAR POWER: INSANITY IN ACTION

Although Dr. Cohen (July 1987) has correctly observed that the public's fear of radiation and nuclear power is grossly out of proportion to their actual risks, his article is a good example of why the public does not respond to technically informed "reason." For example, he asserts, without elaboration, that waste management programs will save only lives many thousands of years in the future, lives that probably would be saved by a cure for cancer expected to be available by then, but ignores the lives in much closer generations, lives of relatives who are likely to bear a closer relationship to us than those strangers now living in under-developed countries and for whom no cancer cure is predicted.

Cohen also undermines his credibility with at best partially correct statements like the claim that regulatory ratcheting alone is responsible for the significant increases in cost of nuclear power plants. Any reader of the Wall Street Journal can tell you that this statement ignores utilities' decisions to deliberately extend construction schedules to match unexpected decreases in load demand and, thereby, drastically increase the costs of power plants by the huge sums of additional interest required to service construction debt.

Finally, Cohen's analysis of the cause of the public's irrational fear is similarly flawed. No doubt, business considerations drive the media to focus on hazards which provide "entertainment" in the sense of attracting an audience. But Cohen does not explain the disporportionate attention paid to the radioactive hazard. Why haven't chemical or toxic waste hazards continued to attract the same level of attention paid to radiation, especially after Bhopal and the Love Canal? I submit that radiation involves something more at a very basic psychological level, and that until that extra dimension is identified neither reason nor finger-pointing will counteract the public's current perception of radiation hazards.

Sheldon L. Trubatch

Response:

Mr. Trubatch's letter raises three issues, one in each paragraph. I respond to them by paragraph number.

1. Trubatch says I "assert, without elaboration...". The elaboration is given in the references cited, Ref. 2,3,4 of my paper. The risk analyses deal with far future effects, and that is what all the money is spent for: geological solutions are appropriate for problems with a geological time scale. If we were concerned only with the near future, above-ground or near-surface storage would be very simple and cheap.

2. Before the regulatory ratcheting brought on drastic cost escalations, financing for the plants was in hand and there is no question but that they would have been completed more or less on schedule. When these unforeseen cost escalations developed, some utilities got into deep financial trouble and found that their best recourse was to extend construction schedules even though that caused further increases in the total cost. These extended construction schedules were made acceptable by a slowed rate of increase (not a "decrease" as Trubatch states) in electricity demand. Plants for which this was a major factor had their costs increased by much more than the $2 billion used in my paper. Most utilities tried very hard to complete their plants and get them into operation as rapidly as possible. My estimates of the increased costs caused by regula

tory ratcheting are developed and explained in Chapter 8 of my book *Before It's Too Late* (Plenum Publ.Co.,1983).

3. The question of the cause of the public's irrational fear is a matter of opinion. Trubatch is entitled to his, and I am entitled to mine without being insulted for it. In rebuttal to his claim that fear of radiation is basic to human psychology, I point out that it did not exist in the 1950s and 1960s before the media "got on the case." In that era, communities vied for the honor of being the site for a nuclear plant, and state governments fought hard to get national nuclear facitilies. Routine medical X-rays giving 10-100 times as much radiation as necessary were employed without question; in fact doctors and dentists used extra X-rays as a selling point for their services. The 1956 accident in the British Windscale plant was far more serious than the Three Mile Island accident but drew very little public interest or concern.

Bernard L. Cohen, University of Pittsburgh

SUPERCONDUCTOR FOLLIES

Robert Park (October 1987) has stated his facts correctly but he has drawn the wrong conclusions. The fact that we are falling far behind the Japanese in commercial electronic products does not demonstrate that "there is no correlation between spending on military research and strength in private sector markets" but rather that there is a strong ***negative*** correlation. The reason for this negative correlation is obvious. Military research programs divert talent and resources from civilian programs. While America's best and brightest engineers and scientists are hard at work developing neutron bombs and high intensity lasers for the star wars program, their counterparts in Japan are working on VCRs, digital tape recorders, electronic calculators and high performance automobiles.

The same conclusion can be drawn about other government nondefense, high cost, high tech, high visibility projects. Where are all the spinoffs that were supposed to come from NASA's Apollo and Space Shuttle Programs? Proponents of the $6 billion superconducting supercollider are also talking about commerical spinoffs. I guess we will continue to hear about such spinoffs until Congress appropriates funds for the supercollider, and then we will hear no more about spinoffs.

Dr. Park is right that in the past, our high tech edge over the Soviets depended on the creative energies of IBM, Bell Labs and Texas Instruments. Now it also depends on the creative energies of Toshiba, Mitsubishi, etc. which provide many components for American military hardware. In a repeat of World War II, the Japanese could win without firing a shot, just by cutting off our supply of high tech components.

Robert Joe Yaes, Department of Radiation Medicine, University of Kentucky.

ARTICLES

SDI NEAR-TERM DEPLOYMENT, PART I: INITIAL DEPLOYMENTS IN CONTEXT

Simon P. Worden, Lt Col, USAF

[Editor's note: We present pro and con on the proposed near-term deployment of the Strategic Defense Initiative.]

SDI is part of a coordinated effort, including arms control and other military programs, to change the basis of our deterrent relationship with the Soviet Union. As a coordinated strategic effort, SDI must compete with several alternative strategies. The choice among these alternatives is the essence of the SDI debate—not technical details such as the proper number of laser battle stations needed.

To place the SDI in context, it is *not* an isolated technological effort. It is *not* a program to build an impenetrable astro-shield behind which the United States could hide and the rest of the world go to hell. The astro-shield is not and never was the goal of the SDI and I defy anyone to find statements of responsible government officials to the contrary.

If you accept the SDI-supported strategy, only then can you examine the initial deployment fairly and see whether it meets the requirements of the strategy it must support. For this reason, my remarks will focus more heavily on the strategic than on the technical.

Strategic theories

For the purposes of discussing the SDI I identify three competing deterrent approaches. Each has as its goal the prevention of nuclear war. These are *deterrent* concepts which must be separated from actions which might be contemplated should deterrence fail.

I name the three deterrent strategies as follows:

1. Vulnerability-based (Mutual Assured Destruction or MAD).
2. Nuclear warfighting (flexible response).
3. Non-nuclear (defense-reliant).

To understand each strategy, we must consider three separate elements in each approach: the roles of offensive forces, defensive forces, and arms control.

For vulnerability-based deterrence, offensive forces must be sufficient to destroy a sizable fraction of an enemy society. U.S. calculations in the 1960s suggested that about 1000 megaton-class weapons directed against enemy population centers would destroy

25% of each superpower's people and 50% of it's industrial infrastructure. Defensive forces, unless impossibly perfect, are to avoided. Defenses make it more difficult to calculate the minimum assured destruction level and have the undesirable side effect of suggesting to the people that nuclear war can be survived. Most important to vulnerability-based deterrence is arms control. To it falls the task of convincing the Soviets to forego their own defenses, thereby rendering themselves vulnerable. Moreover, arms control must arrange for nuclear force level reductions down to the minimum posssible level for assured destruction. Despite popular wisdom, MAD is not the strategic policy of either the United States or the Soviet Union.

Both superpowers have adopted a form of nuclear warfighting deterrence. For this approach to work, offensive nuclear forces must be sufficiently numerous and capable to destroy an enemy's warfighting potential. Strategic targets are enemy armed might and not his society. In this manner both global nuclear war and conventional conflicts are avoided. This "flexible response" strategy—where the Soviets fear that any conflict would escalate into a decisive military defeat—is illustrated in our current NATO posture. Defensive forces are secondary to this strategy, but are still useful insomuch as they protect the warfighting offensive forces from enemy surprise attack.

Both of the previous strategies rely predominately on nuclear, mass destruction weapons. However, new technologies may make a largely or wholly non-nuclear deterrent defensive strategy possible. The key here is arms control. The sides must be persuaded to abandon their current nuclear warfighting strategy in favor of a non-nuclear relationship. Neither side will accept this transition unless the shift is appealing in comparison to maintaining the current relationship. In order to persuade the Soviets to abandon their first-strike offensive warfighting approach, they must be faced with the likelihood of defenses which can deny that offensive strategy. This is SDI's job—to develop and demonstrate those defenses.

Initial defense requirements

Our arms control agenda laid down in the past year and a half drives the dates for initial defense availability.

At the Reykjavik summit meeting and in other communications with the Soviets the United States proposed a transition to the non-nuclear, defense-dominant deterrent relationship I outlined above. The first step would be a 50% cut in nuclear warheads to be accomplished in five years. Over a subsequent five years all ballistic missiles are to be eliminated. Finally, follow-on negotiations would eliminate remaining, non-ballistic nuclear weapons.

Defenses play two roles in this arms control regime. First, they act as an insurance policy to be installed once ballistic missiles reach low or zero levels. Modest defenses in place act as a hedge against cheating on the arms control agreement and as a hedge against reintroduction of ballistic systems. Since cheating would involve relatively small numbers of missiles, the presence of even modest defenses could completely negate these missiles' effectiveness and thereby eliminate any incentive for keeping the illicit missiles. Second, and more important, the *prospect* of effective defenses is a vital spur to get the Soviets to accept the transition we propose and to actually go through with the reductions once agreed to. Should the Soviets balk at any time in the reduction process, U.S. defenses ready to go can force the reductions to continue. We can simply say, "either reduce the weapons as agreed or we'll put in defenses which reduce their effectiveness unilaterally." To meet the schedule proposed, we must be ready to go with defenses no later than the mid-1990s.

What kind of defenses are needed? If the United States prepares the wrong kind of defenses this might not help our arms control agenda. To arrive at the right kind of defenses, we must consider Soviet strategy and analyses since it is their perceptions we are trying to influence.

U.S. strategic analyses proceed from an exchange calculation. Our metric of "goodness" is the damage we can do to the Soviet military after a two-sided exchange with them striking first. In this case, U.S. defenses help and Soviet defenses hurt our metric. If both sides have similar defenses, this analysis tends to conclude that the second-striker is in worse shape. Of course, we would be in worse shape if only the Soviets had defenses. In any case, defenses play a secondary role in the U.S. -type analysis. Soviet analyses, in contrast, are different and are profoundly affected by defensive capabilities, particularly if the defenses are space-based. To understand this, I present here an extremely simplified Soviet-style analysis.

