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THE LAUCKS FOUNDATION
from time to time calls attention to published material that might contribute toward clarification or understanding of issues affecting world peace.

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IS AMERICA PUSHING ITS LUCK? LESSONS OF THE CUBAN MISSILE CRISIS

In 1963, during the Cuban Missile Crisis, Secretary of Defense McNamara wondered how many more sunsets he was destined to see. Secretary of State Rusk said, about a plan for airstrikes, "If we don't do this, we go down with a whimper. Maybe it's better to go down with a bang." Ambassador Llewellyn Thompson told his wife that he would let her know where to go if the Capital were evacuated. This was the mood, as revealed in Elie Abel's *The Missile Crisis* (Lippincott, 1966), where he concludes, "how close we came to Armageddon, I did not fully realize until I started researching this book."

Now it appears that we are back on the escalator to another such crisis. In November, a former Deputy SHAPE Commander, General Lothar Domrose, admitted that the Pershing missile could destroy Moscow from German territory. He told a visitor that, if the Soviet Union did not like this, they could negotiate about it! Now Brezhnev *does* seem to be negotiating, but with threats to put Washington under the same five-minute gun.

Today both sides are focused more than ever before on the vulnerability of command and control and on "decapitation" of command authorities. Thus, these threats could be much more potent today, despite the existing overkill, than were the 40 missiles in Cuba two decades ago—missiles conceded by then-Secretary of Defense McNamara to have no special military significance.

Worst of all, this Administration is more hysterical about such things and already feels strategically cornered. If a sober individual like former Secretary of State Rusk can view missiles in Cuba as an apocalyptic show of force, we can only guess what Secretary of State Haig would think.

In a recent speech, another former Secretary of State, Edmund S. Muskie, described precisely what may now occur:

> "If something is not done *soon* to break this degenerative trend, we and the Soviets may have a serious confrontation not unlike the Cuban missile crisis—but in which the Soviets will vow 'not another humiliation' and our leaders will vow 'no confirmation of a changed balance of power' with no on-going high-level negotiations, no communication process to fall back on, and no political basis for any compromise."

Soviet officials have long suffered what they consider to be the indignities of American impudence—a term under which they lump, among other things, much of that double standard in which, in fact, we have often indulged ourselves. The U.S.S.R. was to be strangled in its cradle, rolled back, threatened with massive retaliation and contained. Because most of our officials have never been to Russia (as theirs have not, with few exceptions, ever been here), the points of view on both sides are startlingly different. To take one example, Moscow has a well-attended museum devoted to the Allied invasion of Russia. But, one would wager, no more than 20% of our Congress even know that American troops ever invaded Russia! (It was in 1917, you dummies.)

As a consequence of this latent resentment, and for other reasons, America is going to have a hard time insisting on a double standard in an age of parity. If we push our luck with strategic developments that upset the Russians, they will, in this age, be able easily to find analogous developments that deeply upset us. And herein lies the danger.

It is to be hoped that the Russian government will keep clearly in mind the unpredictable quality of American government decisions, and the dynamic interplay between popular opinion and political exigencies. At one point during the missile crisis, even President Kennedy was moved to remark that he might have been "impeached" if he had not prevented deployment of these missiles.

Very possibly, in this instance, the European peace movement will save the world from the possibility of another Cuban missile crisis by preventing the deployment of the Pershings, if not the cruise missiles. But the potential for other such incidents is much greater than most people realize, especially in periods of rhetorical confrontation between the two sides and heightened sensitivities.

The urgency of reaching an overall settlement of the arms race has never been so clearly underlined for many years as it is by these recent events. The public has the right to be genuinely alarmed. One more Cuban missile crisis could be our last. □

Of several minds: *Thomas Powers*

HOW ACCURATE'S ACCURATE

A MISS IS AS GOOD AS A MILE

ONE OF THE better-kept secrets of World War II was the fact that bombers had a hard time hitting anything—that is, anything *in particular*. The Norden bombsight was popularly believed to allow "surgical strikes" and "pinpoint bombing" but one man's pinpoint, as the Strategic Bombing Survey revealed after the war, was often another man's cow pasture. Bombs were dropped all over Europe, but rarely on target. A major U.S. daylight raid on the German ball-bearing plants in Schweinfurt in August, 1943, was typical. A total of 1122 high explosive bombs weighing 395 tons were dropped by 376 bombers. The 8th Air Force later concluded there were 88 "direct hits"—that is, bombs which landed in the general plant area—and 55 actual strikes on factory buildings. The rest of the bombs landed somewhere, too, of course, and killed about 300 German civilians, including 26 children, and another 100 slave laborers from Poland and France. In the course of the raid about 60 U.S. bombers with their eight-man crews were shot down—roughly one for every bomb that landed on a factory building. The ball-bearing plant, while damaged, was soon back up to normal production.

The 8th Air Force and the British Bomber Command referred to this sort of thing as "strategic bombing," which they hoped would shorten the war. It did not. German air defenses forced the bombers to fly too high for truly accurate bombing, and the British, at least, decided early in the war to fly only at night. Freeman J. Dyson, the British-born physicist now at Princeton, worked on operational research during the war, and was often appalled at the poor results when he drew up bomb plots after the raids. In his memoirs, *Disturbing the Universe*, Dyson describes the reaction of one Bomber Command official to a preliminary bomb plot recording the results of a raid on Frankfurt. "Awfully few bombs inside the circle," the official said. "You'd better change that to a five-mile circle before it goes in."

Another Bomber Command study, conducted earlier in the war, examined the actual results of bombs dropped by pilots—about half of those taking part in the raid—who *claimed* to have hit the target. Impact photos showed that only one in four had actually dropped bombs within *five miles* of the target.

