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LETTERS

ATMOSPHERIC THREAT

Richard Williams' Comment (April 1988) was a thought-provoking note about some current activities which might develop into a serious threat to the earth's atmosphere. He refers to a recent patent on equipment designed to deliberately alter a region in the earth's atmosphere, ionosphere, and/or magnetosphere by the use of an extremely high intensity beam of radio waves, reportedly using power levels of billions to hundreds of billions of watts. Among the intended uses identified are to disrupt microwave transmissions of satellites or to cause even total disruption of communications over a very large portion of the earth, weather modification, lifting large regions of the atmosphere, and intercepting incoming missiles. His comment indicates that classified work on this topic is in progress at present.

One point that Williams did not make, which I think is also important and worth making, is that some if not all of the modifications and manipulations of the earth's atmosphere and near-space environment which he refers to as resulting from using this technique would appear to have the potential for leading to violations of the Environmental Modification Convention. This Convention, signed in 1977 and ratified by the United States in 1979, prohibits military or any other hostile use of environmental modification techniques, and states that "Each State Party to this convention undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting, or severe effects as the means of destruction, damage or injury to any other State Party." Both the Convention itself and the accompanying Understandings Regarding the Convention make it explicitly clear that the atmosphere, the ionosphere, and near-earth space are included in the Convention.

Please note that the opinions expressed in this letter are my own and should not be interpreted as representing the position of Argonne National Laboratory.

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LAND-MOBILE MIDGETMAN

Art Hobson (April 1988) presents a very interesting analysis of the survivability of land-mobile Midgetman missiles, particularly in the face of barrage attacks by submarine-launched ballistic missiles (SLBMs) with short flight times.

An attack mode with much less warning time is very likely to arise if a (fully or partially) space-based ballistic missile defense (BMD) system is ever believed to be survivable enough to be deployed. The same space-survivability techniques would then make possible at least equally survivable (and therefore unstoppable) nuclear orbit-to-earth missiles (NOEMs), which could masquerade as nuclear X-ray lasers or space mines.

With only half of their mass expended as fuel, NOEMs (accompanied by decoys) could travel from a 500 km-altitude circular earth-orbit to ground in about 4 minutes with, say, a 15 sec-burn-time vertical rocket exhaust velocity of 3 km/sec. Dash-mobile land missiles would then be particularly vulnerable, even with a low-accuracy NOEM barrage attack, as Hobson's Figure 1 makes clear. But modern guided warheads and navigation satellite positioning systems should make NOEMs accurate enough and flexible enough to also make random-mobile and silo-based land missiles vulnerable to targeted attacks.

NOEMs, which were tested by the Soviets in the 1960s, are banned by the 1967 Outer-Space Treaty. However Gorbachev warned, at the 1985 summit, that all arms control "will be blown to the winds" if a space-based BMD (banned by the ABM treaty) is deployed.

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ARTICLES

A CRITICAL LOOK AT LAND-BASED MISSILES, CONTINUED

This issue of *Physics and Society* concludes a brief preview, begun in the April issue, of some of the work of the Forum Study Group on land-based missiles. Although the study is not yet complete, enough material has accumulated to warrant sharing it with you.

WHITHER LAND-BASED MISSILES?

Paul P. Craig

Nuclear weapons systems capable of penetrating to the heartland of the Soviet Union constitute the cornerstone of United States strategic military strategy. These weapons, emplaced on submarines, aircraft, and intercontinental ballistic missiles, comprise the strategic triad. The structure of the triad has evolved over the four decades of the nuclear era. New technological developments on both sides and changing perceptions of threats have over the years led to continuing changes in the triad. At present concerns over vulnerability of the land based leg, and changes in the Soviet Union under Gorbachev (glasnost) make it appropriate to reexamine the role of this leg. The START negotiations for deep cuts in the strategic arsenals of both sides contribute to the need for a of new analysis. This article provides some context.

The strategic arsenals of the US and the Soviet Union differ substantially. The Soviet Union emphasizes land based missiles while the United States places relatively equal emphasis on land, air and sea based missiles. Increasing accuracy is making hardened land based missiles vulnerable, while MIRVing (installing multiple warheads) makes them prime first-strike targets. Plans for modernization should deal with both these issues. Most discussions about the START negotiations focus on reductions of total numbers of warheads. Of at least equal importance is the structuring of forces so as to increase both crisis (short term) and strategic (long term) stability.

Strategic weapons are intended to deter a potential enemy. Under concepts of "rational deterrence" this is accomplished by maintaining a national capability to threaten what the enemy holds dear, even after an enemy attack. The very concept of "rational deterrence raises numerous questions. Only with a clear concept of what strategic weapons are for one can form thoughtful opinions on their characteristics and numbers.

Within the framework of rational deterrence very different perspectives exist. One focuses exclusively on military capability. In this view the civil economy is irrelevant. This perspective was clearly articulated in a presentation to the Forum Land Based Missile Study in Washington in April, 1987. General May of the Air Force Land Based Missile Command told the Study that "the Soviet value structure does not include (emphasis added) its cities". This view stands in dramatic contrast with the philosophy of the French and British. Their nuclear capabilities are designed explicitly to hold major Soviet cities (especially Moscow) at risk.

Targeting philosophy is frequently discussed by military and political leaders, and by analysts. Regardless of announced philosophy, actual targeting plans are not known to an enemy. Weapons characteristics and numbers are known. Potential enemies know too that strategic weapons can be launched before they can be destroyed. The technical capability for launch-on-warning (LOW) always exists. An articulated LOW strategy can be mistaken for a policy of first strike, and hence looks aggressive. The incentive to LOW is especially severe in systems which are vulnerable and systems with limited warning times. For the latter systems - and these include all systems which are probable objects for attack by ICBMs and SLBMs - launch policy must be turned over largely to computers - with all the risks attendant thereto.

Attempts to develop nuclear strategies must inevitably address the fundamental fact that we are affected by decisions made by other nations. The extreme difficulties inherent in analysis have led to the concept of the "rational decision maker." The central concept is an unprovable assertion: deterrence will occur if the United States can retain, following a Soviet first strike, enough destructive capability to destroy so much of the Soviet Union that the advantage of the first strike isn't worth what is gained.

In classical theory of war (e.g. that of Clausewicz), war may occur if one side feels that by going to war there will be gains which exceed the losses. The potential gains can be economic, or political (as occurred in the Argentinean invasion of the Falkland Islands). Alternatively, war can occur if a nation feels it is boxed in. Leaders may go to war in order to prevent an even worse disaster. The latter situation (forestalling a worse disaster) is sometimes given as the reason for the Japanese initiation of World War II by bombing Pearl Harbor despite clear statements by military leaders that Japan's military advantage therefrom would be short lived.

Rational decision maker arguments assume that a potential enemy will undertake some sort of rational analysis of options. An enemy who does not operate this way is "irrational," and it is then entirely unclear what forms of deterrence might work. Two major problems of deterrence theory, and of MAD, are: what do we do if we begin to suspect that our adversaries are not "rational," and what are the risks of inadvertent war? In times of crisis mistakes can be made as a result of human error (e.g. due to intelligence failure or fatigue) or to errors in machinery. Machine errors can almost always be traced back to some error in design; hence they too can be blamed on people.

A remarkable amount of discussion of nuclear deterrence philosophy boils down to one's choice of metaphor. The metaphors of World Wars I and II are dominant. World War I is seen as accidental,

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driven by structural instabilities which could be set off by a bit of tender (the Archduke Ferdinand incident at Sarajevo). World War II is seen as intentional. A current example of the force if these two metaphors is found in the lead article in the Fall 1987 issue of Foreign Affairs (1). In an article generally optimisitc about nuclear stability Hyland expresses his view that war by inadvertence is currently the primary risk: "The specter of Pearl Harbor has been replaced by the specter of Sarajevo." He views the risk of inadvertent war to be acceptably small. Others - myself included - disagree.

The United States seems to prefer technical solutions. This is illustrated in the era lasting roughly from 1972 to 1983, which was characterized on the US side by introduction of smaller strategic nuclear weapons systems with improved accuracy - hence higher kill capability against hardened targets. Delivery systems were MIRVed. United States emphasis on technology is seen currently in the Strategic Defense Initiative. Historically the Soviet Union has always responded in kind, and the United States technological advantage proved short-lived. Though one can argue that we retain stability by running ever faster, this has a certain "Alive-in-Wonderland" flavor (remember the Red Queen).