Soviet strategic analyses focus on two related aspects (1). The basic Soviet measure is a ratio of relative military power—the Correlation of Forces (COF). The COF analysis is a precise quantitative measure of each side's military potential. The second Soviet concept to understand is "stability." Soviet definitions of stability differ greatly from Western understanding. By stability the Soviets mean the predictability of a military campaign and not the permanence of military balance.

A Soviet military commander learns to calculate the COF based on ratios of his and his opponent's overall force levels, strength of each side's defenses, and readiness against surprise. If he can not amass a COF advantage, Soviet rule books mandate that the commander hold defensively or retreat.

Nuclear COF analyses were published by the Soviets in the 1960s (2). In a very simplified form, the nuclear COF is given by

$$\mathrm{COF} = \frac{\mathrm{EMT}_{\mathrm{USSR}} \;\; \mathrm{X} \;\; \mathrm{P}_{\mathrm{USSR}} \;\; \mathrm{X} \;\; \mathrm{D}_{\mathrm{USA}}}{\mathrm{EMT}_{\mathrm{USA}} \;\; \mathrm{X} \;\; \mathrm{P}_{\mathrm{USA}} \;\; \mathrm{X} \;\; \mathrm{D}_{\mathrm{USSR}}}$$

where:

EMT = each side's total equivalent megatonnage,
P = Each side's vulnerability, i.e. probabilitiy of forces being caught in a surprise attack,
D = Strength of enemy defenses.

The Soviet objective is to amass a large COF advantage, in most cases not so much to attack as to control the situation should the need arise. As such, they seek to eliminate types of enemy forces which make the COF difficult for them to calculate. Defenses, particularly space-based, are the most unpredictable and therefore unstable in Soviet eyes. By the 1980s the Soviets had amassed an overall COF advantage of better than 3:1 in strategic nuclear forces (3). A U.S. defense that was near 50% effective against a massive attack would wipe out this advantage. Against smaller attacks, of the type the Soviets might actually mount in an extended campaign, these defenses would be considerably better and disrupt local COF calculations even more.

Technical features of an initial defense

It is now clear what our initial defense must do to give us the leverage we seek. First, it must be good enough to wipe out the current Soviet COF advantage—about 50% effective. Second, it must introduce the vital uncertainty which would stop the Soviets from initiating an attack. Defenses based wholly or partially in space are ideal for this purpose. Third, the defenses must be available by the mid-1990s.

Do we have at hand a defensive system which can meet these requirements and also meet the survivability and cost-effectiveness criteria? It appears that we do. The SDI organization has proposed a system concept and has entered the first stage of the development process—concept validation. I must stress that concept validation does not constitute a decision to deploy or even develop a system. But it is the first step in those directions.

The defensive system we have in mind has two layers. The first, space-based layer would have about 3000 kinetic- energy interceptors based on 300 satellite carriers. Deep-space sensors would provide this sytem the necessary information to intercept attacking boosters in the first few minutes of their flight—in boost and post-boost phase. The interceptors themselves would destroy the boosters by slamming into them and are thus called "hit-to-kill." A second, ground-based layer would also use hit-to-kill interceptors, but would launch these into space on top of small ground-based rockets. This layer would be designed to stop the warheads in the last third of their roughly 30 minute flight—the late midcourse phase. These several thousand interceptors would be guided by ground or air-based sensors, or perhaps low-altitude space-based sensors. This simple system would have an overall effectiveness of about 50% against the Soviet threat postulated for the mid-1990s. Moreover, it would completely disrupt any limited-objective attacks the Soviets might contemplate as an initiation of a prolonged nuclear or conventional war.

What about cost-effectiveness and survivability? Much controversy has surrounded these issues in the past months and most of the criticism is misleading if not outright wrong. To show that the system is cost effective, consider a simple "back-of-the-envelope" calculation. To recover their 1980s-level COF advantage, the Soviet would have to add 5000-10000 new offensive warheads at a cost of close to $200 billion (4). The initial defense cost estimate is less than $100 billion. To understand that this is a reasonable cost estimate consider the space-based interceptor element. As the most numerous element, the space-based interceptors dominate the cost. Each interceptor, including a weight budget for the carrier satellite, would weigh about 300 kilograms. Today, space hardware costs about $30,000 per kilogram to develop, construct and launch (5). If we were to build these 3000 interceptors, even assuming no breakthroughs in lowering launch costs, that would cost about $30 billion. A total system cost of less than $100 billion is thus quite reasonable.

What about survivability? I am convinced that a combination of maneuvering, hardening, defensive decoys, and self defense will make the sytem sufficiently survivable. A detailed argument on this subject is beyond the scope of this paper. However, I can again present a simple calculation against the one specific attack approach the Soviets have voiced: a threat to ring the earth with a cloud of pellets (6). Over a period of months the defensive carrier satellites would begin to collide with these pallets and might be destroyed progressively by these collisions. To put a ring of pellets several tens of kiometers thick would require several hundred tons of pellets—the Soviets could do it, but it would cost. However, 1% of this mass in maneuver fuel would move the defensive constellation above or below the pellet ring (7). Alternately, the spacecraft could be equipped with shields. NASA has developed and tested in space shields against meteorites which would also be effective against Soviet pellets. These shields would also weigh and cost a few percent of the pellet ring. Although this is only one possible survivability threat to a defensive system, it is the one which the Soviets are touting. Yet it is manifestly neither cost-effective nor even effective.

What about longer-term offensive threats such as the so-called fast-burn booster? This is a new offensive missile which burns out before it leaves the atmosphere, thereby becoming invulnerable to space-based interceptors which can not penetrate the atmosphere. To replace their current arsenal with fast-burn boosters would cost the Soviets hundreds of billions of dollars (8). Moreover, the fast-burn booster is not trivial and it would take several decades before they would have sizable numbers of them. Finally, the United States is developing advanced defensive systems, such as space-based lasers, which can stop even fast-burn boosters. These laser defensive systems are progressing so rapidly that we could begin deploying them around the year 2000—well in time to counter the new Soviet offensive systems.

Summary

Strategic defense system deployments must be placed in the context of the strategy they are designed to support. The strategy of the SDI is a non-nuclear deterrent. Arms control can and should play an important role in getting us to this new relationship. Placed in this context, an initial defense of roughly 50% effectiveness available in the mid-1990s appears both feasible and appropriate. The true issues before the American people are thus not technical, but strategic and technical, but strategic and political. We must choose the strategic approach we prefer. As we make that choice we should also keep in mind that the defense-reliant proposal is the only one which does not rely on weapons of mass destruction, nor does it rely on trust of the Soviet Union.

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3. Stephen Meyer, "Soviet Strategic Programs and the U.S. SDI," *Survival,* November-December 1985, pp.274-292.
4. Data obtained from the U.S. Air Force Office of ICBM Modernization in 1986 showed that each deployed MX warhead costs $20 million. This is the same number derived by the

Congressional Office of Technology Assessment in *MX Missile Basing*, U.S. Government Printing Office, OTA-TSC-140, Washington DC (September 1981)

5. The Space Shuttle Orbiter, which weighs about 100 metric tons, costs about $3 billion to duplicate. The NASA Space Telescope, which weighs about 20 metric tons, would cost about $600 million to replace. Small payloads, such as the Defense Meteorological Satellites, also follow this roughly $30,000 per kilogram cost to build and deploy.
6. Soviet Scientists Committee for the Defense of Peace Against Nuclear Threat, *Weaponry in Space: The Dilemma of Security*, Mir Publishers, Moscow (1986) p.99.
7. Gregory H. Canavan, *Survivability of Space Assets*, Los Alamos National Laboratory Publication La-UR-86-4108, August 1987.
8. The mobile, single warhead Midgetman which is not a fast-burn booster has been estimated to cost about $45 billion for a 500 warhead force, or almost $100 million per warhead. It is reason able to assume that a force of small, mobile fast-burn boosters such as proposed by SDI critics would not be any cheaper than the Midgetman warheads.

SDI NEAR-TERM DEPLOYMENT, PART II: IT IS TOO EARLY

Benoit Morel, Carnegie-Mellon University

SDI through the four and a half years of its history has been at once the center of a political controversy and the theater of an intense technological effort. The prospects, successes and failures of the latter play a central role in the former.

One negative effect of the importance given to the technology in this controversy has been to produce the necessity for early tangible technological successes. This put a harmful pressure on the work, encouraged stunts instead of healthy research and translated finally into a sustained unstability in the program through frequent dramatic shifts of priorities between competing technologies, transforming the life of the scientists involved into a roller-coaster (1).

Despite the confusion created by these quakes, a better understanding of the technological challenge represented by SDI emerged. Some major advances took place but fundamental questions are yet unanswered, like the midcourse discrimination of attacking RVs from decoys and the survivability of space-based assets.

The physics of high-power lasers is better understood: it is now clear that high-power lasers will not be operational as interceptors of missiles in the foreseeable future, but they still represent the best hope for strategic defense in the long term.

What is not yet totally clear is the potential of the other directed energy weapons (DEWs), namely the particle beams, either as interceptors or for interactive discrimination.

As compared to DEWs, the technology of kinetic energy weapons (KEWs), and more exactly of the missile interceptors, is more mature. There have been several demonstrations of destruction of targets out of the atmosphere, by kinetic kill: the Homing Overlay Experiment, ASAT tests from an F-15, and perhaps more importantly in September 1986, the experiment Delta 180 where a space-based interceptor homed on the plume of a rocket (2). These experiments suggested that the interception of an ICBM during its boost-phase, but out of the atmosphere, was a physical possibility. Within the atmosphere, an interception using kinetic kill is much more problematic, because the required accuracy is more difficult to achieve. This is due to the fact that the interaction of the atmosphere with the interceptor generates a shockwave and a hot spot in front of the nose of the interceptor, which diminishes the performance of the homing device.

That is one reason why ICBMs with fast-burn boosters (i.e. ICBMs which burn out while still in the atmosphere) are much less vulnerable to space-based kinetic kill vehicles (SBKKVs). Another reason is the shortening of the boost-phase, from about 300 seconds to about 100 seconds.

