THE LAUCKS FOUNDATION —

from time to time calls attention to published material that might contribute toward clarification or understanding of critical issues affecting world peace. The accompanying reprints constitute Mailing No. 23.

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The ultimate contemporary deformation is a condition we may call nuclearism: the passionate embrace of nuclear weapons as a solution to death anxiety and a way of restoring a lost sense of immortality. Nuclearism is a secular religion, a total ideology in which "grace" and even "salvation" — the mastery of death and evil — are achieved through the power of a new technological deity. The deity is seen as capable not only of apocalyptic destruction but also of unlimited creation. And the nuclear believer or "nuclearist" allies himself with that power and feels compelled to expound on the virtues of his deity. He may come to depend on the weapons to keep the world going.

— Robert Jay Lifton, The Broken Connection (Simon and Schuster, New York, 1979, p. 369)

On the Nuclear Standoff and Its Insanity

By GEORGE F. KENNAN

WASHINGTON—Adequate words are lacking to express the full seriousness of the United States' present situation. It is not just that we are, for the moment, on a collision course politically with the Soviet Union, and that the process of rational communication between the two governments seems to have broken down completely; it is also—and even more importantly—the fact that the ultimate sanction behind the conflicting policies of these two governments is a type and volume of weaponry which can not possibly be used without utter disaster for us all.

For more than 30 years wise and farseeing people have been warning us about the futility of any war fought with nuclear weapons and about the dangers involved in their cultivation. Every President from Dwight D. Eisenhower to Jimmy Carter has tried to remind us that there could be no such thing as victory in a war fought with such weapons. So have a great many other eminent persons.

So much has already been said. What is to be gained by reiteration? What good would it now do? Look at the record: Over all these years the competition in the development of nuclear weaponry has proceeded steadily, relentlessly, without the faintest regard for all these warning voices. We have gone on piling weapon upon weapon, missile upon missile, new levels of destructiveness upon old ones.

We have done this helplessly, almost involuntarily: like the victims of some sort of hypnotism, like men in a dream, like lemmings heading for the sea, like the children of Hamelin marching blindly along behind their Pied Piper. And the result is that today we have achieved—we and the Russians together—in the creation of these devices and their means of delivery, levels of redundancy of such grotesque dimensions as to defy rational understanding.

I know of no better way to describe it. But actually, the word redundancy is too mild. It implies that there could be levels of these weapons that would not be redundant. Personally, I doubt that there could. I question whether these devices are really weapons at all. A true weapon is at best something with which you endeavor to affect the behavior of another society by influencing the minds, the calculations, the intentions, of the men who control it; it is not something with which you destroy indiscriminately the lives, the substance, the hopes, the culture, the civilization, of another people.

What a confession of intellectual poverty it would be—what a bankruptcy of intelligent statesmanship—if we had to admit that such blind, senseless acts of destruction were the best use we could make of what we have come to view as the leading elements of our military strength! To my mind, the nuclear bomb is the most useless weapon ever invented. It can be employed to no rational purpose. It is not even an effective defense against itself. It is only something with which, in a moment of petulance or panic, you commit such fearful acts of destruction as no sane person would ever wish to have upon his conscience.

There are those who will agree, with a sigh, to much of this, but who will point to the need for something called deterrence. This is, of course, a concept which attributes to others—to others who, like ourselves, were born of women, walk on two legs, and love their children, to human beings, in short—the most fiendish and inhuman of tendencies. But all right: Accepting for the sake of argument the profound iniquity of these adversaries, no one could deny, I think, that the present Soviet and American arsenals, presenting over a million times the destructive power of the Hiroshima bomb, are simply fantastically redundant to the purpose in question. If the same relative proportions were to be preserved, something well less than 20% of these stocks would surely suffice for the most sanguine concepts of deterrence, whether as between the two nuclear superpowers or with relation to any of those other governments that have been so ill-advised as to enter upon the nuclear path.