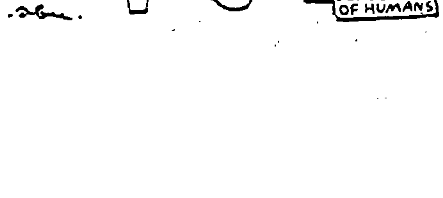
This inability to hit things accurately with bombs had several results. One was a high level of gratuitous killing and destruction. Hundreds of thousands of civilians were killed by the three million tons of Allied bombs dropped on Germany. Their deaths did not shorten the war by a day. Another result was a change in strategy, from "pinpoint" bombing of important factories, railroad marshaling yards, dry docks and so on, to "area bombing." Flying at night at high altitudes, the British switched targets to something they felt they could hit—cities. The new approach, never officially acknowledged, called for destroying the industrial suburbs where workers lived. But even putting it that way is a kind of euphemism. The target was simply people, on the theory that killing enough of them would crack civilian morale and perhaps spark the sort of popular revolution which ended the First World War. This was a failure too. On two occasions—Hamburg in July, 1943, and Dresden in February, 1945—firestorms were created which turned huge areas of the target cities into smoking wastelands, killing scores of thousands of people, but the effect on German war production was negligible. In the final stages of the war against Japan the Americans, too, finally abandoned the illusion of "pinpoint" bombing and adopted the British approach. Early in 1945 a huge 1000-plane raid generated a firestorm in Tokyo which leveled hundreds of acres of housing and killed more people than either Hiroshima or Nagasaki. Cities we could hit, but cities weren't the enemy. Pain we could cause, but pain doesn't win wars.

It is accuracy which determines the efficacy of violence in war. In this regard battle and boxing have much in common. Boxers bob and weave and jab but they do not often land a solid punch. Even one or two, properly placed, can be enough to do the job. War is much the same. It is highly particular. Weapons make an opponent formidable, and it is weapons which must be destroyed. But weapons and the men who wield them are somewhere, and it is there a blow must be landed to be effective. Five miles away won't do. Down the street won't do. The blow must land on the exact spot where a soldier or a tank or a submarine *is*. In modern war the emphasis has been on volume of fire, not target practice, as a means of hitting an enemy. The machine gun, the artillery barrage, and carpet bombing are all ways of directing many lethal missiles to the general area where the enemy is. The law of averages is expected to do what aiming cannot. It takes tons of munitions to produce a single enemy casualty in this way, but production is what modern industrial states are best at. Nevertheless, the goal has always remained accuracy—a particular blow on a particular spot—and the recent development of precision-guided munitions threatens to transform war on the battlefield. The technology which raised volume of fire to nightmarish levels, now allows us to really *hit* things.

With nuclear weapons, in spite of their great power, the importance of accuracy is equally acute. In the popular mind The Bomb is a weapon of Armageddon, a tool of apocalypse, an instrument of total destruction, a means to obliterate an enemy. But who is "the enemy"? Ordinary citizens in crowded cities, men and women like you and me, the victims—not the planners—of war? The first bomb was dropped on Hiroshima because a city was something we could hit. The day of the bombing Truman described the city as a military target, but it was nothing of the sort, as he doubtless knew. It was just a place so big you couldn't miss it, and so crowded with people the result was bound to be on an unprecedented scale of horror.

The plan worked. At any rate, the war ended shortly thereafter. Ever since, cities have been high on the target lists and their dwellers have lived unhappily with a kind of vision of the way the world will end. But it is important to recognize that cities did not become targets because that's where "the enemy" is, but simply because they are big enough to find at night and to hit. The American military—and very likely the Russians as well—were unhappy with this approach. They wanted to win wars, not murder half the globe. As soon as military planners on both sides began to get more accurate weapons, they aimed them at different targets, generally of a military nature. The most important military targets, of course, are weapons, and the most dangerous weapons are nuclear weapons.

This change has been a long time in coming. In the late 1940s and early 1950s the U.S. Air Force had little confidence in its ability to hit things. The B-47 bomber was thought to be doing fine if it dropped its bombs within 2500 feet of the target. With the advent of thermonuclear weapons this was close enough to destroy pretty much anything fixed on the ground, but of course the bombers took so long to arrive there was no chance of finding the enemy's bombers still on the ground. His most important weapons, therefore, could not be destroyed. Missiles were quicker, re-entering the atmosphere at better than 10,000 miles an hour, but the early warheads were so



bulky, and the whole vehicle so technically crude, that the CEP of the first American ICBM—the Atlas—was "several miles," probably about five. CEP means "circular error probable" and refers to the radius, generally given in nautical miles, of a circle around a target within which half the missiles aimed at it will land. A CEP of 5 nm. means half the missiles will land within 5 miles of the target.

The earliest missiles stood up in the open and could be knocked over by a firm shock wave. Five miles was close enough. So the Americans, and later the Russians, put their missiles underground in silos, and then hardened the silos with steel and concrete. They made them very hard indeed. An ordinary brick house in the Georgian style, say, would be largely destroyed by an overpressure of 5 pounds per square inch, or 5 psi. No one knows just how hard modern missile silos are, and the military estimates are naturally classified, but the professional literature on these matters cites figures of 2000-4000 psi. Hardness to that degree means that a missile silo could only be destroyed by a direct hit—a warhead detonating sufficiently close by to put the silo inside the fireball (about a mile in diameter for a 1 megaton burst in the air), or inside the crater (about half a mile in diameter for a 1 megaton burst on the ground). This suggests that a missile intended to destroy a hardened missile silo would require a CEP of about 0.4 nm. for a 1 megaton warhead. There are many other factors which must be weighted in estimating the "probability of kill" (the PK) of a given warhead against a given target, but the most important of them by far is accuracy. That is also the factor which has generated the most argument during the last few years.