The difference in advancement between missile interceptors and DEWs, the apparent readiness of the former, and some impatience, have probably too much to do with the recent proposition of early deployment of some components of SDI.

What "early deployment of SDI" concretely entails varies somewhat from one proponent to the other. In its most ambitious version (3), the idea is to start deploying in the mid-90's a three-layer ABM defense, consisting of SBKKVs for boost-phase interception of the Soviet ICBMs, supplemented by the land-based ERIS (Exoatmospheric Reentry vehicle Interception Subsytem) for late midcourse interception and HEDI (High Endo-atmospheric Interceptor) for interception during reentry of the attacking warheads.

The numbers of each to be deployed vary and depend on what this first phase of SDI is intended to achieve.

Some suggest that at the present state of the technology, a very effective defense can be built and deployed by the mid-90's: in reference (3), an efficiency of more than 90% is quoted. That would be achieved through the deployment of 11,000 SBKKVs deployed in a constellation made of a large numbers of small platforms to maximize their survivability. The cost of deploying all that by the mid-90's is optimistically estimated in reference (3) at around $130 billion.

A more realistic (but still optimistic) estimate of the same scheme (4) puts the cost of such a defense, (11,000 SBKKVs plus 10,000 ERIS and 3000 HEDI and their basing) at $239 billion. That study also gives an estimate of the number of RVs which would pass through the first layer, i.e. which would escape boost-phase interception, as a function of the number of SBKKVs deployed. Against the current Soviet arsenal, 11,000 SBKKVs would let about 2000 RVs (roughly one fifth) go through (assuming optimistically that an SBKKV has a probability of 0.9 of intercepting successfully a Soviet ICBM).

According to this analysis, the most significant effect of deploying such a defense would be to drive the Soviets to redesign their

ICBMs, by providing them with fast-burn boosters. That would essentially make them unvulnerable to boostphase interception.

Such a move would be onerous and expensive for the Soviets. According to the estimates of reference (4), the price of one SS-24 would pass from $31 million to $67 million, whereas the price of one SS-25 would pass from $25 million to $32 million. For a projected arsenal of 600 SS-24s and 600 SS-25s, this would translate into an increase of cost of $26 billion from an original cost of $33 billion.

As high as they are, these numbers are still an order of magnitude smaller than the estimated cost of the defense. If that is all the early deployment scheme wanted to achieve, it would hardly be cost-effective. It is also argued that such a deployment would deprive the Soviets of the capability of a disarming first strike, and therefore enhance deterrence (5). This argument is dangerously erroneous.

First, because a disarming strike on the three legs of the triad at the same time should not be an option for the Soviets if American military planning were adequate. Second, there is no basis to claim that the deployment of SBKKVs would dramatically reduce the lethality of a Soviet first strike of (4). Third, what an ABM defense with limited but non-negligible effectiveness could do, is not to "enhance deterrence," but to make the Soviets more nervous about the credibility of their retaliatory force. It thus becomes an incentive for the Soviets to strike first. Such a defense system would be destabilizing.

Put in the context of the history of SDI, the idea of an early deployment as "an initial phase of star wars" inspires serious concerns:

It implies a new shift of priorities in the program, away from DEWs (especially lasers) towards KEWs and more precisely missiles. This shift shows already in the way the last budget cuts were administered (1). It is far from obvious that slowing down the laser research further is in the best long-term interest of the program.

It overlooks the fact that there are two major unsolved technical problems in SDI, which as long as they do not find an adequate solution put the feasibility of the whole program into question: survivability of space-based assets and midcourse discrimination of RVs from decoys. Both are obviously relevant for the early deployment scheme we discuss here.

Without midcourse discrimination of RVs from decoys, the predicted efficiency of ERIS against a determined nuclear attack is very limited, and that is the situation today. The same is true with HEDI. The notion that atmospheric discrimination would be enough for HEDI to be effective, is erroneous (i.e. the notion that HEDI would not be confused by the decoys because the RVs get separated from the decoys high enough, through the interaction with the atmosphere). A clear separation is achieved only at relatively low altitudes (40 to 50 kilometers), seconds before the interception, and much after the interceptor has been launched and committed.

The need to penetrate such a defense system would certainly not constitute a puzzle too difficult to solve for the Kremlin. Decoys for midcourse deception would not be too demanding to make and would not affect the payload of the ICBMs dramatically (unlike fast-burn boosters which are costly and imply a trade-off between range and payload).

On the other hand, and this is a worrisome aspect of the early deployment scheme, the Soviets could not conceivably passively watch the Americans deploy SKBBVs by the thousands; their present ICBM force using slowly burning propellant would loose part of its effectiveness.

They might as a reply decide to design new ICBMs with fast-burn boosters, but they will more certainly exploit the vulnerability of the space-based assets. They can be expected to upgrade their ASAT capability and provide themselves with the means to destroy at low cost the space-based platforms which they consider threaten their security, or provide themselves with the capability of digging a hole in the constellation of SBKKVs. Destroying a platform is easier and cheaper than deploying it. To reach the altitude at which the platforms orbit does not require as much velocity as to put an object in orbit; to stay in low earth orbit an additional 8 km/s of velocity is necessary. Furthermore spacemines will be lighter than platforms for SBKKVs.

In the event that SBKKVs were beginning to be deployed, one should be prepared to face the threat by the Soviets to destroy them as soon as deployed, or as soon as they appear above their territory. Far from contributing to strategic stability and being conducive to arms reduction (5), an early deployment of that sort could initiate a period of serious confrontation.

Fortunately what early deployment of SDI really entails is still a matter of debate and need not be so extravagant. The deployment of a few SBKKVs, for example, would have completely different implications. It would not affect the efficiency and credibility of the Soviet ICBMs (although it would no doubt make the Soviets somewhat nervous, and it could even have some virtues by providing a symbolic protection against a limited or accidental missile attack.

An important property of SBKKVs which might become contentious, is that they could be given ASAT capability. What is required is that the homing device be made also sensitive to long-wavelength infrared.

Still more important perhaps is the fact that one can doubt that deployable SBKKVs would exist by the mid-90's. Only last June did Marietta receive a contract to "validate the concept;" and Rockwell International is "set to complete a space based interceptor experiment before the mid-1990s that will help determine the feasibility of the concepts and provide realistic data for studies being performed by Rockwell and Martin Marietta" (8).

By far the most advanced project is ERIS (7). It is land based and designed for hard point defense. If it is not made mobile, it could be deployed in compliance with the ABM treaty.

It would contribute significantly to the cost of an ambitious defense system. Deploying 10,000 of them, for example, would cost around $87 billion (4). On the other hand, deployed by itself, one cannot see what ERIS would have that the old dismantled Safeguard system did not have. And supplementing ERIS with HEDI would add to the cost but not much to the efficiency.

A major criticism that any scheme of "early deployment" of SDI has to answer is that it is far from obvious it serves well or at all the interest of SDI, i.e. the endeavor to provide a protection against the Soviet nuclear threat.

1. We have to be convinced that slowing down the DEW research, and letting at the same time the KEW technology develop much faster is in the best interest of SDI. It aggravates the desequilibrium within the program created by the difference of advancement of the two technologies. And there is no indication that a strategic defense based only on KKVs has the long-term potential to provide an adequate protection against the Soviet threat.

2. Speaking of deploying defenses before having answered such

fundamental questions as decoy discrimination and survivability cannot be taken seriously. It is certainly not enough to state that "one of the President's goals is to insure that these defenses are survivable" (5).

3. What is required from any ABM capability is an increased security against the threat of a nuclear war in general, together with some protection against the Soviet nuclear threat, either through a decrease of probability of an accidental nuclear war or through the implementation of a more secure nuclear regime, or otherwise.

What is offered instead is the prospect of a more intense confrontation with the Soviets, at a higher cost to us than to them.

A "clear strategic rationale with compelling benefits" (5) is what the proposition of early deployment needs most and lacks most.

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MONITORING SOLID-FUELED MISSILE PRODUCTION FOR ARMS CONTROL

Valerie Thomas, Program on International Peace and Security, Carnegie Mellon University, Pittsburgh, PA 15213

Monitoring of missile production has been proposed at the INF and START negotiations as an aid to treaty verification (1). Three questions central to the feasibility of these proposals will be examined here. First, can missile production facilities be identified by National Technical Means (NTM)? Second, can the production of different types of missiles be distinguished? And third, what methods can be used to monitor missile production?

The conclusions are that missile production facilities are relatively easy to identify. Missiles and their individual stages are in general distinct and distingishable, although ambiguities are possible.

An agreement restricting production to a specified number of missiles at a designated facility could be monitored on-site by humans or machines, or cooperative measures could be devised to enhance satellite monitoring.

An easier task is the monitoring of a ban on production of a weapon system. But since verification would require widespread monitoring to check for clandestine production, NTM must be relied on for basic intelligence information. Therefore the identifiability of missile production facilities is central to the feasibility of monitoring a missile production agreement.

Production facilities and process

All of the United States' strategic ballistic missiles are solid-fueled. The newer Soviet missiles are also solid-fueled: the land-based SS-20, SS-24, SS-25, and the submarine-launched SS-N-17 and SS-N-20. All modern land-based mobile missiles, both US and Soviet, are solid-fueled. So although most Soviet ICBMs are liquid-fueled, in this report primary consideration will be given to the production of solid-fueled missiles.

The propellant used in solid rocket motors is an explosive. Fires and explosions "are an inherent risk in explosive propellant operations" (2). The Department of Defense has established "quantity-distance" safety regulations which specify the minimum separation between places where explosives are based, stored, or processed and specified locations, such as inhabited buildings, public traffic routes, and recreational areas. The DOD distinguishes two classes of explosive: Class 7 for those that detonate, and Class 2 for those that burn rapidly, or deflagrate. In final form, the propellants used for large solid-fueled rockets are Class 2 explosives, but during manufacture, components of the propellant are Class 7 explosives.

The design, construction, and operating procedures of solid-fuel production facilities reflect these risks. The facilities are large and consist of widely separated buildings protected by earth revetments; these are characteristics which can be identified from satellites.