The arsenals of the United States and the Soviet Union have evolved both quantitatively and qualitatively over the years. Strategic doctrine about the use of nuclear weapons interacts with and coevolves with what is technologically feasible. It is often meaningless to attempt to distinguish which of the two is the primary driving force.

One way to view the evolution of the US strategic arsenal is in terms of the total megatonnage. This reached a peak of about 19,000 Mt (megatons) in 1959, and has since dropped about 5000 Mt (2). The reduction was predominantly following 1961, due to dismantling the enormous weapons deployed on B36 bombers (3). Later reductions resulted from MIRVing of ICBMs and SLBMs. MIRVing results in an increase in warheads per delivery vehicle, but a reduction in total megatonnage on each vehicle. MIRVing occurred at a time when accuracy was increasing rapidly(4). This permitted a reduction in total megatonnage, with no sacrifice in lethality. The United States arsenal retains the ability to destroy the Soviet Union many times over, even in the aftermath of a Soviet first strike.

By the early 1980s the US and the Soviet Union had roughly the same number of strategic weapons - about 10,000 on each side - though the mix and quality of technologies differed considerably. Recognition of essential parity between the two nations has not come easily to the US. There is pressure to try to remain ahead. This philosophy - which is essentially a psychological argument - was clearly expressed by Richard L. Wagner while he was Assistant to the Secretary of Defense for Atomic Energy:

"What it comes down to in the end is to keep [the Soviets'] image of themselves inferior to their image of us, so that if a crisis comes they will have a gut feeling that they won't measure up against us. It is often said that Soviet leaders are conservative. They are when they feel inferior...Our job is to keep them feeling inferior and thus conservative...I believe that our level of technology in itself, quite apart from exactly how it is built into fielded systems, affects their overall image of themselves and of us, and thus can have a significant deterrent effect...By the 90s we'll need some really new technology to keep the image ratio in our favor. The technology of nuclear explosive design is an important part of our overall technological capability."

For a number of years technological developments on the Sovietside have stimulated concern that the land-based leg of the US triad is becomming vulernable. A new missile, the MX or Peacekeeper, was developed. This ten-fold-MIRVed missile was designed to have the accuracy to destroy hardened Soviet land based ICBMs. To meet survivability criteria the missile should be sited so as to be invulnerable to a first strike. But Soviet accuracy continues to improve. Numerous proposals have been made for basing the MX-ranging from deployment in extra hard silos to continual movement among shelters, to location on railroad cars which will be scattered throughout the nation. Survivable basing for the MX has proved elusive. This problem led to the proposal for a mobile missile, Midgetman, which by virture of its single warhead is a less attrractive target, and through its mobility is hard to target.

Survivable systems deter by threateneing post-attack retaliation. Four major approaches have been proposed:

Deception. This includes hiding. For example the siting scheme for the MX missile in which a few missiles would be hidden amongst a large number of decoys.

Mobility. By moving missiles around it becomes difficult for the enemy to know where any one is. A strategy of mobility may drastically reduce the need for hardening. Mobility is most obvious with submarines. Many deployment schemes for land-based missiles attempt to make hiding possible on land as well as at sea. The Soviet SS-20 and SS-25 are examples of this strategy. So too are the proposed rail garrison MX and road-based Midgetman.

Hardening. The land-based ICBMs of both the United States and the Soviet Union are defended by being placed in hardened silos This strategy is plausible until the kill capability (accuracy, primarily) of the enemy weaponry increases sufficiently, at which point the hardening no longer provides protection. Such capability has almost been attained on both sides.

Active Defense. (e.g. ABM systems and point defense components of SDI systems). The Soviet Union has long maintained a large air defense system covering the entire nation, and an ABM missile defense in the Moscow area (as permitted by the ABM treaty). The United States has abjured both approaches. Reexamination of the future of the land based leg of the strategic triad should include the possibility of terminal defense.

Survivability cannot be considered in terms of a single leg of the triad alone. The legs of the US Strategic Triad act synergistically. For example, if Soviet ICBMs are fired at the US land based ICBM fleet, it is possible that many of our ICBMs will be lost. However, the tactical warning (up to 30 minutes or so) provides ample time for our bomber fleet to become airborne. As the number and accuracy of off-shore Soviet submarines increases this type of symbiosis will work less well.

An important argument for a triad is based on technological and military change. By having several strategic systems relying on quite different technologies, it is likely that we will never be so surprised by new developments that we lose so much deterrent capability as to be vulnerable to threats. This line of reasoning also underlies the US practice of having at least two different warheads for each leg of the triad.

The vulnerability of the Minuteman silo basing mode for the MX stems from the observation that a first strike would require only two Soviet warheads (the second is to make sure of success in case of a miss by the first) to destroy the 10 warheads in the MIRVed MX (see the April 6, 1983 Report to the President of the Scowcroft Commission).

In contrast to the United States triad, the Soviet strategic system emphasizes primarily land based ICBMs. This Soviet strategy is viewed by some United States analysts as unfortunate. According to this view we would like the Soviet Union ICBM fleet to be as invulnerable as our own. The recent Soviet moves toward mobile land based missiles (the SS-24 and SS-25) are thus seen as stabilizing. These systems can hide on land in much the way that submarines hide at sea.

The present START negotiations and the ferment over the future of the land based leg of the US strategic nuclear arsenal make the next few years especially important. Decisions will be made which may affect fundamentally the nature of our national defense. They may also determine the feasibility of future arms reductions. The issues are complex and involve military, technical, political, economic, social and perceptual issues.

Deep cuts by themselves could prove destabilizing. Imagine, for example, that both the United States and the Soviet Union reduce their strategic arsenals to only a hundred or so warheads located on highly MIRVed delivery vehicles. The incentive for a first strike would surely be increased. In addition, the arsenals would be comparable to those of France and Britain, and hence the world would no longer be in a mode of bilateral balance.

Today every issue is ripe for reexamination. Some are relatively narrow: Do we even need a Triad? Might not cruise missiles take over the role now played by ICBMs? Should we abandon MIRVing? Should we encourage or discourage mobile ICBMs? Others are more fundamental: Is it possible that the Soviet Union is changing so much that we may soon no longer need massive arsenals? How do we balance the risk of war against the risk of accident?

The next few years will see renewed examination of all these issues. This is a fascinating period. For the first time in decades conditions appear ripe for major change in our nuclear policy.

REFERENCES AND NOTES

1. William Hyland,"Reagan-Gorbachev III", *Foreign Affairs*, Fall 1987, pp. 7-21.
2. There are numerous ways of expressing the arsenal sizes. Total megatons as used here, and equivalent megatons (EMT) are common. The EMT of an individual warhead is defined as the megatonnage to the two-thirds power. EMT is a measure of the area of destruction produced by the weapon.
3. Many of the enormous warheads used during this period were mothballed. One of these, the 9 Mt B53 bomb deployed at one time on B-52 aircraft is the largest weapon in the US arsenal. In mid-1987 the B53 warheads are again being returned to the US stockpile.
4. The ability of a given weapons system to destroy a hardened target varies as the yield divided by the accuracy cubed. Hence a factor of two increase in accuracy permits an eight-fold reduction in yield for the same kill probability.

THE MX RAIL-GARRISON BASING SYSTEM

Peter D. Zimmerman

The MX program was intended to give the United States the ability to hold the hardest Soviet targets at risk, and to provide a highly survivable land-based strategic ballistic missile to replace the silo-bound Minuteman III. Early plans called for the missile to be deployed in a "race track" system with multiple protective shelters (MX-MPS), the missile being moved periodically from shelter to shelter. With "luck" and very good mimicking of the missile's signatures, the Soviet forces would not know which shelter was occupied, and so would have to shot at least two warheads at each one. Twenty shelters were contemplated for each missile.