The argument, highly technical in its extended form, centers on a claim by a group of defense analysts in Washington that the Soviets now have missiles sufficiently accurate to serve as counter-force weapons—that is, to pose a threat to our weapons of fixed location (Minuteman silos, bombers on airfields, and nuclear submarines in port). The Soviet counter-force threat is cited as a principal argument for building the MX or some other, perhaps mobile, land-based system of *un*-fixed location, and for building counter-force (i.e., accurate) missiles of our own. A second group of defense analysts claims the first is crying "Wolf!" where the Soviets are concerned, and that the advent of counter-force weapons will destabilize the balance of terror by pushing both sides to fire first in a crisis, rather than run the risk of losing its weapons on the ground. In the literature this is referred to as the "use it or lose it syndrome." A further danger posed by a counter-force threat is the fact that the best defense against it would be a computer-controlled launch-on-warning system. This might "save" the threatened weapons (by using them) but it would make the world hostage to computer-error, which while it might be improbable, could never be impossible. Then, truly, the human race would have surrendered its fate to Fate.

The argument over counter-force accuracy centers on three points. The first is whether *any* missile can have a reliable CEP on the order of 0.1 to 0.3 nm. The Air Force, which periodically fires Minuteman III missiles from Vandenberg Air Force Base in California to Kwajalein Lagoon in the Southern Pacific, claims we are already within that range and that the MX will do even better. One Air Force officer told me a year ago that he and his colleagues routinely cite CEPs in terms of feet, and another said the second generation MX, already being designed, will have a CEP of about 90 feet.

The second point of contention, pressed by the cautionary critics, concerns the question of bias—the known *tendency* of any missile to miss the target. Bias is a fixed quantity, a number like CEP, which represents the distance between the center of a cluster of impact points and the intended target, as established by actual test results. A missile with a CEP of 0.25 nm. might have a bias of 0.1 nm. According to the defense consultant Richard Garwin, an authority in these matters, *every* missile has a bias, and it has *never* been predicted in advance. A bias can have many causes—idiosyncracies of the hardware, gravitational anomalies along its flight path, severe weather conditions in the area of re-entry. American missile tests are mostly conducted from East to West across the Pacific. An attack on Russia would require firing over the North Pole. The cautionary critics argue that variations in bias make CEPs unreliable. The trouble with this argument is that ICBMs have been tested over a long period of time, and results show whatever they show. Military and technical men who have studied the results generally insist the missiles can really attain the accuracies claimed for them. Charles Draper, the Einstein of missile guidance who runs the laboratory named after him at MIT, recently published a letter in the *New York Times* in which he admitted the bias problem but said the point was whether it was "greater than the lethal radius of the warhead . . ." Back in the late 1940s, when missile-designers were still thinking in terms of 5 nm. CEPs, Draper predicted we would eventually get to 0.1 nm. No man has had more to do with making American missiles accurate, and he claims bias is not greater than the lethal radius. "There is indeed grave risk in using ballistic missiles," he concluded, "but that risk is not uncertainty of accuracy."

But the point of contention most difficult to settle involves the problems in coordinating the launch of many hundreds of missiles so that their warheads would land pretty much simultaneously on their targets, a *sine qua non* for a successful first-strike. For one thing, many of the missiles would have to pass through the same "window" at the apogee of their trajectories in order to land on contiguous targets. Another problem is "fratricide"—the danger that warheads exploding on target will destroy others as they arrive nearby. A coordinated mass launch involves so many unknowns and imponderables that Jimmy Carter's Secretary of Defense, Harold Brown, once referred to it as "a cosmic throw of the dice." What ruling group, the cautionary critics ask, would risk the fate of its regime and country on something which has to work perfectly the first time?

But this shifts the whole discussion from a technical point to a debating point—from the question of accuracy to a question of Russian intent to prepare for a first-strike. From time to time, since 1945, the defense community in Washington has alarmed itself with claims the Russians were close to achieving a genuine first-strike capability. The "bomber gap" of the early-50s and the "missile gap" of a few years later proved chimerical. The current episode of fear has not yet ended. But talk of first strikes has an unreal quality to it. With a handful of fanatic exceptions, not even the military believe the Russians are craftily preparing a surprise blow. The first strike argument is in fact little more than a useful theoretical tool for comparing the characteristics of weapons. It is the technical point, the question of accuracy, which really matters.

It is our genius as a species to be able to find a way to do anything we can imagine. The truth of the matter is that missiles are accurate enough to serve as counter-force weapons. They can destroy anything on or reasonably near the surface of the earth, so long as we know where it is. The long history of technical improvement of inertial guidance systems has reduced CEPs from miles to fractions of miles to hundreds of feet. Further improvements in accuracy can be expected from terminal-guidance—that is, homing techniques—and from satellite-navigational systems. The significance of accuracy is not that it clears the way for a first strike. The cautionary critics are right about that; a regime would have to be crazy to contemplate such a thing. But in the event of war it would be equally crazy to let alone what immediately threatens—weapons and the systems which control them. Accurate missiles prepare the ground for nuclear *war*—extended fighting for purely military objectives, a clash of weapons. No one doubts such a war would wreck the world. It is said that the towns in Germany are only two kilotons apart. But missile accuracy makes such a war possible and indeed forces the hand of military planners. If you *can* destroy enemy weapons, you *must*. This fact is now the driving force behind American nuclear weapons policy, the thing which explains what we are building and why we are building it.

THOMAS POWERS

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A Fatal Flaw in the Concept of Space War

The exotic weaponry on which the Pentagon now spends more than $300 million a year would be rendered useless by a single nuclear blast in outer space

The laser weapons and particle beams that promise to turn space into the next battlefield have a critical flaw that most Pentagon planners and congressional advocates have ignored. The exotic weapons and other military satellites could easily be destroyed by a single nuclear blast in outer space.