The propellants used for large solid-fueled rockets consist of oxidizer, powdered fuel and binder. A preliminary step in propellant production is the grinding of the oxidizer, usually ammonium perchlorate. Course grade (400-600μ) and medium grade (50-200μ) are Class 2 explosives, whereas fine (5-15μ) and ultrafine (submicron to 5μ) are Class 7 high explosives. Course grade oxidizer is ground to about 10-12 microns at the production facility. Since the product is a high explosive, oxidizer is ground in a building separate from the rest of the production facility (3).

The ground oxidizer is then mixed into the binder and powdered aluminum fuel. Mixing is the most dangerous process in the manufacture of solid propellant. A typical mixer holds 6000 pounds of propellant (4). Each mixer is housed in a small revetted building well separated from other mixers and from other buildings, in accordance with quantity-distance regulations. For example, at the Wasatch facility of Morton Thiokiol, the largest US producer of solid rockets, mixers are separated by a quarter mile, and the mixer

(continued on p. 9)

FORUM ELECTIONS

Now is the time for all good Forum members to elect their officers. This year elections are being held for the offices of Vice-Chairperson, Forum Councilor, Seretary-Treasurer, and two Executive Committee Members. This issue of *Physics and Society* features a centerfold which contains the candidates' statements and a ballot for the Forum elections. Indicate your choices on the ballot, which can then be folded and mailed to the address shown on the reverse side. Please return it by 8 January 1988. The nominations committee was chaired by Evans Harrell.

CAMPAIGN STATEMENTS

Marc Ross (Vice-Chair)

BACKGROUND: Marc Ross is a professor of physics at the University of Michigan. His research focuses on the use of energy in the economy, especially on energy-intensive technology in manufacturing and in related policy issues. He received his Ph.D. in theoretical nuclear physics from the University of Wisconsin and spent his first twenty years as a physicist applying concepts from nuclear physics to the theory of fundamental particles. Ross has served on the Executive Committee of the Division of Particles and Fields and, recently, on POPA. In 1974 he co-directed one of the first APS summer studies, on Efficient Use of Energy. In June, 1986, he published an article in *Scientific American* on the future use of materials in bulk, with implications for energy requirements and pollution.

STATEMENT: I am intensely concerned with several technically-related issues that face the nation: The low quality of much pre-college education and the difficulties experienced by areas of manufacturing in innovation call for major changes in priorities. Environmental policies, weapons policies, research policies; there are critical problems at every hand. And yet these issues, as such, are not as critical as the informed involvement of all of us in the process of governance — in our neighborhood, in our workplace, and at "higher" levels. To this end the Forum should continue its efforts to help physicists better understand societal issues which touch our profession or are touched by it.

The primary function of the Forum is to facilitate exchange of useful information. Our sessions at APS meetings serve this function. *Physics and Society* is becoming a valuable journal. I would emphasize the commissioning of articles on selected topics to be published in *Physics and Society* and possibly in *Physics Today* or other journals widely available to physicists. For example, the community is poorly informed about the decision-making processes affecting us. How does the APS really make its important decisions? What are some cutting edges in federal decisions on research or on education? We are also poorly informed about the flows and stocks of physics personnel. What are the coming areas of oversupply and shortage? In addition to its rôle in the exchange of information, the Forum's presence in the Panel on Public Affairs has been valuable. This rôle and other involvement with APS and AIP should be emphasized. I am less enthusiastic about formal studies by the Forum. The APS, as such, is open to conducting studies under its auspices and has much greater capacity than the Forum for carrying them out and promulgating their results. I am not criticizing studies that have been undertaken, rather, I am supporting the direction taken by recent Forum leadership emphasizing acting through the APS.

Richard A. Scribner (Vice-Chair)

BACKGROUND: Dick Scribner is a visiting fellow at the Center for International Security and Arms Control, Stanford University. He has a Ph.D. in low-temperature/solid-state physics from the University of Florida, and has been Director of the Program on Science, Arms Control, and National Security, and, earlier, Director of Science and Public Policy Programs of the AAAS. He has also been Director of the AAAS Congressional and Diplomacy Science and Engineering Fellow programs. He has taught and done research at Florida, Stevens Institute of Technology, American University, George Washington University, and the U.S. Foreign Service Institute. He has been a visiting research associate at the Institute on Global Cooperation and Conflict at the University of California at San Diego, a consultant to NATO, the US Department of State, and private foundations, and was Special Assistant to the Undersecretary of State for Security Assistance, Science, and Technology. Scribner co-authored the book *The Verification Challenge*, monographs *The Strategic Defense Initiative: Arms Control Implications*, and *Avoiding Nuclear War: Steps That Can Be Taken Now*, and numerous other monographs and articles on physics, science policy, and international security. In 1986 he produced a broadcast quality video program, *Fear of Cheating, Fear of Spying*. He is the recipient of the 1987 APS Forum Award. A member of the APS since 1968, he is currently on the Forum Awards Nominating Committee.

STATEMENT: The Forum was established to explore key issues of physics and society, promote studies, and facilitate the development of new institutions to deal with those issues. The APS, with assistance and guidance from the Forum and the POPA, has been a leader in addressing key science and policy issues. The current Forum activities, including *Physics and Society*, the study groups, and the APS meetings' topical sessions, must all be continued and further improved. While the Forum and the APS must sometimes address difficult and controversial issues, as the APS did so effectively in its recent Directed Energy Weapons study, they must also continue to do so with depth, objectivity, balance, and policy sophistication. Doing and releasing a good study, however, may not be enough. The APS or the Forum may want to anticipate controversy and misunderstanding and set up many briefings, forums, debates, symposia, video presentations, and other mechanisms for disseminating the results and exposing them to constructive critical examination. The Forum could examine this question and make recommendations to the APS for action.

I would like to see the Forum select one or two issue areas and make some breakthrough contribution in each. In the international security and arms control area, topics that might be useful to address include: (1) the state of the art in seismic explosion detection and discriminationtechnology; (2) key issues for the future in the area of arms control verification science and technology; and (3) an evaluation of nonproliferation safeguards in anticipation of the 1990 Nonproliferation Treaty Review Conference. I would like to see the Forum review and critique some of the APS special session papers with an eye to having them broadened and improved to the point where they can be published in forums that will get more attention, such as *Foreign Affairs* and *Scientific American*. I would like the Forum to further address the question of nontraditional careers for physicists. In general, I will be seeking ideas from a number of interested Forum members and using my energies to increase the reach, productivity, and effectiveness of the Forum and the APS.

David Hafemeister (Forum Councillor)

BACKGROUND: Dave Hafemeister is currently AAAS Science, Arms Control, and National Security Fellow with the Office of Strategic Nuclear Policy, Department of State (Geneva Talks). Usually he is a professor of physics at California Polytechnic University. He has been Special Assistant to the Undersecretary of State for nonproliferation, 1977-79; AAAS Congressional Fellow and Science Advisor with Senator John Glenn, 1975-77, working on energy and nonproliferation; and Visiting Scientist at the Program in Science and Technology for International Security, MIT, 1983-84. He has visited LBL (to work on energy conservation) and the University of Groningen. He was at Carnegie-Mellon University, 1966-69 after a Post-doc at Los Alamos, working on solids and nuclear physics, and a Ph.D. from Illinois. He is coeditor of books on the arms race (AIP 104), energy conservation (AIP 135), treaty verification, acid rain, and of the *American Journal of Physics*
STATEMENT: If the Forum didn't exist, it would have to be invented. The APS/Forum and the AAAS organize the best debates on the science/society applications of physics (arms, energy, environs). As scientists we do have a form of a "hippocratic oath" to tell the truth. Why not have a session a year which invites those who make "outlandish statements" to defend them in a debate? The Forum newsletter, *Physics and Society*, under Art Hobson is moving towards "journal quality," so let's encourage more APS members to research and publish in these areas. Let's redouble our efforts to create new Forum studies, short courses, and, thus, make the study of physics and public policy a legitimate discipline.

Leo Sartori (Forum Councillor)

BACKGROUND: Leo Sartori is a professor of physics and of political science at the University of Nebraska-Lincoln. He got his Ph.D. at MIT, and has taught at Princeton, Rutgers, MIT, and Nebraska (Chair, 1978-81). He has been on leave at the Strategic Affairs Division, U.S. Arms Control and Disarmament Agency, 1978-81, was Senior ACDA Advisor to the U.S. SALT delegation in 1979, and has continued as a consultant with ACDA since 1981. He has been a visiting scholar with the Program in Science and Technology for International Security, MIT, 1982, and with the Stanford Center for International Security and Arms Control, 1985, 1986.

Sartori served on the Forum Executive Committee 1981-87, and was Chairman in 1984-85. He was on the Forum Awards Committee in 1983 and has chaired ad hoc committees on Forum studies and on creating a journal of physics and society. In 1983 he participated in the drafting of the proposal for the APS study on directed energy weapons.
STATEMENT: There is every reason to believe that during the coming years the APS will continue to be heavily involved in "Forum issues." The Forum Councillor must play a major rôle in this process, articulating the Forum's views forcefully on issues that come before the APS Council and bringing constructive suggestions to the Council on behalf of the Forum. I believe I am well qualified to carry out these tasks, having served the Forum in a variety of capacities for more than a decade.

I would like to add that my opponent in this election is equally qualified; I am sure that if he is elected he will do an excellent job of representing the Forum.

Henry Barschall (Secretary-Treasurer)

BACKGROUND: Henry Barschall has a Ph.D. from Princeton and has taught physics at the University of Wisconsin-Madison since 1946. He has spent much time and effort on APS activities, as a member of Forum Executive and Fellowship Committees and of the APS Council, Chairman of the Division of Nuclear Physics, and Editor of Physical Review C (for fifteen years). He currently represents the APS on the Governing Board of the American Institute of Physics and chairs the AIP Subcommittee on Information Technology. He is a fellow of the AAAS and of the American Academy of Arts and Sciences, and a past chairman of the NAS physics section.
STATEMENT: Having recently retired from many of my professional assignments I would have time to help the Forum by taking care of the needed paperwork. I have served on enough APS, AIP, and NAS/NRC Committees that I am very familiar with the organizations with which the Secretary-Treasurer has to interact. This experience may benefit the Forum.