The MX-MPS system foundered for several reasons. It was opposed by environmentalists, arms controllers, and those concerned about the size of the budget for strategic offensive arms. The MPS system occupied too much land, required the land to be used only by the Air Force, might have had serious effects on the water supply in generally arid regions, was extremely expensive per surviving warhead, and gave the appearance of being a first-strike weapon because of its lack of manifest survivability (1). A major study conducted by the Congressional Office of Technology Assessment (2) failed to identify any other basing schemes with the requisite manifest survivability which also incorporated the robust communications possible for land-based systems. That study did examine rail-mobile missiles, but with theunstated assuption that such missiles would be on the rails at all times. According to the OTA, rail-mobile missiles were survivable at any foreseeable level of the Soviet arsenal, but in peacetime would contribute to traffic congestion on the rail system and would be vulnerable to accidents, sabotage and terrorism.

Congress allowed the Air Force to deploy the first fifty MX missiles in silos as direct replacements for Minuteman III missiles, but insisted that no further missiles would be procured until a survivable basing mode was developed. The rail garrison MX program was produced in response to that challenge.

The rail garrison deployment system envisions 25 trains, each with a complement of two MX missiles, each train being permanently stationed on existing Strategic Air Command bases. Between 7 and 17 SAC bases would receive the missile trains. According to Air Force figures, three hours after a decision to sortie from garrison was made, the system could not be barraged by the current Soviet SS-18 inventory assuming a yield of about 500 Kt (kilotons) per warhead. Four hours after sortie, the force would be safe against even the largest projected increases in the SS-18 force. These figures assume a 50-80 km/h speed for the trains and minimal start-up time (possible since the trains will use diesel locomotives) from "track alert" status (3). It is assumed that the first bifurcation in the

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available track occurs where the spur from the garrison meets the main line, a distance of not over 15 km from base. From that point on track is generated at least twice as fast as the train moves since there is at least a two-fold ambiguity as to the course of the train.

The Air Force safety figures for the rail-garrison system are arrived at by assuming that the readily achievable hardness of a loaded rail car is 5 p.s.i. (4,5) and that a single 500 Kt warhead,exploded at optimum altitude,can produce at least a 5 p.s.i. overpressure along a 7 km length of track. Each SS-18 could possibly have a war loading of 12 re-entry vehicles. This is two in excess of the SALT II limit. However, SS-18s which executed 10 real and two additional simulated releases of RVs have been tested. Assuming that the Soviet Union has confined its deployments to the ten warhead SALT II limit reduces the length of track which can be barraged by a single missile. All forms of a Strategic Arms Reduction Treaty (START Treaty) now under consideration would, in fact, cut the SS-18 force roughly in half while permitting the deployment of at least 100 MX missiles.

It is possible that the Air Force figures are, for once, unduly conservative. Trains are significantly harder against explosions either in front of or behind them — up to 90 p.s.i. for explosions where the blast wave strikes the locomotive. If the correct criterion is a blast with a 5 p.s.i. component perpendicular to the tract, the length which can be destroyed by a single missile is greatly reduced.

Nevertheless, it is clear that several hours need to be available in order to assure the safety of the entire rail-mobile system. When the survivability of a weapons system depends on warning time, the enemy would be encouraged to strike soon rather than wait. It might perceive the vulnerable missiles to be either allocated to a first strike or operating in a launch-under attack mode. The President can defuse the situation by ordering the trains to sortie from their garrison. The President might be reluctant to give this order for fear of raising tensions in a delicate situation. On the other hand, it could be viewed as a reassuring step. Missiles which are unlocatable and "untargetable" can be considered part of a secure second-strike reserve. Furthermore, because of the vibration and dislocation involved in moving a missile on the rails, it is probable that the guidance system of a rail-mobile missile will be less accurate for several hours after a major movement than would be the same system housed in a silo. This could add to a general perception that scrambling the trains was a purely defensive and stabilizing gesture.

Some argue that rail-mobile missiles complicate the verification of arms control agreements. These points are raised: rail-mobile missiles can roam all over the country, be hidden in tunnels and buildings, or be concealed in trains that resemble civilian trains. But rail-mobile missiles are just that — confined to the railroad net. Rail lines are easily recognized features when seen in satellite photography, even at the 10 meter resolution provided by the French SPOT 1 satellite. The Soviet rail net is particularly easy to inspect, since it is a skeleton whose back bone is formed by the trans-Siberian and BAM rail lines stretching across 7 times zones, but which has few ribs running perpendicular to the spine. Trains on tracks are identifiable in high-resolution imagery, but such pictures necessarily cover only fairly narrow angles of view. Hence, they cannot be used effectively to search for trains which have been ordered to sortie from garrison. Furthermore, the missile train could not be distinguished from any other train from a satellite photo.

Trains cannot be hidden for long periods in tunnels; concealing a missile there would block an entire rail line, and construction of special tunnels would be observed. Trains cannot circulate at random, but must follow schedules — particularly on a single-track main line such as the Trans-Siberian — since trains in opposite directions can only meet where sidings exist. Rails rarely enter buildings; they stop at loading docks.

Finally, the facilities at which missiles are mated to rail cars will be very distinctive, easily recognized in satellite photography. Relatively straightforward analysis based on imagery of such a facility can provide good estimates of its maximum through-put, and hence an upper limit to the number of deployed rail-mobile missiles. The number of such facilities in each country can readily be made a part of any future arms limitation or reduction agreements.

Since the signing of the INF Treaty in December 1987, it is clear that verification does not have to be conducted solely by national technical means (NTM), in effect from satellites. Co-operative means of inspection and verification will shortly become the rule in strategic arms control agreements. Under such a regime, portal-perimeter monitoring of the rail-missile integration facilities could provide a highly accurate count of the number of missiles deployed on the rails.

Public acceptance of rail mobile missiles would not be forthcoming if such a deployment meant that nuclear-armed missiles would be intermingled with ordinary rail traffic in ordinary times. The *garrison* feature of rail garrison MX directly addresses that problem. Despite Pentagon models of American rail-mobile MX missiles concealed in ordinary box cars, moving in ordinary freight trains, such a deployment is unlikely. The National Command Authority is unlikely to give the order for the trains to sortie except under conditions of DefCon 1 or DefCon 2 when the United States anticipates that a nuclear attack is imminent; such an increase in the state of alert is apt to occur several hours before a premeditated attack occurs. While the garrison facilities are usually shown as simple structures, they can be built as "horizontal silos". One source estimates a hardness of 2000 p.s.i. for such structures, giving garrisoned trains a reasonable chance of survival. The garrison could be designed to permit missiles to be fired after an attack.

Rail garrison mobile ICBMs, generically, provide a nearly indestructible deterrent force because they can "generate trackage" in which the location of the train becomes uncertain so rapidly that they cannot be barraged. The track itself, together with the fiber-optics communications systems which parallel most of the U.S. rail network, virtually guarantee communications even under the conditions of a nuclear attack. The personnel costs of rail garrison missiles are low compared to those for truck mobile systems. Railroad equipment is vastly cheaper than, for example, any proposed version of a hardened mobile launcher. On the used market diesel locomotives can be bought for a few hundred thousand dollars or less; new they are in the one to two million dollar price range. No 35-100 psi hard HML is competitive with the costs of the rail equipment needed to transport a missile. For MIRVed rail-mobile systems, garrison basing is very nearly as cheap, per warhead, as present silos.

But the rail mobile system, by itself, does not address the problem of vulnerability in case of a "bolt out of the blue," or "Pearl Harbor" attack. Under those circumstances, many missiles in garrison will probably be destroyed. Although nuclear bolts out of the blue seem improbable, rail mobility might need to be complemented by other basing modes — such as superhard silos or truck-mobile smaller missiles — for a limited number of land-based missiles, if absolute assurance that a fraction of the land-based leg of the triad will survive is sought.