Such a blast would instantly set up an electric pulse of up to a million volts per meter in hundreds of satellites and battle stations, disabling them and replacing the bold vision of a *Star Wars* conflict with the dreary reality of a nuclear graveyard. A 2-megaton blast just outside the earth's atmosphere would set up a pulse in objects as far away as geosynchronous orbit, some 36,000 kilometers above the earth. The effects of a larger bomb would reach even further.

Despite this apparently fatal flaw, the military's fascination with high-technology weaponry and the can-do spirit of military contractors have combined to create a laser weapons program that is now soaking up more than $300 million a year.

How did this come about? One reason is that the crippling effects of nuclear weapons in space have only recently dawned on a handful of military planners. Another reason, far more fundamental, is that these few planners are located in a relatively neglected segment of the sprawling military bureaucracy, a segment quite separate from where the exotic weapons are dreamed up.

The people who design laser battle stations work in the high-rise offices of the Defense Advanced Research Projects Agency (DARPA), just a stone's throw from the Pentagon. The people who envision the effects of nuclear explosives work in the squat offices of the Defense Nuclear Agency (DNA), off in the suburbs of Virginia. This separation of responsibilities can easily result in the neglect of important flaws in the concept of new weapons systems. "There's nobody at DARPA who addresses the problem of nuclear effects in space," says David T. Petter, a special assistant to the DARPA director. "On the directed energy stuff [lasers and particle beams], we work on the pointing and tracking, or whatever it might be. We are very much into the R & D side and haven't gotten down to the nitty-gritty."

The nuclear threat to space weapons has not been aired outside the military. Deep within the defense community, however, some military contractors have voiced concern. "It's fine to play all these games on paper," said one West Coast consultant, who asked not to be named. "But what happens when push comes to shove and we have to fight in space under realistic conditions?"

Much of the concern about war in space has been touched off by the fact that the Soviets during the past 14 years have performed several tests with killer satellites. These devices maneuver close to a target and then explode in a hail of shrapnel.

In response to the perceived threat from such satellites, the U.S. military has come up with a number of ideas. The lead project in DARPA's futuristic arsenal is an anti-satellite (A-SAT) weapon based on lasers. The Pentagon has already spent more than $1.6 billion on laser weapon development, and it is currently one of the military's most heavily funded research efforts. A laser A-SAT could sit in geosynchronous orbit, conceivably to defend a flock of unarmed satellites that are critical to U.S. national security. These satellites could include DSCS II (military communications), DSP (early warning of missile attack), NATO III C (NATO communications), and Fleet Sat Com (Navy communications). If a Soviet killer satellite started to approach, a laser death ray would flash into action, heating the skin of the target and weakening the structure until it fractured or blew itself apart. Pentagon officials estimate that 8 to 12 such battle stations could be on duty by 1995, at a cost of slightly more than $15 billion. There are no technological hurdles, say the experts. All it takes is time, patience, and money.

Such visions have won the support of the Reagan Administration and members of Congress. The Senate, in a floor amendment tacked on to the fiscal year 1982 Defense Authorization Bill, added $50 million to the Administration's request for the development of space-based laser weapons—an extra $30 million for the Air Force and $20 million for DARPA. "The language in the bill is quite clear," Malcolm Wallop (R–Wyo.) told a reporter (*1*). "It directs the Air Force to get on with it, to do high-energy laser integration and battle management."

Although it has been known since the early 1970's that satellites could be damaged by a nuclear pulse, new strategic realities are making the threat more worrisome. A nuclear blast in outer space sends out in all directions an immense number of prompt gamma rays and x-rays. On earth this radiation would be quickly attenuated by the atmosphere. When these radiations strike a metal object in space, such as a satellite, they knock out Compton electrons, creating a charge imbalance in the skin of the satellite and setting up extremely high electric fields—on the order of 100,000 to 1 million volts per meter (*2*). These surface fields induce large currents and voltages in the electronic payload, causing disruptions and burnouts. It is as if the delicate semiconductors that lie at the heart of a satellite were suddenly hit by a bolt of lightning. The whole effect is called a system-generated electromagnetic pulse (SGEMP). The distances over which it can occur are immense, an unprotected satellite suffering equipment upset from a 1-megaton nuclear blast some 25,000 kilometers away. The closer the satellite or battle station to the blast and the greater the yield of the weapon, the larger and more damaging is the pulse.

When scientists at DNA first started to realize the strategic implications of SGEMP in the early 1970's, they built machines that would simulate the pulse so they could measure the vulnerabilities of electronic equipment. The largest such machine in the world today is located just north of Washington, D.C. Called Aurora, it is more than five stories high and almost as long as a city block. Despite its size, the machine still is not powerful enough to simulate the actual radiation that would strike a satellite tens of thousands of kilometers away from a nuclear blast in space. Aurora went on