Herbert H. Nelson (Secretary-Treasurer)

BACKGROUND: Herb Nelson is a staff scientist at the Naval Research Laboratory, Washington, D.C., working in chemical physics. His background includes a Ph.D. in physical chemistry from Berkeley and a postdoc at NRL before joining the staff there. He has been a member of the Forum study group on the Future of Land-Based Missiles and is currently a member of the Forum Committee on Studies.
STATEMENT: I see the following areas as appropriate and important for the Forum to invest its energy and resources in: Continuation of the development of the upgraded *Physics and Society* toward a high-quality, balanced journal in the field. An increase in the pool of contributors to our sessions and newsletter and involvement in our affairs. This can be brought about in two ways, both of which we should pursue. Increase our emphasis on energy and environment and science-funding issues, though not at the expense of our efforts in national security/arms control, so as to overlap with the interests and expertise of more physicists and increase our outreach efforts to younger physicists and students through joint programs with the Society for Physics Students and AAPT.

E. William Colglazier (Executive Committee)

BACKGROUND: William Colglazier is the director of the Energy, Environment, and Resources Center and a professor of physics at the University of Tennessee. He also directs the Waste Management Research and Education Institute and the Water Resources Research Center at the university. He received his Ph.D. in physics from Caltech and was a research fellow at SLAC and the Institute for Advanced Study. He was a Congressional Science Fellow for AAAS and spent five years at the Kennedy School of Government at Harvard working on science, technology, and public policy research. He also served as associate director of the Aspen Institute Program in Science, Technology, and Humanism while at Harvard. His current research includes energy and environmental policy, nuclear and hazardous waste management, arms control and international security, and risk assessment methodologies. He is a member of the Board on Radioactive Waste Management of the NAS and a member of the National Council of the Federation of American Scientists.

STATEMENT: Having changed my career from research in physics to research on public policy issues involving science and technology, I am a strong believer in the importance of the Forum to the physics community. Having served previously as a member of POPA and secretary-treasurer of the Forum, I am also familiar with APS activities dealing with science and society issues. I strongly support an active rôle by the Forum, particularly in organizing sessions at APS meetings focusing on current societal issues where Sinitiate APS studies on these issues. I also strongly support a vigorous newsletter as a means of exchanging views among the physics community, and maintaining the Forum awards as a means of honoring physicists and other scientists who have made a distin- science and technology have a major impact and in helping to ished contribution in the science and society arena.

FORUM ON PHYSICS AND SOCIETY
1988 ELECTION BALLOT

Place an X in the box for the candidates of your choice.

VICE-CHAIR (vote for one):

☐ **Marc Ross**

☐ **Richard A. Scribner**

FORUM COUNCILOR (vote for one):

☐ **David Hafemeister**

☐ **Leo Sartori**

SECRETARY - TREASURER (vote for one):

☐ **Henry Barschall**

☐ **Herbert H. Nelson**

EXECUTIVE COMMITTEE (vote for one):

☐ **E. William Colglazier**

☐ **Glennys Farrar**

☐ **Gerald E. Marsh**

☐ **Lester G. Paldy**

Please fold and tape this ballot and return to Peter Zimmerman by 8 January 1988. The reverse side is already addressed.

Glennys Farrar (Executive Committee)

BACKGROUND: Glennys Farrar is a professor of physics at Rutgers University working on theoretical particle physics, with emphasis on experimental predictions of QCD, supersymmetry, and conjectural models. After Berkeley and a year of independent research in India she went to Princeton for a Ph.D., and then held positions at the Institute for Advanced Study and Caltech before going to Rutgers. She has held A.P. Sloan and Guggenhein fellowships and is a fellow of the APS.

STATEMENT: The APS can and should contribute to our society in a variety of ways. Perhaps the most important is promoting better elementary and high school education in science and mathematics. This includes improvement of the educational material directly, promoting the prestige and quality of physics teachers, and working to increase the desire of students, especially girls, minorities, and children of poor families, to learn about and perhaps have a career in physics.

Also, the APS can promote the accurate and balanced discussion of public issues involving physics. An excellent example of this was the report on SDI technology. Other approaches in this area would be to facilitate the publication of articles by physicists in the popular press — helping individual physicists who wished to publish on a topic of their expertise with criticism to make the article accessible to the general public, and helping make contact with suitable publications.

Gerald E. Marsh (Executive Committee)

BACKGROUND: Jerry Marsh is a defense analyst with the Office of Arms Control and Defense Sciences within the Energy and Environmental Systems Division of Argonne National Laboratory. As a consultant to the Department of Defense he has conducted studies in a variety of defense policy and technical areas. Marsh is author of numerous articles on defense-related issues and coauthor of "Born Secret: The H-Bomb, The *Progressive* Case, and National Security."

STATEMENT: Physics entered the public consciousness with the advent of the atomic bomb at the end of World War II: The emphasis within the Forum on arms control and defense issues is therefore well placed. Yet the real challenge to the Forum is to broaden the perception of the relationship between science, technology, and society within both the public and the physics community.

This relationship should be viewed as more than a question of where and how public funds should be allocated. It should stimulate an understanding of the implications that new discoveries and innovations have for society and identify, in terms that the public and its representatives can understand, both the beneficial and detrimental aspects of potential applications.

The arms control and defense area is a good place to begin. All too often we see technological innovations driving military policy: sometimes because the technology is irresistable, and often because of political pressure brought by defense contractors and the weapons laboratories to serve their own economic or institutional ends. An understanding of the dynamics of the arms race requires more than a familiarity with the related military hardware; it also necessitates an examination of related political, economic, and social issues. I would hope to further investigation by the Forum into these areas.

Lester G. Paldy (Executive Committee)

BACKGROUND: Les Paldy is the director of the Center for Science, Mathematics, and Technology Education at the State University of New York at Stony Brook. He teaches courses which explore issues associated with nuclear weapons proliferation and the verification of arms-control agreements. He has served as the editor of the *Journal of College Science Teaching* since 1978. Last year he served on the National Science Board Committee on Undergraduate Science and Engineering Education. He has served on assignments at the National Science Foundation in 1972-73 and 1983-84.

STATEMENT: Many of the most important issues of our time involve science and technology. Arms control is pressing and visible, but waste disposal, science and technology assistance to developing nations, energy conservation, and environmental protection are equally important. We have both an opportunity and an obligation to help expand public awareness and knowledge of these issues.

The quality of precollege education in the U.S. is poor, yet the views of professional societies are rarely considered by local decision-making groups such as boards of education. College and university core curricula rarely deal with science and technology, much less physics, in an adequate manner. Undergraduate and graduate science students do not have enough opportunities to study issues that cut across disciplinary boundaries or to consider the social implications of their sciences.

Cooperation is the key. The Forum can offer support and policy-making assistance to other groups such as AAPT, AAAS, and NSTA. It can play an important leadership rôle in efforts to improve the education in science of those citizens who are now effectively disenfranchised by their lack of understanding. It should provide sound information to groups responsible for making public policy on issues where science and technology have a part to play.

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Forum Secretary/Treasurer
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area is separated from the casting/curing area by half a mile. The propellant is moved by truck from the mixing area to the casting area (5).

After mixing, the propellant is poured into a prepared casing in a separate casting/curing facility. A mandrel is inserted down the center of the casing to form the internal surface. The rocket motor is cured in place for 3 to 5 days at 140 to 165 degrees Farenheit (6). During this time the propellant binder polymerizes and the propellant solidifies into its final form. When curing is complete, the madrel is removed from the center of the rocket. The solidified propellant is trimmed, the end of the booster is sealed, and the igniter and nozzle are installed. The booster is complete.

In summary, solid-fuel rocket production facilities can be expected to have separate buildings for grinding, mixing, and curing, all widely spaced and/or protected by revetments. Of course, Soviet production facilities are not built to U. S. Department of Defense specifications; the identifiability of typical production facilities does not prove that clandestine production is impossible. But the explosive nature of the materials and processes used in rocket motor production place severe constraints on the design and operation of production facilities.

Monitoring Soviet production

Soviet missile production is monitored by the United States as part of its basic intelligence gathering activities. According to William Perry, Undersecretary of Defense in the Carter administration, "We monitor the Soviet activity at the design bureaus and production plants well enough that we have been able to predict every ICBM before it even began its tests" (7).

Solid-fueled missiles are produced by the Nadiradze Design Bureau in the city of Biisk (8). "Soviet plants for solid fuel missiles exhibit a similar pattern (to U.S. plants), though in a somewhat more confined space. Detection of such plants by U.S. satellite photography has reportedly not proved difficult" (9).

How could compliance with production limitations be monitored? Satellite monitoring can produce an estimate of the production rate, through observation of the number of mixers and casting facilities, number of workers, the approximate number of shipments leaving the facility, and the raw materials coming in. But it may be difficult to get an exact count of the number of rocket motors produced under ordinary production procedures. Satellite coverage of the Soviet Union is at most about once a day for a given spot; missiles are primarily produced indoors and most likely would not be shipped out when a satellite was overhead.

The United States proposes to monitor production through on-site inspection. A "tamper-resistant electronic counter" has been developed for this purpose, although its details have not been made public (10). There would be one portal though which completed missiles would leave the factory; the entire perimeter would also be monitored to prevent other exits from being employed. Even if the actual monitoring were done by machine, inspectors from the monitoring nation would be needed for installation and maintenance.

An alternative to on-site monitoring was developed for the proposed MX Multiple Protective Shelter plan. The MX was to be assembled slowly in a designated open construction hall, allowing observation by satellites (11).

A missile production facility could be designed with similar principles. Design of NTM-visible production practices would be aided by the inherent time scale of rocket production; the production of a single rocket booster requires at least three days for the curing process. The curing facility could be operated so that its production was fully monitorable by NTM if it were separated from the rest of the production area by a unique road and surrounded by a barrier system.

Distinguishability of missiles

A total ban on the production of all solid-fueled rockets is unlikely. Continuing production might include space boosters, replacements for aging missiles, short-range, conventionally armed missiles, and any other rocket types not limited by the treaty.