REFERENCES AND NOTES

1. An ICBM which is both able to strike the missile silos of a potential enemy *and* which is itself vulnerable is a "shoot it or lose it" weapon. Since the missile force cannot ride out an attack and survive for later discriminate use, its owner must plan on using it before it is attacked — and its opponent must regard the missile as having been constructed for executing a first strike attack.
2. *MX Missile Basing*, Office of Technology Assessment, September 1981.
3. "Track alert" would be the rail-garrison version of putting bombers on strip alert where the aircraft are manned and ready to take off but without engines running.
4. Above ground nuclear weapons tests conducted before the 1963 Limited Test Ban Treaty demonstrated conclusively that even *wooden* boxcars were usable after experiencing 6 p.s.i. over-pressures.
5. S. Glasstone and P.J. Dolan, *The Effects of Nuclear Weapons*, third edition, United States Departments of Defense and Energy, Washington, DC, 1977, pp. 192-3

TERMINAL DEFENSES AS AN OPTION FOR MAKING LAND-BASED MISSILES SURVIVABLE

Ruth Howes

From a strategic viewpoint, defensive systems fall into two clear categories, area defenses and point defenses. Area defenses have the ability to protect all targets within substantial areas of a country. Such defenses must be based at least partly in space to intercept missiles early in their flight while they can still potentially reach a wide range of targets. For examples, layered defenses based largely in space might protect the eastern seaboard of the United States from Soviet missiles. Space-based interceptors which attack missiles early in their flights are intrinsically capable of area defense since they can attack missiles aimed at many targets. Point defenses protect single targets which have been "hardened," that is reinforced against the blast, thermal radiation and other effects of a nuclear attack. Typical point defenses might protect the NORAD command center under Cheyenne Mountain in Colorado but would offer no protection to Denver. Point defenses do not require a very large range because they must protect only one specific target. They are frequently based on the ground near the target they protect or have some limited mobility. Point defenses might, for example, depend on sensors based on aircraft which take off on warning of an attack. Point defenses also depend on target acquisition by remote radars.

Strategically, some feel that area defenses are inherently destabilizing. If either the U.S. or the USSR deploys defenses with a limited area capability, the other side will be more tempted to strike first in a military crisis than it would be in a scenario without defenses. This happens because the side without defenses sees that the defenses will degrade but not defeat his first strike attack. On the other hand, even limited area defenses might significantly limit damage to the enemy from a "ragged retaliation" following the defended side's attack on the undefended side's nuclear weapons. Thus deployed defenses with some capability as area defenses give the other side a strong incentive to strike first in a nuclear crisis. If both sides deploy defenses, the incentive to attack first in a crisis would be even stronger for *both* sides and the result of the defenses would be increased instability in global crises. Perfect defenses that stop all incoming nuclear weapons would not, of course, destabilize the strategic balance but even if they should be technically feasible in the future, the defender could never be confident that his defenses were completely impenetrable. Deploying a partially effective area defense would encourage the other side to deploy its own defenses and seek to develop an offense that could penetrate the other side's defenses. Thus deploying area defenses without treaty limitations on offensive weapons would encourage an offensive-defensive arms race.

Point defenses protect only specific targets such as missiles based in hardened silos. They increase the enemy's uncertainty that a first nuclear attack could disarm the defended side and discourage him from launching a nuclear first strike that would be met by a major retaliation. True point defenses do not offer any protection to population, even against a limited retaliation following a first nuclear attack. Thus point defenses of land-based missiles are strategically equivalent to mobile basing modes or superhardened missile silos. They arguably stabilize the nuclear balance in a crisis situation, although they may still fuel an offensive-defensive arms race. Some extend this argument to area defenses by claiming that they serve only as insurance against a first nuclear strike and are not inherently destabilizing.

Because this study concerns itself with the survivability of the land-based leg of the triad and any defense with area capabilities opens other strategic issues, we will deal only with hard point terminal defenses and not discuss any space-based defensive sys

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tems. A second reason for avoiding discussion of systems based in space is that their architecture is still undefined and any discussion of their merits would be speculative.

Point terminal defenses come in two basic classes. The first, which we shall call conventional, consists of rocket powered interceptors based near the target to be defended and launched to intercept missiles entering the terminal phase of their flight toward the target. Conventional terminal defenses may protect both hardened targets such as missile silos, and softer targets nearby such as communication facilities. They are thus designed to intercept incoming warheads at such an altitude that a nuclear detonation from either the attacking reentry vehicle or the interceptor missile would do minimum harm to targets on the ground. The interceptor may be guided toward its target by infrared, optical or radar sensors carried on board, or it may be guided by sensors based on the ground or on a mobile platform such as an aircraft. Incoming RVs might be destroyed by nuclear detonations, conventional explosions or the launch of devices such as pellet swarms in the path of the targeted RV. Because the time involved in terminal phase is on the order of a minute or less and RVs must be destroyed at least ten kilometers above the surface in order to protect soft targets if the warhead is fused to detonate on attack, the interceptors require high acceleration boosters to get them to their targets in time. Hardened silos require smaller keepout ranges of less than one kilometer, so the task of interception is easier. Other critical technologies for conventional interceptors include target acquisition and tracking systems such as defense site radars and airborne or space-based radar, infrared and optical sensors as well as systems for terminal guidance of the attacking interceptor. The defender must consider countermeasures that could destroy, confuse or saturate his defenses.

Both the United States and the Soviet Union have at some time deployed terminal defenses using land-based interceptors and radars. The Soviet Galosh anti ballistic missile system which is deployed around Moscow is of this type and the Untied States deployed and then mothballed a similar system around missile silos at Grand Forks, North Dakota. The Anti Ballistic Missile Treaty as amended in 1976 allows each nation to deploy one system of terminal point defenses containing 100 interceptors either around its national capital or at one base around missiles in hardened silos. Therefore terminal defenses of a limited number of missiles is clearly a legal option in the United States for ensuring the survival of a portion of the land-based leg of the triad. The Soviets have already deployed their allowed system around Moscow.

So far, deployed terminal defenses consist of high acceleration interceptors, at least some of which carry nuclear warheads. Interceptors are guided to their targets by radars stationed near their silos. The targeting radars are alerted to the presence of incoming missiles first by satellite warning of an enemy launch and then by early warning radars which include large phased array radars stationed around the perimeter of both superpowers and over-the-horizon radars which guard the more southern lines of attack. The large phased array radars have the ability to track incoming missiles and to pass targeting information to tracking radars located near defensive silos. In the past, such terminal defenses have been vulnerable to attack on the radars which guide the missiles to their targets. Large phased array radars are very soft targets and are vulnerable to nuclear attack. They are expensive, take years to construct and thus cannot be easily proliferated. The early U.S. Safeguard/Sentinal system also suffered from a lack of computer capability for battle management.

Technical improvements which may make terminal defenses more effective and less vulnerable include interceptors which have on-board tracking capability, more sophisticated computers and software development techniques, mobile radars and infrared or optical sensors such as those to be tested aboard the Airborne Optical Adjunct experiment under the auspices of SDI. Since the ABM Treaty explicitly forbids development of mobile components of ABM systems, the legality of such tests depends on the detailed interpretation of what exactly constitutes a "component" of an ABM system and whether or not such systems are based on "new" physical principles. The Soviets have deployed a massive defense against aircraft and their newest surface-to-air missiles may have a limited capability against incoming RVs from ballistic missiles. Any terminal defense is subject to direct attack, enemy countermeasures designed to fool it such as decoys, and to saturation by an enemy who simply proliferates his offensive warheads.

The second class of terminal defense, novel defenses, involve defenses of missiles in silos that are not based on rocket-launched interceptors. These defenses are discussed in the literature but have not yet been deployed. They include concepts such as dust defenses, fratricide of missiles induced by close spacing of silos, or powerful lasers based at the site of the silos to be defended. The general argument in favor of such systems is their low cost relative to traditional terminal defenses and their immunity to saturation by a single massive strike. In many cases, novel defenses may produce significant damage to the population or environment, which argues against deploying them. For example nuclear detonations near the surface in a defense that works by fratricide produce large quantities of lethal radioactive fallout which might cause a significant number of civilian casualties. Most novel defenses are designed to operate with a very small keep-out volume so they defend only hardened targets and offer no protection to nearby soft targets such as command and control radars. In this sense they are less likely to trigger an offensive/defensive arms race because their use is clearly an act of desperation on the part of the defender. Some novel defenses also depend critically on warning of an attack to trigger their use and are vulnerable to a false alarm which might cause significant damage to the defender's own territory.