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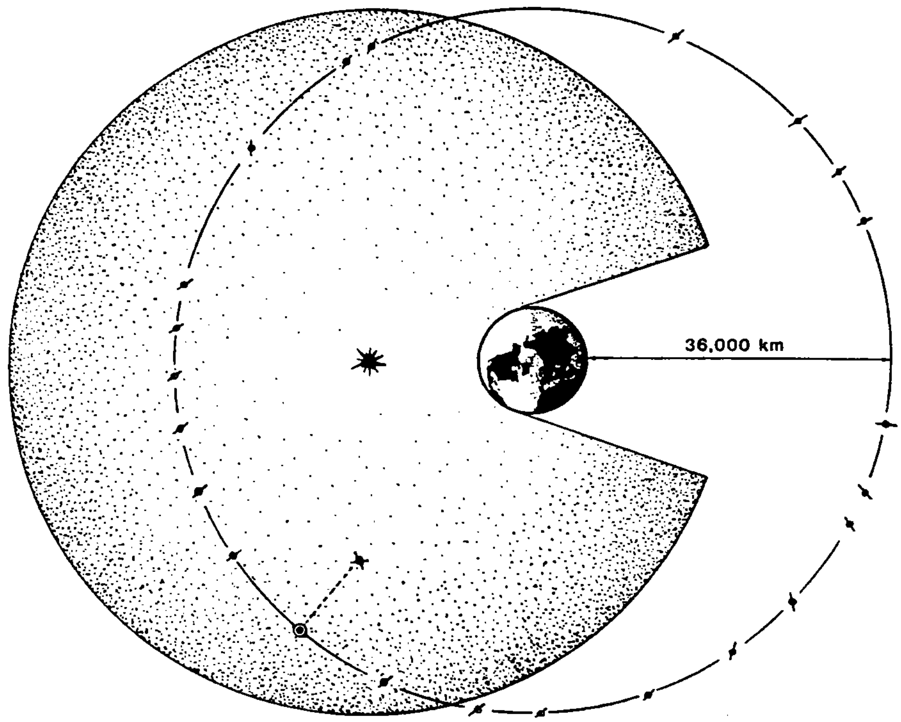
line in 1972, and ever since DNA officials have been pressing for a larger simulator.

"There is an urgent need for such a laboratory simulation facility," the director of DNA, Vice Admiral R. R. Monroe, told Congress in 1979 (*3*). The name of the proposed machine was the satellite x-ray test facility (SXTF), a behemoth that would cost $100 million to build. Though Congress in the past had not proved sympathetic, the new DNA director renewed the plea in April 1981 (*4*). "These tests," said Harry A. Griffith, "are absolutely essential if we are to have confidence in nuclear survivability of our military systems."

Then, unexpectedly, DNA itself decided late last year not to push for construction of the huge new simulator.

What happened bears some pondering, since it has implications for all of the U.S. military efforts in space. The key development was a shift in strategic thinking. In the past, it was considered likely that nuclear blasts might occur just outside the earth's atmosphere, produced by an enemy intent on disrupting land-based communications in the United States with a type of electromagnetic pulse. Easy to produce and attractive to use, this type of pulse would shut down the nation's power grid and knock out unprotected communications from coast to coast (*5*). Any effect on satellites would have been an accidental by-product, or "collateral," as the strategists put it. It would be worth trying to simulate the relatively weak pulses in space at the very edge of the danger area, since testing would show if satellites out in this area could be "hardened." The outer skin of a satellite, for instance, can be separated from the inner skin, setting up a barrier to high voltages. Electronic circuitry can also be designed in a way that minimizes the damage caused by surges in voltage and current.

This protection, however, would not be sufficient against a very strong pulse. Such a pulse would be generated if a Soviet killer satellite carried a nuclear payload into space, a possibility that has profoundly disturbed the nuclear strategists. If a nuclear blast occurred far from the earth, close to the geosynchronous orbit, it would blanket a huge tract of space with powerful radiation that might cripple hundreds of satellites and battle stations. The currents might be so large that none of the nominal protections would help. Induced currents, for instance, would be set up in the inner skins of satellites, knocking out internal electronics. Proximity is the main problem. The radiation striking a satellite from a nuclear blast depends on the square of the distance between the blast and the satellite (*6*). Thus the damage increases geometrically as the distance decreases. "The philosophy of SXTF," says Gordon Soper, scientific adviser to the deputy director of DNA, "was for a distant burst environment." Soper continued in his explication, with bureaucratic understatement: "Weighing heavily in the decision not to proceed at this time is the fact that other levels are now envisioned."

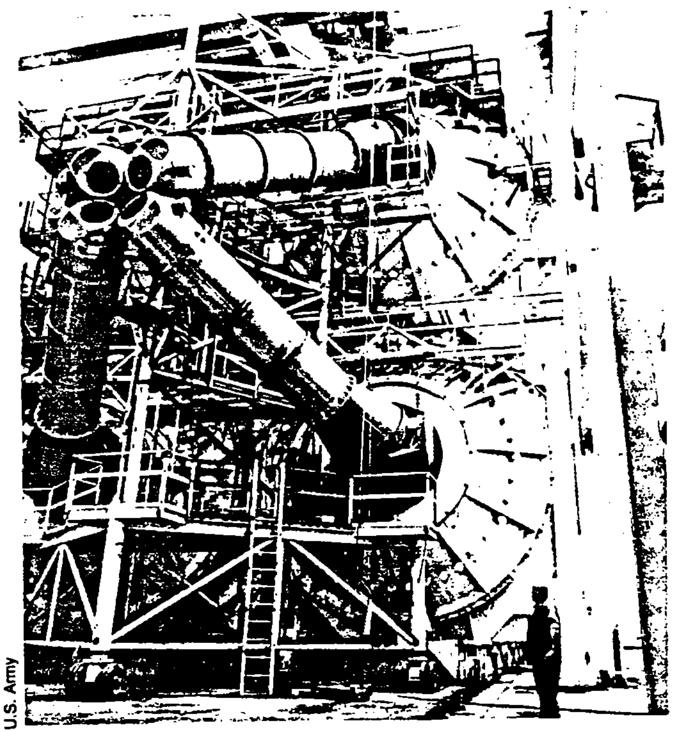


Shown is a space war scenario in which a 3-megaton nuclear bomb is detonated some 14,000 kilometers above the earth. Unprotected satellites within the shaded area would suffer equipment upset or damage, depending on how close they were to the blast. The satellites shown are in geosynchronous orbit, although many others would be closer to the earth and the blast. The extent of the nuclear threat is contrasted to a laser battle station in geosynchronous orbit, firing at a killer satellite some 10,000 kilometers away.