The production of these types of missiles must be distinguished from the banned production. In practice, the stages of missiles do have differences which are observable by satellite, the most obvious being length and diameter. The table shows the length and diameter of the first stages of some Soviet solid-fueled missiles.

Table: Soviet Solid-Fueled Missile 1st Stage Dimensions

Missile	Length (m)	Diameter (m)	Range (km)
SS-25	8.0(12)	2.0	10,500

Ambiguities are possible. The SS-20 is an intermediate-range ballistic missile which consists of the first two stages of the 3-stage, long-range SS-16. In this case production of the stages of an intermediate-range missile is only distinguishable from long-range missile production at the point of assembly. In principle, a third stage could be added on to the two stages of the SS-20 to convert it into a long-range missile. A production monitoring agreement should take such ambiguities into account.

In conclusion, the characteristics of solid-fueled rocket production facilities make them easy to monitor and difficult to conceal. The stages of Soviet missiles can, for the most part, be unambiguously identified. Soviet missile production is routinely monitored by US intelligence agencies; further information which may be required for treaty verification could be acquired through on-site monitoring or through adoption of special NTM-visible production prcedures. These characteristics suggest that the verification of a limitation or ban on the production of large solid-fueled rockets is feasible.

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PHYSICS AND SOCIETY: NOT SUBJECTS APART

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[This article is based on a talk given by the author at a symposium on physics and society teaching, sponsored by the Forum on Physics and Society, at the San Francisco meeting of the APS, in January 1987.]

Introduction

In physics education we must meet the needs both of those who plan to become professional physicists and of those who do not plan to become physicists. However in recent decades, the education of physicists rather than of the public has been at the center of the efforts of the physics community. The standard parameter by which we measure the success of our undergraduate physics curricula is the fraction of our graduating seniors who go on to take up graduate work in physics. We record no pride in the fraction of our bachelor's level graduates who go on and take up respectable employment in our society and we conveniently forget to note that only an infintesimal fraction of our institution's graduates are physics majors.

Departmental review panels are now the rage and I suspect that distinguished members of these panels give enormously more attention to the way the reviewee educates majors and graduate students than to the efforts that are made by the reviewee to bring physics to a larger fraction of the undergraduate population of the institution. We seem to forget that a large fraction of all college graduates take up employment in areas different from the area of their college major and many more change fields during their careers. Our goal seems to be to prepare people for physics rather than for broadly flexible and productive lives in our multi-faceted society.

We seem to be responding to an almost biological drive to reproduce ourselves. Perhaps we feel that we will become extinct if we don't concentrate all of our resources in the processes of self-reproduction. We should learn from biology that the most successful ecosystems are those of the greatest diversity while a monoculture can quickly succumb to a single pest.

For decades we have seen a continuous flow of reports of the ways in which advanced topics in physics can be "taught" (presented?) to students in our elementary courses, and one is reminded of the caption of the cartoon by Brickman (1):

> "Hoo Boy, our educational system is really
> something. They're teaching advanced
> algebra in the third grade and remedial
> writing in college."

However, the great majority of college students don't wish to become physicists, so they are never the recipients of the tender loving challenges that we lavish on those few who do. How did things get to be this way?

An overview of events

Decades ago, before WW II, physicists were regarded as having about the same utility to society as classicists. Elementary physics texts from this period were loaded with photos and discussions of the applications of physics in the real world because we sought to prove to ourselves and to our students that physics did play an important role in our society, even if this was not widely appreciated throughout the society. The public's recognition of the role of physics in society was miniscule but physicists gave the role significant attention in courses. Thus there was little need then to consider offering special courses on "Physics and Society". A fair fraction of our college students took elementary physics because these courses had the attraction and appeal of being significantly oriented toward improving the students' understanding and appreciation of the principles and the applications of these principles which one could see in action in everyday life. It was clear that physics courses helped people understand significant aspects of the real world. By today's standards these introductory courses were not terribly difficult and so their appeal reached far beyond the narrow group of pre-professional students. Some physicists today might look at introductory physics courses prior to WW II and dismiss them as being low-level pre-engineering courses. I think they might better be characterized as "Physics and Society" courses with the emphasis on physics. At least they sufficed at a time when physics had rather little recognition from society.

World War I has been characterized as the war in which chemistry became prominent. In a similar way, World War II was the war in which physics exploded into prominence. As the perils of nuclear energy began to dawn on an unprepared world, physicists thrust themselves into society and they made a great effort to educate national policy makers to the problems and perils that lay ahead. Following some initial successes, this effort to relate physics and society dwindled. One generation of national leaders had been given some minimal appreciation of the problems of physics and society and so we then turned our attention inward and focused on the creation of improved copies of ourselves. We seemed confident that society would be better served by better physicists rather than by improving the understanding and mutual appreciation of physics and society in a larger fraction of our population. During this period we re-examined our curricula and strengthened our introductory courses, making them less applied, more analytical, more mathematical, more abstract, and hence, more pure. The applied topics that we did not deign to offer were discarded. We judged our courses then to be better (meaning more advanced) but in the minds of students this meant "tougher", so there was a decline in the fraction of the general students who took our courses. Physics was just starting to be recognized by the world at large to be an integral part of our society, yet we reacted by reducing the "physics and society" content of our courses and curricula.

Then, in the late 1960's came the devastation of the war in Viet Nam, the shock of the "limits to growth"(2), the tragically moving "silent springs"(3) and the energy crisis(4). These combined to produce a great burst of effort and concern within the physics community and resulted in the appearance of the courses we now know as "physics and society" courses. In a sense we could say that the appearance of the physics and society courses was a reflection of our exclusion of the physics and society component in our physics curricula. Perhaps we thought that "separate but equal" was an appropriate way to deal with physics and society. "Separate but equal" has not worked in other segments of our society and it did not work here. For example, on our campus in 1968 we had to rent a commercial movie theater to accommodate the approximately 800 sutdents who clamored to enroll in a newly established course on physics and society. The course today enrolls about 20 students.

A parallel situation

Perhaps there are lessons to be learned from a parallel but independent evolutionary sequence of events that has taken place in the American automobile industry(5).

Prior to WW II, cars were not very complex and the average American had some first-hand experience in the repair and maintenance of cars. For example, go today to an automobile museum and look under the hood of a Model-A Ford. It is like staring into a nearly empty closet. The three or four main components are all visible and accessible. In contrast, when you look under the hood of almost any car toay you would think you had opened the door to Fibber McGee's closet(6). In the 1930's, concern for the public was an integral part of the automobile industry just as "physics and society" was an integral part of our curricula. But the seeds of decline of the auto industry had been sewn with the introduction of the annual model change which quickly became more cosmetic than concrete.

Key factors in the American victories in WW II were the incredible industrial production of our automobile industry and the achievements of our physicists. After the war physicists turned their attention inward toward the "beauty" of physics and the autmobile industry turned its attention inward to concentrate on the "beauty" of their products. The motivations were similar. American physicists wanted to improve the competitive edge of our physicists over foreign physicists. American automotive companies wanted to improve their competitive edge with regard to one another and they gave no concern to the possibility of serious foreign competition.

In the automotive area we saw a gradual reversal of the roles of "cause" and "effect". Originally the desires of the public for vehicle improvement, as determined by the PR people, were the "causes", and the resulting changes were the "effects". But then automotive management came to believe that a program of perpetual change was the key to perpetual sales success so planned obsolescence became the order of the day. Instead of convincing management of the need for changes as requested by customers, the task of the PR people became that of convincing customers that they should want the model changes that had been made by management. The indelible legacy of Detroit is the widespread semantic confusion of the words "change" and "improvement."

In physics we shifted the content of our introductory courses away from what we had thought would be best for society to what we thought would be best for physicists. Our reasoning was perhaps parallel to that of Charles Wilson of General Motors as we imagined that, "What's good for physics is good for the U.S."(7). "Planned obsolescence" came to introductory physics as our textbook authors produced numerous new editions whose successive changes were just sufficient so that the (n-1)st edition could not be used in a course for which the nth edition was the official text.

As the focus of their attention narrowed from the nation to the board room and the balance sheet, the automotive people shut themselves off from an appreciation of what was happening and what was important. This is best illustrated by the evolution of automobile headlights. For many decades lamp bulbs were placed at the focus of parabolic reflectors which were covered by a moulded glass lens. Road dirt would gradually reduce the reflectance of the reflectors, so the invention (in the 1930's) of sealed-beam headlights (in which the lamp and reflector were a single integral unit) was an enormous technical step forward. As it usually is with optics, these headlights were naturally circular. At some point the perceived need for change led the industry to invent rectangular headlights which retail for about twice the cost of the more natural round headlights without giving any improvement in illumination. And now the continued need for change has driven the industry back more than 50 years as they return to bulbs in reflectors that are covered by individually designed moulded lenses whose replacement cost is many times that of a good sealed beam headlight. These lenses are now an integral part of the streamlined exterior of many contemporary cars. And so while Detroit concentrated their research efforts on making square headlights, their competitors from abroad concentrated on making better cars and took the market away from Detroit.

While we concentrate on giving more and more physics to a declining fraction of the population our competitors abroad may be maintaining or even improving their record of taking introductory physics to a large fraction of their school-age population.

American pre-eminence in physics could go the way of the American auto industry. U. S. physicists and U.S. automobile executives need an improved understanding of the role of their respective enterprises in our society. We have both become very detached and isolated.

We are not alone

What we have done to ourselves in physics is now being copied in other areas. Read, for example, about the Dean of a School of Nursing who wants to shift the school's emphasis away from the preparation of practioneers to a "prominent research/theory-based academic nursing program preparing advanced clinicians for the 21st century." "Preparing students for such a profession requires a highly trained doctoral faculty." In the Dean's view, "serving returning students and developing graduate education is the way of the future" for the profession. "For nursing to achieve its full professional stature, professional nurses of the future will require a nursing doctorate." Here again we could paraphrase Charles Wilson.

What do we do?