A final issue in designing hard target terminal defenses is that the defender must decide what to defend. If he decides to defend only a fixed percentage of his silos, he can concentrate defenses on those silos and significantly improve their efficiency. Such limited terminal defenses obviously involve difficult strategic decisions about just how many land-based missiles and of what type are needed to retaliate against the Soviets following a nuclear attack. Ideally, limited terminal defenses would be deployed so that the Soviets wouldn't know which silos are being defended and would have to target all silos as if they were heavily defended. This drives up the Soviets' offensive costs while reducing our defensive costs.

Partially effective terminal defenses of hardened silos are technically feasible today. The Soviets have deployed terminal defenses around Moscow. The system employs nuclear-armed exoatmospheric Galosh interceptors and high acceleration nuclear-armed Gazelle endoatmospheric interceptors with large ground-based radars for target acquisition and tracking. It is vulnerable both to direct attack and saturation.

Strategically, point defenses are comparable to other methods proposed to increase the survivability of the land-based leg of the triad such as mobile basing modes. Their effectiveness will depend on future treaty limitations on offensive weapons and on changes in the ABM Treaty to allow such options as deployment at more than one site and the use of mobile sensor platforms. It seems likely that terminal defenses will be expensive relative to alternative such as rail garrison basing, but the exact costs cannot be estimated without postulating a detailed architecture for the system.

STABILITY OF NUCLEAR FORCE STRUCTURES

Barbara Levi and David Hafemeister

Introduction

In its 1983 review of the U.S. strategic modernization program, the Scowcroft Commission became the first high-level government study to consider the destabilizing aspects of land-based multiple-warhead missiles and to recommend specific steps to enhance stability (1). One of the three steps toward modernization which they proposed was to initiate "engineering design of a single-warhead small ICBM, to reduce target value and permit flexibility in basing for better long-term survivability." They pointed out that "a more stable structure of ICBM deployments would exist if both sides moved toward more survivable methods of basing." They further note that "...from the point of view of enhancing...stability,...there is considerable merit in moving toward an ICBM force structure in which potential targets are of comparatively low value — missiles containing only one warhead."

Although the concept of stability has many meanings, we confine ourselves here to the one implied by the Scowcroft Commission's concern —crisis stability. Crisis stability would exist if, in a time of great tension between the superpowers, neither side felt it could gain by being the first to initiate a nuclear exchange. Pressure to "go first" might exist if one side felt its nuclear weapons were vulnerable to a first strike by the other, or if one side calculated that, with a first strike, it could destroy more warheads than it used.

A simple exchange model

There are no unique, definitive criteria with which to determine the crisis stability of a particular basing mode, or the size of the force structure. Four possible criteria for assessing stability are as follows:

- Warhead exchange ratio R = (warheads destroyed) / (warheads used).
  This ratio measures the relative advantage of the attacker. A ratio much greater than one indicates that the side being attacked probably has multiple-warhead missiles in relatively vulnerable basing modes.
- Warhead gain (or loss) factor F = (warheads destroyed) - (warheads used).
  This quantity would indicate how the attack has altered the overall nuclear balance.
- Surviving Warheads.
  This parameter indicates the ability of either side to launch a second strike. If, for example, the attacker destroys 2 or 3 times more warheads than it uses, but its enemy still retains several hundred or more warheads, the attacker has not necessarily gained a meaningful advantage. The adversary can retaliate with a devastating blow (providing it can still control its forces).
- Ratio of Surviving Warheads.
  This ratio might indicate whether the attacking side has altered the strategic balance in its favor, if indeed any such comparison is meaningful.

We can understand these parameters better by adopting a simple model to calculate their sensitivity to various properties of nuclear arsenals. Our simple model will seek to calculate the four parameters defined above for a hypothetical first strike by one of the superpowers on the other. We make the following assumptions (2):

- When Side A attacks side B, a fraction fa of B's aircraft are on alert and fs of B's submarines are at sea and therefore safe from attack.
- Side A has a total of WA warheads. They are carried to their targets by missiles with a reliability of r. Each reliable warhead has a certain probability of destroying a missile in a single shot, denoted by SSKP.
- Side A would target each missile silo with two warheads to ensure high enough probability of destruction. Side A would also spend two warheads on each port serving as home to nuclear submarines. They would probably aim two warheads at the runways of bomber bases and also detonate airbursts in a pattern of perhaps 14 warheads around the bases to try to destroy aircraft attempting to take off.
- Side B has LLB land-based missiles, carrying a total of WLB warheads.
- Side B has all its bombers distributed among a total of BAB bases. Bombers at base and on alert carry a total of WAB warheads.
- Side B has all its submarines stationed at a total of BSB ports. Submarines at sea and in port carry a total of WSB warheads.
- If side B deployed LMB land-mobile missiles on alert, carry-

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ing WMB warheads, side A would have to create a barrage attack over the entire deployment area (or linear tract area in the case of rail-mobile missiles) to have a reasonable chance of destroying them all. We assume that the ratio of warheads for Side A to attack the mobile component of side B's land-based forces is given by M. Let A be the area (or linear track length) of required destruction created by each attacking warhead and AD be the area (or length) over which the mobile launchers are dispersed.

With the parameters as defined above, we can write an equation for the number of warheads of side A required for an attack on all the nuclear forces of side B. (We ignore the command and control centers and other military targets, which would also be attacked.) We get

$$WA\ (used) = 2 * LLB + 2 * BSB + 16 * BAB + M * LMB.$$

The warheads destroyed depend on the reliability of these weapons and the fraction of the warheads that are caught on base:

$$\begin{aligned} WB\ (destroyed) = & \{1-(1-r * SSKP)2\} * WLB \\ & + \{(1-fs) * WSB + (1-fa) * WAB\} \{1-(1-r)2\} \\ & + r * (M * A) / AD * WAB. \end{aligned}$$

Note that, for the attacks with two warheads on one target (missile silos, submarine bases and airbases), we have included a term to calculate the combined reliability of two warheads, each with an independent reliability r. For the attack on missile silos, we include the combined probability of "kill" with two warheads, each with a single silo kill probability of SSKP. For barrage attacks on mobile missiles (on alert) with no overlap of the destructive areas of each warhead, the probability of destruction might be approximated by the total area of destruction caused by M * LMB warheads divided by the total area of dispersal.

Evaluation of exchange criteria

One can put in any choice of assumptions. We have done a set of calculations of the exchange criteria for an attack by the Soviet Union on the U.S. that catches the U.S. forces in their everyday state of alert. We assume the following parameters (3):

fa = 0.33 and fs = 0.60
r = 0.9 SSKP = 0.66

Side A is the Soviet Union so that current force levels are

LLA = 1392	WLA = 6846
LAA = 155	WAA = 1170
LSA = 928	WSA = 3232
	WA = 11,248

Side B is the United States so that current force levels are

LLB = 1000	WLB = 2310
BAB = 34	WAB = 4956
BSB = 4	WSB = 5632
	WB = 12,898

With these values for the parameters, we find that

$$WA\ (used) = 2 * 1000 + 2 * 4 + 16 * 34 = 2552$$
$$WB\ (destroyed) = .84 * 2310 + .99 * .4 * 5632 + .99 * .67 * 4956 = 7457.$$

Thus the warhead exchange ratio for an attack by the Soviet Union on the U.S.is about 2.9. The ratio of surviving warheads is 1.6. The warhead gain would be 4905. From those numbers the first strike looks advantageous to the attacker. But the U.S. would still retain over 5,000 warheads and could cause massive damage in retaliation.

Note that side A gains most of its leverage by destroying a large number of bombers at base and submarines in port with a small number of its warheads. The leverage would be reduced if there were enough warning of the attack to allow more submarines to sail out to sea or more planes either to take off or to disperse to other air bases.

Although the Soviet Union might appear to have significant leverage, the attack still does not come close to disarming the U.S. That is because a significant portion of the bombers on alert and submarines at sea are survivable at the present time. Moreover, the first strike would by no means be what some term "surgical." It might kill tens of millions of people and would surely invite a massive retaliation. Strategic planners worry nonetheless that communications with these bombers and submarines might not be sufficiently secure to enable command and control over these forces to mount the retaliatory attack.

We have done similar calculations with other force structures, as summarized in Table 1, and have compared the results in Table 2. Note that single warhead mobile missiles add a great deal of stability, making an increasingly larger difference as the arsenals shrink. Although our model is a very simple one, the exchange ratios are qualitatively similar to those from more sophisticated models (4).