The severity of the threat has been compounded by the development of warheads capable of turning much more of their mass into damage-producing radiation. Although neutron bombs and other enhanced radiation warheads are often depicted as being used only on the earth, they could just as well be used in space.

Technologists who still want to try to protect space hardware have not given up hope, but they paint a gloomy picture. Rather than trying to build protection into valuable satellites, the emphasis is now shifting to taking them completely out of the danger zone. A satellite equipped with special sensors and engines might be able to detect a nuclear-armed killer satellite thousands of kilometers away and kick itself into a distant orbit so as to avoid the damaging rays from the blast. From there it might still be able to perform its critical mission. Defense officials admit the concept is technologically difficult, but they also note the lack of easy alternatives.

In addition to the newly realized dangers of SGEMP, a host of other nuclear effects would vex the operation of electrical devices during a nuclear blast in space. Neutrons and gamma rays can directly penetrate satellites and battle stations, causing TREE effects (transient radiation effects on electronics). TREE would alter gate voltage thresholds in transistors, would damage the crystalline lattice of semiconductors, and would set up spurious current pulses in solid-state devices (*7*). Even blasts close to the earth would eventually have a serious impact on satellites. They would produce a band of trapped electrons as the bomb's fission fragments started to decay. This band would drift around the earth, damaging over the course of weeks and months electronic devices and solar cells in satellites. This type of damage, in fact, plagued the few satellites that were exposed to the aftermath of the 1962 nuclear tests conducted by the United States high above the Pacific Ocean. None of the satellites was in a position to be directly damaged by radiation from these blasts, but over the following weeks, degradation of performance was extensive. The satellites even-



U.S. Army

Aurora, the world's largest flash x-ray machine, since 1972 has been used to simulate the effects of nuclear blasts in space. Electronic parts or whole systems are placed where the four tubes come together, and an intense flash of x-rays then tests their vulnerabilities. The machine is located at the Harry Diamond Laboratories, just north of the beltway outside Washington, D.C. Even secretaries at the facility must have a security clearance of at least secret.

tually affected by trapped electrons included Transit 4B, OSO 1, Telstar 1, Relay 1, and Explorers 14 and 15.

In attempting to build in protection against some of these nuclear effects, design changes must be considered very early in the planning stages of a satellite. "If you wait until the end," says Soper at DNA, "the changes are so difficult and expensive that they are often ignored."

Nevertheless, the designers of laser battle stations and high-technology weapons apparently have a penchant for leaving the worst problems till last. "We're not looking at the overall system," says Petter of DARPA. "That responsibility belongs to the Air Force, and the Air Force would be doing that kind of thing way down the pike."

As a matter of policy, Soper and other military officials who study nuclear effects do not criticize the high-technologists at DARPA or make comments about the possible damage a nuclear blast in space would cause any specific weapon system. They speak only in generalities about satellites and space systems, and they speak in somber tones.

In promoting their projects, DARPA officials tend to ignore the nuclear side of space war. They note that space lasers could be used to shoot down Soviet ballistic missiles in the atmosphere, although critics say this idea has more flaws than warfare limited to space (*8*). Advocates of laser war also note that nuclear blasts in space are banned by the 1967 treaty forbidding "weapons of mass destruction." And it is unlikely the treaty would be broken, they say, because a nuclear blast in space would also hurt the Soviets.

Would the Soviets detonate a nuclear bomb that would knock out many of their own satellites? At first sight it might seem implausible. Yet the timing and placement of the attack could ensure that their critical satellites were shielded from damaging radiations by the earth itself or were far enough away from the blast that circuit-damaging pulses were kept to a minimum. After all, the few satellites aloft during the exoatmospheric tests of 1962 were not instantly shut down because they were on the far side of the earth, protected from prompt gamma rays and x-rays. Another consideration is that the Soviets do not rely on satellites to the same extent as the United States.

Perhaps one reason why officials at DARPA and the Air Force have ignored nuclear blasts is the magnitude of the problem they would have to confront. For one thing, a laser weapon would be huge, requiring large fuel tanks in which an especially strong surge of SGEMP would be produced and passed along to delicate electronics. For another, the space laser itself, as currently envisioned, would be dependent on a relay satellite for communications with the ground, and that satellite might easily be put out of service by the radiation from a distant nuclear blast. Lastly, even if the space laser could still function after a blast, the battlefield would have been swept clean, with little left to shoot at.

Recent changes in the defense hierarchy will not improve matters. With the release of the fiscal year 1983 budget, Defense Secretary Caspar Weinberger noted that he intends to boost the director of DARPA into a new bureaucratic role so that he also wears the hat of an assistant secretary for research and technology. One purpose of the heightened status is to speed up the pace at which new ideas are incorporated into military hardware.

In contrast to the increased prominence of the high-technology enthusiasts, the scientists and administrators at DNA have, if anything, suffered a reduction in visibility. Their $300-million-a-year research budget has not grown in real terms for nearly a decade, despite the fact that the nuclear realities they must envision and prepare for have steadily grown in scope and complexity.

The issues are indeed formidable. Rather than ignoring the flaws in the concept of space war, officials at DNA are currently looking for better ways to simulate the effects of nuclear blasts in outer space. Since machines are proving too small for the task, the focus is shifting to the underground test site in Nevada, where dummy satellites are sealed into evacuated shafts that mimic the void of outer space. At the far end of a shaft is a nuclear bomb. It explodes, sending out its lethal by-products, including an immense amount of radiation. The picture is not pretty, yet it is one that many people, not just the bureaucrats and scientists at DNA, should examine in detail.—WILLIAM J. BROAD

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6. The equation that describes the edge of the area at which damage to an unprotected satellite would start to occur is:

$$\frac{6.4\,Y}{R^2} = 10^{-5}\ \text{cal/cm}^2$$

where Y is the yield in kilotons and R is the distance from the blast in kilometers.
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SCIENCE AND TECHNOLOGY

America thinks it is short of plutonium for its weapons

America's non-proliferation stance is looking more and more shaky. One blow was the recent report to America's Nuclear Regulatory Commission, written by a former commission staff member, which poked holes in the credibility of international safeguards against the diversion of nuclear fuels from peaceful to weapons uses. More trouble will be caused by America's proposals for stretching its own supplies of weapon-grade fuels.