A major movement is now afoot to re-examine our introductory courses. It is said that the courses need to be "modernized" and to be "made more attractive". Our standard introductory texts are pronounced outmoded and obsolete, perhaps simply because of their longevity and success. Suggestions as to topics that need to be added to these courses cover a wide range of current and contemporary exotica, not unlike the chrome and gee gaws that decorated cars a decade or so ago. The superficial annual model change seems to be coming to physics. If adding exotica is judged to be moving forward, then let me make a suggestion that will be regarded as a giant leap backward. Let me suggest that we add (restore) a large component of physics and society to these courses and to our curricula. For example, two Canadian high school physics texts illustrate this very well. Hirsh's(8) Chapter 6 is "Mechanical Power and Energy" which is followed by Chapter 7, "Energy in a Modern World" in which he discusses such things as the "Daily Average Energy Consumption per Person" in societies ranging from primitive to modern, the "Approximate Metabolic Rates of Humans" in (W/kg) for various activity levels. He then discusses non-renewable and renewable energy resources and "Society's Responsibilites to Itself" in areas such as "Improving the Efficiency of Energy Use", "Pullution Control", efficiency of appliances and "Our Personal Responsibilities in Solving Energy Problems. In a similar way, Spencer, McNiell and MacLachlan(9) have an extensive section on the arithmetic of growth as it is applied to the consumption of non-renewable fuels, the importance of efficiency in the use of energy, and an examination of the views of optimists and pessimists about the long range effects of continued population growth. Throughout all of their chapters, both of these books stress the relationships of physics with the real world.

It is essential that students in our introductory courses be treated, not as potential physics majors, but as active interdisciplinary participants and leaders in a society of educated people. By letting introductory physics be significantly an introduction to physics and society we will likely broaden the appeal of our subject and increase the numbers of students who elect to major in phsyics. Let our undergraduate curricula be heavily oriented toward the production of increased numbers of terminal BA or BS people whose breadth of education is such that they can move comfortably into an enormous range of positions in the spectrum from the technical to the non-technical. From this large group of bachelor's degree people a small fraction will be selected to go on to doctoral programs.

Two things are essential if this program is to be a success. First, we must reverse the ubiquitous trend of putting yesterday's Ph.D. physics content into today's undergraduate physics courses. Second, we must increase the focus of our undergraduate courses on the area of physics, science, and society. We must then keep science and society as a central aspect of our curricula so that our graduates can be said to be truly educated. By treating "physics" and "society" as subjects apart we may be setting the stage in physics for a decline that will be similar to the decline we have seen in the American automboile industry.

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NEWS

SHORT COURSE: NUCLEAR ARMS RACE TECHNOLOGIES

We would like to announce a short course on Nuclear Arms Race Technologies: The 1990s, to be held 16 and 17 April 1988, in Washington, DC. This is to be a topical meeting sponsored by the Forum on Physics and Society of the American Physical Society and by the American Association of Physics Teachers.

This short course will follow the tradition of the two previous courses offered in 1982 and 1983. The latter resulted in the AIP Conference Proceedings #104: Physics, Technology And The Nuclear Arms Race, edited by D. Hafemeister and D. Schroeer, who are also organizing the course for 1988. The course is intended to supply information to physicists who either plan to teach about the arms race or who want to study the issues of the arms race more deeply. The talks will emphasize the technical aspects of the arms race.

Fifteen 1-hour talks by experts are planned, starting at 14:00 on Saturday, 16 April, and ending in the evening of Sunday, 17 April. These are the two days preceeding the general meeting of the APS that will be held in Baltimore. The sessions will take place at George Washington University in Washington, D.C.

The registration fee for preregistrants is $60, which includes the cost (about $50) of the resulting 500-page AIP Conference Series book. Send registrations and requests for additional information to Professor Dietrich Schroeer, Department of Physics and Astronomy, 278 Phillips Hall - CB#3255, University of North Carolina, Chapel Hill, NC 27599-3255.

COMING FORUM SESSIONS

General Meeting, Crystal City, 25-28 January 1988

1. NUCLEAR PROLIFERATION
   Monday evening, 25 January: Anthony Fainberg, Office of Technology Assessment, presiding.
   - Marvin Miller, MIT, "Stemming the tide of proliferation: a look ahead."
   - Willy Higinbotham, Brookhaven National Laboratory, "Instrumentation that can be applied to IAEA safeguards."
   - Jim deMontmollin, Sandia National Laboratory, "The means of applying technology to safeguards."
   - Mike Rosenthal, ACDA, "Export controls and safeguards."
   - Harold Feiveson, Princeton University, "A wolf in sheep's clothing: is there such a thing as a peaceful atom?"
2. EDUCATING THE PUBLIC FOR TECHNICAL DECISION MAKING
   Tuesday evening, 26 January: Sallie Watkins, presiding.
   - Philip Morrison, MIT, "The scientist's responsibility."
   - Carol Rogers, Head of the AAAS Office of Communications and Membership, "How science is covered in the media."
   - Jon Miller, Director of the Public Opinion Laboratory, Northern Illinois University, "Science education for citizenship."
3. RENEWABLE ENERGY REVISITED
   Thursday afternoon, 28 January, 14:00: Marc Ross, presiding.
   - Joan Ogden, Princeton University, "Hydrogen for solar photovoltaics: implications for the amorphous silicon revolution."
   - Leonard Rogers, Department of Energy, "Status of wind technology in the U.S.."
   - Ed Witt, Solar Energy Research Institute, "SERI photovoltaic research program."

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COMMENT

PHYSICS AND ENERGY TECHNOLOGIES: A NEW FORUM STUDY

The sudden increase in oil prices brought about by the actions of OPEC in the early 1970s caught the United States by surprise. Our national dependence on petroleum as a source of energy prompted a major economic and technological crisis. The government initiated a series of crash energy research programs. We were encouraged to adopt energy conservation measures we'd never considered necessary. The White House urged us to control the resultant inflation by wearing "WIN" buttons. The Department of Energy was formed to recognize the problem at cabinet level. Texas, Louisiana and Okalhoma boomed as oil drilling rigs sprouted on the prairie while the industrial midwest entered a deep recession. We physicists enthusiastically lectured our freshman classes on energy and thermodynamics. Many of us began research projects on energy-related topics, funded by the generous flow of federal funds dedicated to these problems. Universities invested in million-dollar energy research centers.

Today, the price of oil has dropped dramatically. The midwest has managed economic recovery while the oil riggers in Texas are looking for jobs. Federal funding for energy-related research has decreased with oil prices. Many worthwhile (and some not-so-worthwhile) research projects have been discontinued along with state tax credits for energy-saving home improvements. Our freshman students doze through thermodynamics again, asking only whether this material has any relevance other than its inevitable appearance on the exam. The American public has forgotten the concept of an energy crisis!

The physics and geophysics community has certainly not forgotten energy problems. Al Bartlett's video tape "Expotential Growth in a Finite Environment" is as valid today as it was a dozen years ago. The universities and the national and industrial laboratories continue to produce new and excellent research on energy topics ranging from photovoltaic systems and more efficient light bulbs to nuclear fusion and breeder reactors. By personal dedication and shrewd political infighting, many physicists have sustained long-range, well-planned productive research programs in energy-related areas.

Despite these bright spots, energy research and education have lost popular support and visibility as well as funding. Gasoline efficiency in automobiles no longer shows annual dramatic increases and public funds don't underwrite energy efficiency in building. It is harder for physicists to stay current in many energy-related areas since the flow of reports and summaries that crossed our desks in the late seventies has dried up. The accidents at Chernobyl and Three Mile Island have reduced public confidence in nuclear fission power plants. The environmental costs of some of the energy technologies introduced during the height of the energy crisis have begun to appear. An excellent example is the build-up of pollutants inside super-insulated buildings which is currently publicized in stories on the health hazards of radon appearing in women's magazines. (See David BOdansky, "Perspectives on Radon," *Physics and Society*, October 1987, pp. 6-8.) Cheap oil has encouraged the country to return to its dependence on petroleum as an exclusive source of energy.

As we grow increasingly dependent on oil, the world's oil supply seems no more stable than it did at the time of the energy crisis. The reflagging of the Kuwaiti tankers is a reminder that Western Europe and Japan depend on Middle Eastern oil even more than we do. It is no accident that the trigger for World War III in Tom Clancy's novel *Red Storm Rising* is the Soviet need for the oil resources of the Middle East. It is premature to assume that we can afford to abandon the search for new sources of energy, and techniques for making more efficient use of the energy we have.

As physicists concerned with technical issues that affect society, members of the Forum on Physics and Society should be concerned wth updating ourselves and the physics community on the state of energy research. For this reason the Forum has started a new study on the topic "What Should the United States Be Doing to Prepare for the Next Energy Crisis?" The new study will start with three broad questions: (l) When can we expect the next energy crisis and what are our current energy resources? (2) What is the "state of the art" in various areas of energy research and what research programs are needed? (3) What educational activities should we as physicists undertake to increase public awareness of energy-related issues? The exact form of the study will be shaped by the interests of the participants who will work on their own initially in areas in which they are interested. In the past, study groups have been able to meet for briefings from experts in the area so that their work is up to date. Forum studies emphasize the technical rather than the political aspects of a problem and strive for a balanced presentation of controversial issues.

The study is open to all interested Forum members whether or not they have ever conducted energy-related research. The major goal of Forum studies has been to produce a useful product like the book, *Civil Defense: A Choice of Disasters*, which resulted from a previous Forum study, but a fringe benefit to participants is a chance to get actively involved in research involving issues in physics and society and with the Forum itself. The technology of energy production and use will continue to be an important area at the interface of physics with society. A Forum study in the area will be a timely update for the physics commuity and may provide an overview of the problems and available solutions for society at large.

You are welcome to become involved. Send a letter to one of the study organizers indicating your interest and how you can be contacted. Depending on the number of responses we receive, we will organize one or more study groups and contact you to work out details. The people to write are: Ruth Howes, Department of Physics and Astronomy, Ball State University, Muncie, IN 47306 or Tony Fainberg, Office of Technology Assessment, Washington, D.C. 20003.

Ruth H. Howes, Department of Physics, Ball State Unviersity.

WHAT'S NEXT IN PHYSICS FOR THE LIBERAL ARTS?