Of course, while these numerical measures of "stability" may measure one factor that could influence the action of a nation during a crisis, it is only one such factor. As long as the nuclear arsenals remain as large as they are, both superpowers must realize that any attack, even if restricted to the military targets of the other side, would kill tens of millions of civilians and surely invite an equally devastating retaliation of the attacker.

REFERENCES AND NOTES

1. *Report of the President's Commission on Strategic Forces,* April 1983, reprinted by the Library of Congress, Washington, DC, 1983.
2. In the names of parameters, the first letter will be L for launchers, W for warheads or B for bases. The second letter will be L for land based, S for sea based, A for air and M for mobile. The last letter will denote either side A or side B.
3. T. Cochran, ***Bulletin of the Atomic Scientists,*** Jan. 1988, p.56; ***The Military Balance 1987-88,*** International Institute of Strategic Studies.
4. M. May, G. Bing, J. Steinbruner, "Strategic Arms Reductions," to be published in *International Security.*

Table 1. Four Scenarios

Scenario	Warheads side A: Land	Sea	Air	Warheads side B: Land	Sea	Air	Mobile
Current arsenals	6846	3232	1170	2310	5632	4956	0
START treaty no mobiles	3000	1900	1100	1900	3000	1100	0
START treaty w/mobiles	3000	1900	1100	1400	3000	1100	500
2000-warhead arsenals with mobiles	600	1000	400	0	1000	400	600

Table 2. Results of Stability Calculations

Scenario	Ratio of warheads Destroyed	Surviving	Warhead gain (or loss)	Surviving warheads
Current arsenals	2.9	1.6	4905	5442
START treaty with no mobile missiles	2.2	1.8	1928	2486
START treaty with some mobile missiles	0.9	0.9	-238	2486
2000-warhead arsenals with all land-based missiles being mobile	0.4	0	-1095	1095

REVIEW

SOCIETAL ISSUES: SCIENTIFIC VIEWPOINTS edited by Margaret Strom

American Institute of Physics, 1987, 240 pages, cloth $41.25, paper $31.25, 20% off for AIP members

By this time, most of us agree that the world should consider *both* the benefits and risks of the technologies that have sprouted from the garden of basic research. This nice collection of 50 reprints is "aimed primarily at college students in social sciences, writing, science, or any study that examines the interaction of science and society." The sweep of topics by the prestigious list of authors (12 Nobel laureates, etc.) is broad, including arms, conservation, hunger, and space. Overall, I think the book is well suited for its intended audience. It is particularly suited as a text for a broader "science and man" course, and as a general reference for our physics libraries. It establishes a beginning point for those that wish to explore more deeply. Let's briefly examine six of the contributions:

Andre Cournand, "The Scientist and Ethics." As scientists, we generally believe that we should take the high road of "honesty, objectivity, tolerance, and doubt of certitude." However, Cournand warns that these lofty goals are threatened unless broadened to apply to the nonscientific arena. He cites overspecialization of scientists as one of the main causes for the politicization of science. This essay caused me to ask; what are the Lysenkoist issues of today, 1988? Of course both sides of the political aisle have stretched the truth with errors of omission and commission, but I do wonder about some of the promises of SDI, the lack of proveability of some treaty-compliance issues, and the false promise of the man-in-space station. I still believe that a proper "due process" could sort out some of the facts from fiction.

Andre Sakharov, "Nuclear War" and "The Arms Race." In the first article, written in 1983 in pre-glasnost Gorki, Sakharov responded to a speech on the arms race by Sidney Drell. Sakharov comments that "If the nuclear threshold is crossed...the further events would be difficult to control, and the most probable result would be swift escalation leading...to an all-out nuclear war, i.e., to a general suicide." Sakharov predicts that the MX would be a useful bargaining chip in dealing with Soviets: "If it is necessary to spend a few billion dollars on MX missiles to alter this situation, then perhaps this is what the West must do." He believes that both sides have contributed to the problem: "It would be absolutely wrong to see only Moscow's hand everywhere." The second article was written in 1987 in the Glasnost-Perestroika era for the "Forum for a Nuclear-Free World" held in Moscow. Sakharov disagrees with Gorbachev's view linking agreement on START with controls on SDI, an issue still in transition. He agrees with Gorbachev that "greater openness and democracy in our country are necessary," but warns that "if the West tries to use the arms race to exhaust the USSR, the course of world events will be extremely gloomy." He is pessimistic on SDI: "Any ABM system...can be effectively overcome by simply increasing the number of decoys and operational warheads, by jamming and by various other methods of deception. The claim that the existence of the SDI program has spurred the USSR to disarmament negotiation is also wrong. On the contrary, the SDI program is impeding those negotiations."

M. King Hubbert, "Exponential Growth as a Transient Phenomenon." This classic has been forgotten by the nation as OPEC has declined. Hubbert's classic calculations of oil resources successfully predicted in 1957 that the production from the lower 48 states would peak at about 3.3 billion barrels per year in about 1971. His model uses the Verhulst differential equations and the concept of the "finite resource." Nowadays, one should incorporate the economics of supply and demand elasticities. His classic work should be known to all in both the humanities and the sciences, but, alas, it is not.

Jay W. Forrester, "Behavior of Social Systems." This pioneering work was the predecessor to Meadows', which was the rage of the coffee houses in the early 1970s. Of course, the world consists of more than 5 state functions (population, pollution, capital investment, natural resources, quality of life). Some of the detractors have shown that a 6th function called technology "might" make all turn out well. Unfortunately, we are still waiting for energy that is so cheap that one does not bother to meter it. The work of Forrester and Meadows was and will be very important as a teaching tool, without predictive accuracy. We must first of all crawl with the ideas of our coupled, complex world before we can begin to walk and, perhaps, run.

Alvin M. Weinberg, "Science and Its Limits: The Regulator's Dilemma." Nuclear power is on the ropes for a variety of reasons. In the future it is clear that a second-generation nuclear option must be compared to both conservation (advanced-end-use efficiency) and coal. We have all heard both sides fib on this one.

James van Allen, "Myths and Realities of Space Flight." Van Allen favors instruments in space over man in space: "I am quite unable to support the declaration that the manifest destiny of mankind is to live and work in space." He is pessimistic that the public can differentiate between the "large number of futuristic proposals for space flight...solar power satellites, manufacturing in space, manned space stations in Earth orbit, on the moon, and on Mars." An OTA report has discussed some of the short-comings of the space station; we need more ventilation like this on these issues to separate the cream from the milk.

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NEWS

SAVE THE NEWSLETTER!

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

CALL FOR FORUM AWARD NOMINATIONS

Now is the time for you to submit nominations for the two annual Forum awards. The Szilard Award is given to an individual or group who has applied physics in the public interest. The APS Forum Award is given to an individual or group who has promoted the public understanding of the relation of physics to society. The awards will be presented in the Spring of 1989, at the Spring meeting of the APS.

In 1988, Robert Williams of the Center for Energy and Environmental Studies at Princeton University received the Szilard Award for applying physics to end-use energy efficiency and educating physicists, members of Congress, and the public, on energy conservation issues. Ashton B. Carter of the Center for Science and International Affairs at the Kennedy School of Government at Harvard University received the Forum Award for his exposition of the physics issues in the nuclear arms race.

Nominations, with supporting material, should be sent to the awards committee chairperson, Peter Zimmerman, Carnegie Foundation for International Peace, 11 Dupont Circle, NW, Washington, DC 20036.

CALL FOR APS-FORUM FELLOWS NOMINATIONS

Now is also the time to submit your nominations to the Forum for new APS Fellows. In 1988, there were four new Fellows of the APS who were elected on the basis of a Forum nomination. Robert J. Budnitz was elected for applying physics to environmental and energy policy and for studies of nuclear reactor safety technology. Jack M. Hollander was elected for his research on energy and the environment and for his studies of global energy resources. Anthony V. Nero was elected for his study of indoor radon and his assessment of risks associated with the nuclear, geothermal, and fossil fuel generation of electric power. Richard A. Scribner was elected for his application of physics to arms control and for developing the Scientific Congressional Fellowship Program.

Nominations, with supporting material, should be sent to Anthony Nero, Lawrence Berkeley Laboratory, 1 Cyclotron Blvd., Berkeley, CA 94720.