America's problem is embarrassingly simple: it has not got enough weapon-grade plutonium to build the 14,000 new nuclear warheads that President Reagan wants added to the stockpile over the next eight years. The United States energy department has produced a controversial plan to plug the gap. Two proposals involve a blurring of the distinction between civil and military uses of plutonium.

One proposal is to buy plutonium from Britain's Central Electricity Generating Board. Although this material would not itself be used for defence purposes, its availability would enable an existing civil facility to be converted to making weapon-grade plutonium.

The second controversial proposal is to use a process called laser-isotope separation (LIS) to convert spent fuel from civil reactors into weapon-grade material.

You need plutonium to make it go

Two radioactive isotopes are suitable for making bombs, uranium-235 and plutonium-239. Weapon designers now prefer the plutonium isotope, as a smaller amount will produce the "critical mass" needed for an explosion. In a civil reactor, plutonium-239 is continuously produced as an end-product of radioactive decay. But the process does not stop there. Plutonium-239 can absorb a neutron and so become plutonium-240.

In a civil reactor, this does not matter. For weapons purposes it does: plutonium-240 spoils the fission process. To avoid a build-up of plutonium-240—weapon-grade material must have less than 6% of the stuff—bomb-makers need to extract the fuel rods from a reactor after only a short time.

The current source of weapon-grade plutonium in America is the Savannah River plant in South Carolina, where three ageing reactors are dedicated to military use. However, Savannah River cannot meet both the Pentagon's future needs (assuming congress approves them) and the energy department's requirements for its experimental fast-reactor project.

To uncork the bottleneck, Savannah River will reportedly become the site for the new LIS facility. This will break the moratorium on reprocessing spent fuel imposed by the Ford and Carter administrations as part of America's non-proliferation policy.

The LIS technology to be exploited has already been applied to uranium. There are two uranium isotopes—uranium-238 (accounting for 99.3% of mined uranium ore) and uranium-235. The two isotopes are chemically identical but they have different numbers of neutrons and, so, different atomic masses. It is this difference in mass that LIS uses to separate the fissile uranium-235 from the uranium-238.

The process starts with gaseous uranium hexafluoride. The gas molecules have varying masses, depending on which uranium isotope has combined with the fluorine. They also have different characteristic vibrational frequencies. An infrared laser can be tuned to the frequency that excites only those molecules that contain the fissile isotope uranium-235.

Then an ultraviolet laser can be tuned to a frequency which zeroes in on the excited molecules and knocks out a fluorine atom from each molecule. This leaves a powder (easily removed from the surrounding gas) which contains only the wanted uranium-235.

America's Lawrence Livermore Laboratory has adapted this LIS technique for plutonium. Like the uranium LIS technology, it works. No doubt, like the uranium technology, it is expensive. But nobody is much fussed about price competitiveness when it comes to defence. And the United States energy department will further stretch its weapon-grade plutonium supplies by mixing its existing reactor-grade plutonium (12% plutonium-240) with its stock of super-grade plutonium (3% plutonium-240).

Mr Sigvard Eklund, director general of the International Atomic Energy Agency, has already warned the American administration of the probable consequences in Europe of an overt link between civil and military nuclear programmes. The American energy department seems determined to stand fast none the less. Mr Bernard Ruschke, special assistant to the secretary of energy, says of the distinction between civil and military uses: "That separation may be more psychological than real".

Colleges and Universities Urged to Join Nuclear-Warfare Debate by Providing Active Leadership and More Rigorous Scholarship

By MALCOLM G. SCULLY

WASHINGTON

As the House of Representatives began debate last week on a measure calling for an immediate freeze on the production of nuclear weapons, American colleges and universities were being accused of paying insufficient attention to the threat of nuclear war.

"I think we have to acknowledge the scandal that this central issue of our times has been fundamentally ignored in our universities," said Robert Jay Lifton, professor of psychiatry at Yale University.

Recently, he added, "there has been a wave of concern about nuclear-weapons education, but it is very belated. Very little of the anti-nuclear discussion came from students or faculty members. It is high time that this is changing."

Mr. Lifton and other panelists at a meeting here on the "role of the academy in addressing the issues of nuclear war" called for widespread academic involvement in debates over such issues as arms control, disarmament, the proliferation of nuclear weapons, and the threat of nuclear war.

"Physicians, lawyers, and scientists have been and are speaking up," said Adele S. Simmons, president of Hampshire College. "Where are the college presidents?"

"I realize that in the last few years, college presidents have been reluctant to speak out on issues other than those directly related to their own institutions, such as financial aid.

"However, unless we speak up and provide leadership in the search for a saner society, it may not matter whether we get an extra bit of money from some donor who would be offended by our taking a particular position.

"Perhaps more than any other subject, the study of war and peace in the nuclear age is the vehicle in which we espouse all the values of a liberal education."

Ms. Simmons called for the establishment of "at least one interdisciplinary core course on arms control and nuclear war" at every college and university in the country.

"We should take the issues of war and peace away from the lunatic fringe and put them at the center of the academic enterprise," she said.