I thought of it thirty years ago, even before I finished college. Physicists were not meeting their responsibilities to the liberal arts student. Physics was available only in our demanding, highly mathematical, heirarchical sequences, designed for the science major bound for graduate school, for the engineer, at best for the pre-med — weeks and weeks of problem-solving on constant acceleration, conserved angular momentum, DC circuits, etc. If the college was rigorous enough to impose a science requirement on the non-science major, the students chose biology or geology.

By the time I finished graduate school and began teaching I discovered that I wasn't the only one who saw that something was missing. Across the country physicists were devising new courses for the non-scientist, courses naively called "physics for poets," euphemistically called "descriptive". (I saw some of this happen as a teaching assistant under one of the leaders of the movement, Gerald Holton.) We knew we were sitting on the most interesting subject of them all, but we also knew that students couldn't do mathematics. We taught philosophy of science and history of science. We introduced relativity and quantum theory (philosophical implications of the uncertainty principle), physics of music, light and life, astronomy with slides. C.P. Snow demanded the second law. As current events dictated we added new subjects — physics and the environment, energy, the arms race. Art Hobson's "Physics and Evolution" (Physics and Society, July, 1987) was a new one to me.

Self-interest guided us. If the student cannot do mathematics, we provide science without mathematics. This happened in the sixties with physics enrollments declining sharply. It was a matter of FTE's, of budget, indeed of survival.

But mathematical illiteracy in the United States is a matter of serious concern, and as physicists we have a special responsibility. Although educators and parents across the country are looking for ways to upgrade the curriculum, there are trends in the area of mathematics that are not necessarily healthy. Mathematics, we all know, tends toward the abstract. It is sometimes part of the problem. Computer people urge the replacement of analysis by discrete mathematics and programming. Without denying the importance of these other pursuits, we physicists must insist that mathematics is a language for describing things in the real world, a language that is easier and more useful than words.

Of course we cannot expect all undergraduates to take a course with Halliday and Resnick. Indeed the mathematics used in a traditional physics course is more than just algebra, trigonometry, and calculus. It is what we sometimes call "being clever", knowing how to catalogue unknowns and knowns, how to read the conditions of a problem and decide which equation applies. It's what we thought was fun, and what brought many of us into physics.

But there is a middle ground between that kind of physics and the qualitative physics (and astonomy and chemistry) we have developed in the curriculum over the last twenty years. It is a physics that involves familiarity, indeed comfort, with proportionality and inverse proportionality. It involves knowing *why* something might go with the square of something else. (I would like to tell my students that the pressure of a gas goes with the square of the velocity because there are two different ways in which the velocity affects a molecule's hitting of the wall. But only three or four out of sixty will get it.) It means knowing when to expect something to vary in an oscillatory way, when in an exponential way — how to describe these things (without using calculus, but using mathematics). And there is also the matter of numbers measured in experiments, significant figures, graphs, smooth curves and straight lines through scattered points.

There is a terrible mismatch between mathematics as learned in high schools (as well as the ubiquitous remedial programs in colleges) and what students need to know to use math in science and in the practical world. My students have spent weeks learning to solve quadratic equations (even with quadratic formula), but I am starting from scratch when I try to explain the meaning of the square in $s = (1/2)\,at^2$. They have done problems like $a^{17}a^9 = a^{26}$, but they quail at powers of ten. They might recall the formula for the volume of a sphere, but they seem too old to be taught that volume and surface scale differently with size. They react to zeroth and first order approximation as to black magic.

I cannot outline an entire mathematics curriculum here. But we in physics must make the point that liberal arts students should learn science, and that science should be quantitative. We must lay out the kind of mathematics students need for this college-level work. And then we must articulate — at least as far back as the beginning of high school — where and how that mathematics should be placed in the curriculum in order that every college-bound student be appropriately prepared. Finally we must develop a new generation of physics courses for liberal arts students, who then will become scientifically and mathematically literate, and ready to meet their responsibilities in a technological world.

Michael I. Sobel, Professor of Physics, Brooklyn College of CUNY, Brooklyn, NY 11210.

FROM THE CHAIRMAN

Forum functions are progressing well. Art Hobson has worked very hard on the newsletter, particularly in completing this election issue on schedule—the product is very good. The Forum study on the Minuteman missile is moving ahead very well; a September meeting at Princeton of the study group is leading to the preparation of a draft document. As discussed elsewhere in this newsletter, Ruth Howes is interested in initiating a new study on Physics and Energy Technologies.

Barbara Levi, together with her program committee, is putting together a very nice program of invited Forum sessions for this coming year; some of these sessions are listed elsewhere in this newsletter. Some concern has been expressed that the Forum is becoming too one-sided in its interest in the arms race; Barbara has tried to correct for this tendency. But it is true that there are cycles in the interests of physicists, and it is currently the turn of the arms race—hence the short course "Nuclear Arms Race Technologies: The 1990s" that is described elsewhere in this newsletter. Since these interests seem to change about once every ten years, it is approaching time for interest in the energy crisis to resurface.

The nomination process for the Forum and Szilard awards is now synchronized with the other APS awards. Thanks to some hard work by Ruth Howes and her awards committee we will meet the October 15 deadline for selecting candidates for these awards. Fundraising for the two awards was discussed in the last newsletter; it is too early to report anything, but contributions are most welcome. The selection of a slate of candidates for Forum offices has run quite smoothly, thanks to Evans Harrell and his nominating committee. The fellowship committee to nominate APS Fellows on behalf of the Forum is proceeding; it continues to look for recommendations, preferably with documentation.

The Forum is always looking for suggestions, e.g. names of candidates not only for APS Fellows, but also for awards and officer positions. Proposals for Forum studies are always welcome. Send any suggestions and comments to: Dietrich Schroeer, Dept. of Physics and Astronomy—CB #3255, University of North Carolina, Chapel Hill, NC 27514-3255

EDITORIAL: PHYSICS TEACHING AND NUCLEAR WAR

We physicists tend to preach only to the converted. High school physics courses are aimed at students who are not only college-bound and science-bound, but also, preferably, physics-bound. Ph.D.-granting physics departments give top priority to research, next priority to their graduate students, next priority to undergraduate physics majors, next-to-lowest priority to other science undergraduates, and zero priority to non-science students. In some research-oriented institutions, non-majors might be said to receive a "negative" priority, in the sense that faculty members actively avoid commitments to the non-physicists and, especially, to the non-scientists, for such commitments seem uninteresting to many and in any case can only detract from the really important and point-winning work of the department, namely research. Serious involvement with undergraduate courses for non-majors can actually be the kiss of death for aspiring non-tenured faculty members. Thus we devote 90% of our educational efforts to the 1% of our college students who major in physics, and nearly all our remaining effort goes to the 20% who major in other sciences.

The abandoned child in all of this is the great bulk of college students whose primary interests lie outside science, in areas like business, education, and the liberal arts. No wonder so many Americans have so many misperceptions about radiation, nuclear weapons, energy resources, scientific risks and benefits, and the methods of science, not to mention such oddities as astrology, UFOs, and creationism!

The recent (since about 1980) advent of nuclear war education, and the involvement of physicists in this process, is a small but significant development that works in the other direction, toward greater outreach by physicists. Many, perhaps most, campuses now offer at least one non-specialists' course about nuclear war and peace. Such courses are often science- and technology-oriented and often taught in whole or in part by physicists. Three excellent textbooks by physicists have been written for such courses. In chronological order, they are *Science, Technology and the Nuclear Arms Race* by Dietrich Schroeer (Wiley, New York, 1984), *Waging Nuclear Peace* by Robert Ehrlich (State University of New York Press, Albany, 1985), and *Nuclear Arms Race* by Paul Craig and John Jungerman (McGraw-Hill, New York, 1986).

But these praiseworthy courses are still directed primarily at the already committed, in the sense that any student enrolling in them is already sufficiently interested in either science or technology or the arms race to sign up for some 45 classroom hours on nuclear war topics. We are still tending to teach to the one percent who are already motivated.

If physics and nuclear war are important parts of the intellectual, cultural, or social world, then these topics deserve to be communicated to the great bulk of our educated non-scientists. Probably the only efficient way to do this is by devoting a serious teaching effort to a large introductory general-physics course taken by most non-scientists, and to include nuclear war topics in such a course. Other significant physics-related social and philosophical topics should, of course, also be included. See the July and October editorials for examples. Although such an approach cannot go into much detail, it can reach the great bulk of non-science students with at least a broad picture of nuclear war problems and some possible solutions. This approach thus compliments the more focused nuclear war course by reaching a larger and broader group of students, and in fact offers the advantage of placing the issue into its context in the full sweep of physics and its implications. Far from detracting from the more focused higher-level course, the general course can prepare students for the later course, and direct students toward it.

Because liberal-arts physics courses are fairly flexible, as compared with the more technical introductory physics courses, it is easy and natural to introduce social topics such as the arms race into them. Nevertheless, I know of few liberal-arts physics courses today that include nuclear war topics. I do not know the reasons for this, but it seems to me that physics, education, and society are all the worse off for it.

I can testify that it is interesting, and not especially difficult, to introduce nuclear war topics into liberal-arts physics courses. On our campus, our "Physics and Human Affairs" is one of several courses that students can select to help satisfy a three-course lab-science requirement for non-scientists. It enrolls 250 students per semester plus 100 in the summer, and thus reaches a large fraction of the non-scientists on our campus.

Nuclear war is discussed in three or four lectures toward the end of the course. It fits quite naturally into a sequence of a dozen lectures (25% of the course) on nuclear physics and its implications. Topics include the Manhattan Project, the construction of A-bombs and H-bombs, the physical effects of individual weapons and of nuclear war, a brief listing and discussion of some of the social effects, a few details from the history of the nuclear arms race, today's nuclear arsenals, and brief overviews of deterrence, strategic defense, and arms control, all interspersed with a lot of class discussion. Students are sufficiently interested that they ask questions and offer comments even in our large class.

There is obviously plenty of physics in most of this. It would be difficult to find a topic more intellectually exciting or socially challenging. Certainly nothing is more important, for physics as well as society will cease to exist if there is a full-scale nuclear war. It is thus difficult to understand why nuclear war and peace topics are not routinely taught in introductory physics courses, particularly the courses for non-scientists.

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