CALL FOR FORUM OFFICER NOMINATIONS

One more time: Also, send in your nominations for Forum officers. Forum elections will be held in January 1989, with terms to begin in April 1989. We will be electing a vice-chairperson and three executive committee members. Send your nominations to Anthony Fainberg, Office of Technology Assessment, U. S. Congress, Washington, DC 20510.

CURRENT FORUM OFFICERS

Chairperson: Barbara Levi.

Vice-chairperson: Richard Scribner.

Executive Committee: Elmer W. Colglazier, Martin B. Einhorn, Anthony Fainberg, Glanys R. Farrar, Anthony V. Nero.

Representative to the Forum from the APS Council: Francis Perkins.

Representative to the APS Council from the Forum: David Hafemeister.

Editor of the Forum Newsletter: Art Hobson.

APS COUNCILOR'S REPORT

Research funding for physics: The APS Council commissions a summer study to recommend to the APS council ways to assess priorities between the various subfields of physics. The data clearly shows that there will be a short-fall in planned physics funding because of at least 6 causes: (1) NSF is directed to spend more money on applied science and engineering, while funds are constant; (2) NSF solid-state funding didn't follow projections; (3) "post-industrial pork," the Congressional creating of too many institutes without sufficient operating funds; (4) DOE wants 5 new large facilities; (5) the SSC; (6) budget and trade deficits. The APS Panel on Public Affairs (POPA) is preparing a paper on the data for funding pf physics research for publication in the Bulletin of the APS.

APS votes to stay in New York and not move to Washington, DC, primarily because of the inertia of personnel, money, and the NY publishing environs.

APS sent letters to the Presidential candidates to strengthen the position of Science Advisor to the President (see APS Council's statement, below).

APS is searching for ways to strengthen the Washington DC spring meeting, as the January meeting becomes history after January 1990.

APS dues will rise, perhaps including APS Divisions and the Forum

Dave Hafemeister,
Forum's APS Councilor,
and Leo Sartori

APS COUNCIL STATEMENT ON THE NEED TO STRENGTHEN THE WHITE HOUSE SCIENCE OFFICE

The following statement was adopted at the 24 January 1988 APS Council meeting:

The most serious challenges that confront the United States, from arms control and environmental degradation to the spread of AIDS and the worsening trade imbalance, involve complex scientific and technical issues. Leadership in meeting these challenges must come from the Office of the President.

The responsibility for ensuring that the President receives balanced and responsible scientific advice should lie with the Science Advisor to the President and the Science Advisory Council. The

Science Advisor's Office can discharge these responsibilities only through a close contact with the scientific and technical community at large. The apparent inability of the Science Advisor's Office to provide adequate and sound technical advice on some recent critical issues can be ascribed in part to this lack of needed contacts.

We therefore urge a new Administration to put into place a prestigious and influential Science Advisory Office to address the opportunities that science and technology offer for the 1990s.

FEDERAL AWARENESS SERVICE

The American Institute of Physics is offering a "Federal Awareness Service" as part of its PI-NET electronic database service. The available information, frequently updated, includes: legislative information, such as schedules of Congressional committee hearings, status of bills relevant to physics, and membership of committees; also executive-branch information, such as notices of proposed rule-making, scheduled meetings, and requests for proposals. Most of the information is searchable. It is presently offered free to the physics community (a modest connect charge will be implemented this fall).

INSTRUCTIONS FOR ACCESS: Dial local Telenet number (for help, call 1-800-336-0437). At the high-pitched tone, press <ENTER> twice. At the display TERMINAL=, press <ENTER> again. At the @ prompt, type TELEMAIL and press <ENTER>. For Username? type AIP.ONLINE and press <ENTER>. For Password? type NEWUSER and press <ENTER>. Information and further instructions will then be displayed.

JOIN THE FORUM! GET THE NEWSLETTER!

If you are an APS member it is easy, and free to join the Forum and receive our newsletter. Just complete and mail (to the editor) the following form, or mail us a letter containing this information. (Nonmembers: see the masthead, on p.2).

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

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COMMENT

IS THERE A SCIENCE ADVISER TO THE PRESIDENT?

As the race for the White House began in earnest early this year, a small group of science-policy experts in Washington sought meetings with key advisers of the Presidential candidates. Although no one expected science to become an issue in the campaign, the group wanted to stimulate thinking about how the candidates might structure their science-advisory apparatus if they should become President.

The meetings seemed to follow a pattern. As the group began to describe its concerns, looks of puzzlement would appear in the eyes of the candidates' representatives, followed by some version of the question, "Is there a science adviser to the President?" It's a good question.

Indeed, for a time during the first year of the Reagan Administration, there was no adviser. The scientific community still winces at the memory of that hiatus. The President was not convinced of the need for a science adviser. He moved to fill the post required by Congress only after a visit from a concerned Congressional delegation. By the time an adviser had been recruited, it was already several months into the budget cycle. The result was that federal spending on science took a drubbing from which it has never fully recovered.

While Congress can insist that the President name a science adviser, it cannot compel the President to seek his or her advice. Mr. Reagan's March 1983 "Star Wars" speech, calling on scientists "to give us the means of rendering nuclear weapons impotent and obsolete," had awesome implications for the nuclear stability of the world, not to mention our economic health. The entire Strategic Defense Initiative rests on questions of technical feasibility. So what was the recommendation of the President's science adviser, George Keyworth, on this weighty technical issue? Well, actually, he wasn't consulted until three days before the speech was to be delivered, and then only as an afterthought by Robert C. McFarlane, then the Deputy National Security Adviser.

Apparently, the technical basis for the President's vision of "rendering nuclear weapons impotent and obsolete" was a briefing by Edward Teller, the legendary father of the H-bomb, on progress toward the development of an X-ray laser weapon. Mr. Teller, who is notorious for his unrestrained technological exuberance, promoted the X-ray laser as a sort of ultimate weapon, with the capacity to destroy an entire fleet of incoming missiles simultaneously.

Just prior to the Reykjavik Summit, Mr. Teller informed the President and his inner circle of scientifically innocent advisers that the X-ray laser program was entering the "engineering phase." In fact, officials in charge of the program at Lawrence Livermore Laboratory acknowledge that it will take at least five more years and $1-billion to determine whether an X-ray laser weapon is even possible. The leader of the free world apparently entered into arms negotiations, on whose outcome the very survival of civilization may depend, seriously misinformed about the strength of his hand.

The President is,of course, free to seek advice from whomever he chooses, including the controversial Mr. Teller. Unfortunately, Presidents have a strong preference for advisers who tell them what they want to hear. When former President Nixon failed to get the advice he wanted on the anti-ballistic-missile system and the supersonic transport, he simply abolished the post of Special Assistant to the President for Science, and disbanded the President's Science Advisory Committee. Mr. Reagan's solution has been less direct. The science adviser is officially part of the President's staff, but he has been reduced to little more than a cheerleader for the President's programs.

We are confronted on every hand with science-related problems that demand solutions—and honest technical advice even when it's not what the boss wants to hear. For example:

- The National Air and Space Administration, the agency that once sent astronauts to the Moon and robots to Mars, has been reduced to a pitiful beached whale. The only thing in NASA that still goes up is the cost estimate of the manned space station.
- While the Japanese prepare to challenge American dominance in the biotechnology industry, fundamentalists in the United States, with encouragement from the White House, seek to purge the great unifying principle of biology from our textbooks.
- We depend on foreign students to fill our science classrooms, as America's young dabbles in New Age mysticism, attributing supernatural powers to crystals, but disdaining crystallography.

In addition, the AIDS virus continues to spread unchecked. The sky rains acid on dying forests and lakes. A hole has appeared in the ozone layer. The energy crisis lies in ambush around the next bend.

Proposed cures for the ailing White House Science Office are often tinged with nostalgia for a golden age of science advice in the 50's and 60's. They range from the creation of a Secretary of Science and Technology to a resurrection of the President's Science Advisory Committee. Lewis Branscomb, a former member of the committee, favors amending the Federal Advisory Committee Act of 1972 to permit greater privacy for groups advising the President. Ashton Carter of Harvard University's Kennedy School of Government proposes just the opposite. He argues for greater reliance by the White House on advisory institutions that openly publish their analyses for all interested consumers.