'Language Is Central'

Dr. Lifton, who has studied in detail the psychological and social consequences of the U.S. attack on Hiroshima and Nagasaki in 1945, said virtually every academic discipline—from literature to physics—could include materials on the existence of nuclear weapons and their effects on human beings. Even linguists should be interested, he added, because "language is central" in discussions of nuclear war.

"What is a 'nuclear exchange'?" he asked. "It sounds like the exchange of gifts, doesn't it?"

A third participant—Bruce M. Russett, professor of political science at Yale University—said that until recently "the universities have been quite quiescent in terms of research and serious scholarship" on arms control, the arms race, and nuclear warfare.

"We have gone through a dry spell," he said. "A whole generation of serious analysts of these questions has almost been lost."

One of the chief jobs facing universities, Mr. Russett added, is the restoration of a cadre of serious scholars on arms control and nuclear weapons—"scholars with a solid base of analytical skills who are outside the defense establishment."

The conference was sponsored by the American Council on Education, the Association of American Colleges, and Hobart and William Smith Colleges.

The panelists agreed that, belatedly, the issues of nuclear war were beginning to generate interest at U.S. colleges and universities, but they said the interest had not come from within the institutions themselves.

Instead, they pointed to sources outside the academy that have generated new attention to arms control, disarmament, and nuclear warfare. Among them:

▶ A burgeoning anti-nuclear movement in Western Europe that has begun, in the words of one participant, "to spread its contagion" to students in the United States.

▶ Concern that President Reagan is pursuing a foreign policy that will accelerate the arms race and make the prospect of nuclear war more likely.

▶ The contrast between the Administration's increases in the defense budget and its cuts in many social and educational programs.

▶ The publication by the *New Yorker* of a three-part article by Jonathan Schell in which he examined in graphic detail the possible consequences of all-out thermonuclear war.

Richard W. Lyman, president of the Rockefeller Foundation, reported the views of a friend that Mr. Schell's article would be "to the arms-control movement what Rachel Carson's works were to the environmental movement."

Like many other panelists, Mr. Lyman commented on the dramatic groundswell of public concern over the threat of a nuclear war.

Teach-ins on 150 Campuses

"After several decades in which scarcely anyone but a few indestructible peaceniks and the limited fraternity of arms-controls specialists gave any sustained attention to the peril of nuclear destruction in war, it is being written about and talked about on every side," Mr. Lyman said.

At colleges and universities, such attention led to teach-ins, sponsored by the Union of Concerned Scientists, at 150 campuses last November. As a result of the teach-ins, a new organization—the United Campuses to Prevent Nuclear War—was formed, in the words of its charter, to "coordinate and facilitate nationwide educational and political activities directed against the threat of nuclear war."

Peter C. Stein, chairman of the organization's steering committee and a professor of physics at Cornell University, said some 250 colleges and universities would hold teach-ins about the threat on April 22.

"We plan to take even more effective political action next fall during election time," Mr. Stein said.

Much of the discussion at the meeting here focused on the recent lack of campus attention to the issues and on the best ways for colleges and universities to become involved in the nuclear debate.

Mr. Lyman said it was not difficult, "especially for those of us with some experience of the late 1960's, to imagine one possible outcome of the burgeoning effort to awaken people to the enormous danger to civilization that uncontrolled increase and proliferation of nuclear weaponry holds.

"We may see the streets filled with demonstrators, mainly youthful, as a good many European streets were on occasion filled this past year."

However, he warned, "mass protests are not enough and they are not always even useful."

Mr. Lyman added that "there is certainly no shortage of things for higher education to do to fulfill its role in this ultimate question for humankind," but he warned that colleges and universities might not have the will to do them.

"What is unhappily likely, given the distracted and dispirited state of academia today, is that the energy, the vision, and the determination to do these things will be found wanting," he said. "It would be far too easy, and tragically shortsighted, to allow such energies as we can muster to be siphoned off into promoting protest, and nothing more.

"Almost the worst thing we could do—worse even than restoring the apathy of just a few years back—would be to opt for a few easy and dramatic gestures, satisfying outlets for our frustrations that might make us all feel a nice, warm glow of self-righteousness but would do nothing to advance our basic understanding of the problems."

Questions of Objectivity

For Mr. Lyman and some other participants, the question of how colleges and universities should become involved in the nuclear debate raised many of the questions of the Vietnam era about academic objectivity and institutional advocacy of political positions.

Marshall D. Shulman, director of the Russian Institute at Columbia University and an adviser on Soviet affairs to the State Department during the Carter Administration, said he was "a little disturbed by a note I detect" that colleges and universities should become advocates for a specific point of view.

"It seems to me that our function is not indoctrination," Mr. Shulman said. "It is to give people an understanding of a very complex topic."

Mr. Shulman also warned that opposition to nuclear weapons "not be regarded as a soft or a liberal issue. It is an issue that should cross the political spectrum in the U.S."

Concern with arms control and disarmament should not be associated with "a benign and naive view of the Soviet Union," he added.

Over all, participants agreed that the growing concern with nuclear war was taking place at a time when the prospects for avoiding such a war seemed to be dwindling.

"There is a very greatly increased public recognition of the seriousness of this problem," said Herbert Scoville, Jr., president of the Arms Control Association. "I am truly amazed and terribly gratified by what we've seen in the last months."

Gloomy Outlook

Nonetheless, he said, the outlook for successful control of nuclear weapons appears gloomy. Both the United States and the Soviet Union are "acquiring new delivery systems which, instead of promoting deterrence, are making nuclear war more likely," he said.

Such reports led to numerous calls for greater academic involvement in a campaign against the use of nuclear weapons.

Dr. Lifton of Yale called for "appropriate passion" in the universities—a combination of passionate opposition to nuclear weapons and rigorous scholarship and research on their effects on modern society.

When such passion is present, he said, "our intellectual work becomes a very significant moral and political act."

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