Mr. Carter's is a refreshing idea. If there is one lesson we should have learned from the sad comedy of "Star Wars"—and more recently from the Iran-contra scandal—it is that flawed advice, if given in secret, may go unchallenged at great cost to democracy.

Robert L. Park
Professor of Physics
University of Maryland at College Park
Director, APS Washington office

FROM THE CHAIRMAN

The Forum Executive Committee held its annual meeting during the recent APS Meeting in Baltimore. Reports from various committee chairmen indicated that all activities are running smoothly. The Forum awards are now handled in the same manner as other American Physical Society awards, and the Executive Committee will be exploring various ways to increase the financial remuneration fo those awards. The Forum submitted to the APS Council a number of names to be considered as APS Fellows; the results of that consideration should be announced in the next newsletter.

The Forum ran a total of 10 topical programs at four different APS meetings this year. The only disappointment was that the attendance at some of the evening sessions was lower than that in the past, especially at the Baltimore meeting. I'm sure that Richard Schribner, the current program chairman, would love to hear your ideas for future programs! We have not been as successful with the contributed paper session (with only three contributions this year) as we have been with the invited-paper sessions. Consider what you might contribute to that session in the future.

The Executive Committee is pleased with the continued high quality of the newsletter. There was some concern that many libraries routinely toss the newsletter when the next issue arrives, as they do with other such newsletters. Please ask your own librarian to keep back copies.

Members of the Study Group on Land-Based Missiles were polishing their final drafts to meet a May deadline, and the group hopes to submit their combined efforts in book form to a publisher this summer.

The Executive Committee approved funding for a new Study Group on Energy that is already off the ground under the leadership of Ruth Howes.

David Hafemeister and Dietrich Schroeer, who organized a short course on arms control during the weekend prior to the Baltimore meeting, reported that the course had been very successful. If you missed the course but would like to purchase the conference proceedings, you can do so from AIP.

As a special activity in this election year, the Forum will be helping the APS to formulate some questions to ask the Presidential candidates.

One issue of concern among scientists in this election year is the Presidential Science Advisor. As Robert Park points out in this newsletter, the position is currently downgraded and underutilized. The APS has joined other scientific societies in expressing its concern. The statement on science advising approved by the APS Council (see copy reprinted in this issue) was sent by APS President Val Fitch to each of the presidential hopefuls. At the risk of seeming like a faint ripple atop such a large ground swell, I urge you to support these efforts. The issue strikes me as being at the heart of what the Forum stands for. As the scientific component of many societal issues grows, it becomes increasingly imperative for the President to seek well-informed advice. The White House should open its doors to a strong science advisor who can assure that the President will receive the wisest counsel on these complex topics.

Barbara Levi
Forum Chairman

EDITORIAL: THE FRANKENSTEIN COMPLEX

In a recent example of the tension between science and society, coalitions of neighborhood activists and animal rightists are seeking to block new biology labs in the San Francisco area. The report, in *Science* magazine, 11 March 1988, points up the fear that many politically aware and active people have of science. Borrowing from Mary Shelly's nineteenth century novel, we might call it the "Frankenstein complex."

In the San Francisco case, opponents have briefly shut down research at a new lab at the University of California at San Francisco, have sued to stop construction of an animal facility at the University of California at Berkeley, and have forced Stanford University to postpone construction of two buildings for a least a year at a cost of up to $1.8 million. If the protests succeed, they will place an "impossible burden" on research institutions to prove, in advance, that their activities will be harmless, says Ethan Schulman, an attorney for the University of California at San Francisco.

Opponents say the public has a right to know whether a laboratory in their neighborhood is dangerous. They are concerned about the safety of genetic engineering. Aroused by accidents such as the ones at Bhopal and Chernobyl, they question the use of chemicals and radiation. And the animal rights movement contributes its growing visibility and political savvy to the opposition by focusing attention on what goes on behind laboratory doors. Protesters are afraid that genetically engineered creatures will escape and run amok, that laboratory cockroaches will spread disease, that delivery trucks will spill chemicals, and that fumes from rooftop vents will cause cancer.

Safety experts dismiss these fears. "These laboratories represent, from the standpoint of environmental impact, really no significant potential problems, in my judgment," said Robert McKinney, director of the safety division at the National Institutes of Health, one of the federal agencies that sets safety standards for laboratories.

Officials at the three universities seem at a loss to know how to prevent similar attacks and delays in the future. Stanford President Donald Kennedy argues that, in the long run, the solution is to raise the level of public understanding of science. What links these movements, Kennedy says, is a "vague and alarming mistrust of science, indeed of the elitism of expertise." The Frankenstein complex.

"Unfortunately," continues Kennedy, "part of it relates to the disappointing level of scientific literacy displayed by voters--and by their elected representatives. If a substantial proportion of our adult population believes in astrology and the efficacy of pyramidal objects in promoting health, why should we expect thoughtful analysis of problems like these?"

Short of the kind of deep solution proposed by Kennedy, our scientific assurances that the risks are negligible are doomed to failure in a democratic society. In effect, people are saying "I don't really understand what is going on in your lab, and in light of Bhopal, Chernobyl, Challenger, and The Bomb, why should I take your project on trust?" Assurances will not change this attitude. People do not understand what it is they are being assured of, they feel out of touch with nuclear power and the rest, and they will not grant their blessing until they do understand, until they do feel in touch.

The fault may lie in ourselves, for we scientists do nothing to remedy the problem. For example, college physics faculties communicate essentially nothing to non-scientists about science-related social issues. Those few instructors who even bother to teach anything to non-scientists typically limit themselves to standard applications such as blocks sliding down inclined planes or how a lightbulb works, as though for instance ozone depletion, nuclear war, pseudo-science, philosophy, and history didn't exist. There is no humanism, no context. Out teaching is a cartoon imitation of the real universe.

We are so wrapped up in our research, our grant proposals, our research-based tenure decisions, that we have little time to communicate with non-scientists. There is irony here, for science and society are coming full circle: scientists' research obsession has advanced technique far beyond the ordinary citizen's comprehension, producing confusion and fear and thus a backlash that tries to slow science to the point that society can, once again, absorb it.

Activists ask us to deaccelerate, to take time to bring the people into our confidence, so that we can all consider the intended and unintended consequences of new techniques. They ask us to devote less attention to research, and more attention to understanding the full context of the scientific enterprise.

It is not too much to ask.

Art Hobson

EDITORIAL POLICY

Physics and Society publishes articles, letters, news, book reviews, and commentary on physics-related social topics. We publish quarterly, in January, April, July, and October.

All articles should be grounded in physics and/or its history or philosophy, i.e. articles should have a physics perspective. Since they are directed to physicists, articles may be (but are not required to be) technical. All articles are submitted to outside review. It is inevitable and healthy that many articles will take one or another political or philosophical point of view. However, articles tending toward opinion or propaganda rather than toward rational and well-substantiated analysis will be rejected.

Letters, on the other hand, may be opinionated, especially when commenting on previous articles. Debate is welcome. Letters on new topics are welcome.

You, the readers, are the natural pool of contributors to this newsletter, and so it is up to you to keep the newsletter broad and balanced. All points of view, and all physics-related topics, are welcome. If you object to any political or topical bias you might detect, please submit something on the other side or ask a colleague to submit something. Especially on complex social topics, truth is more likely to arise from the interaction of many views on many topics, than from any narrow focus.

Physics and Society is happy to publish announcements of conferences, reports, organizations, projects, and other news items. These will be accepted on a space-available basis, with Forum and APS activities getting first priority. I need to receive your announcements at least six weeks before the publication date of the newsletter.

Details: Due to space constraints, letters must be held to 500 words and articles to 2500 words, including the word-equivalent of the space needed for tables and graphs. I will edit longer letters to bring them into line, and return longer articles for cutting. Think of your *Physics and Society* manuscript as a summary or extended abstract of the longer article you really wanted to write. Manuscripts should be typed, double-space, styled like other *P & S* articles, and submitted in duplicate. If you set your manuscript up on a word-processor, you can save us time by sending us a disk in addition to the manuscript copies. Try to stick to metric units.

Art Hobson