Whatever their suspicions of each other, there can be no excuse on the part of the United States or the Soviet Union for holding, poised against each other and poised in a sense against the whole Northern Hemisphere, quantities of these weapons so vastly in excess of any rational and demonstrable requirements.

How have we got ourselves into this dangerous mess?

Let us not confuse the question by blaming it all on our Soviet adversaries. They have, of course, their share of the blame, and not least in their cavalier dismissal of the Baruch Plan (which would have established international supervision of atomic development) so many years ago. They, too, have made their mistakes; and I should be the last to deny it. But we must remember that it has been we Americans who, at almost every step on the road, have taken the lead in the development of this sort of weaponry. It was we who first produced and tested such a device; we who were the first to raise its destructiveness to a new level with the hydrogen bomb; we who introduced the multiple warhead; we who have declined every proposal for the renunciation of the principle of "first use"; and we alone, so help us God, who have used the weapon in anger against others, and against tens of thousands of helpless noncombatants at that.

I know that reasons were offered for some of these things. I know that others might have taken this sort of a lead, had we not done so. But let us not, in the face of this record, so lose ourselves in self-righteousness and hypocrisy as to forget our own measure of complicity in creating the situation we face today.

What is it then, if not our own will, and if not the supposed wickedness of our opponents, that has brought us to this pass?

The answer, I think, is clear. It is primarily the inner momentum, the independent momentum of the weapons race itself—the compulsions that arise and take charge of great powers when they enter upon a competition with each other in the building up of major armaments of any sort.

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We have to break out of the circle. We have no other choice.

How are we to do it?

I must confess that I see no possibility of doing this by means of discussions along the lines of the negotiations that have been in progress, off and on, over this past decade, under the acronym of SALT (Strategic Arms Limitation Treaty). I regret, to be sure, that the most recent SALT agreement has not been ratified. I regret it, because if the benefits to be expected from that agreement were slight, its disadvantages were even slighter; and it had a symbolic value which should not have been so lightly sacrificed. But I have no illusion that negotiations on the SALT pattern—negotiations, that is, in which each side is obsessed with the chimera of relative advantage and strives only to retain a maximum of the weaponry for itself while putting its opponent to the maximum disadvantage—I have no illusion that such negotiations could ever be adequate to get us out of this hole. They are not a way of escape from the weapons race; they are an integral part of it.

Whoever does not understand that, when it comes to nuclear weapons, the whole concept of relative advantage is illusory—whoever does not understand that when you are talking about absurd and preposterous quantities of overkill the relative sizes of arsenals have no serious meaning—whoever does not understand that the danger lies not in the possibility that someone else might have more missiles and warheads than we do, but in the very existence of these unconscionable quantities of highly poisonous explosives, and their existence, above all, in hands as weak and shaky and undependable as those of ourselves or our adversaries or any other mere human beings: whoever does not understand these things is never going to guide us out of this increasingly dark and menacing forest of bewilderments into which we have all wandered.

I can see no way out of this dilemma other than by a bold and sweeping departure—a departure that would cut surgically through the exaggerated anxieties, the self-engendered nightmares, and the sophisticated mathematics of destruction—in which we have all been entangled over these recent years—and would permit us to move, with courage and decision, to the heart of the problem.

President Ronald Reagan recently said, and I think very wisely, that he would "negotiate as long as necessary to reduce the numbers of nuclear weapons to a point where neither side threatens the survival of the other." But I wonder whether the negotiations would really have to be at such great length. What I would like to see the President do, after due consultation with Congress, would be to propose to the Soviet government an immediate across-the-board reduction by 50% of the nuclear arsenals now being maintained by the two superpowers—a reduction affecting in equal measure all forms of the weapon, strategic, medium range and tactical, as well as all means of their delivery.

All this would be implemented at once and without further wrangling among the experts, and would be subject to such national means of verification as now lie at the disposal of the two powers. Whether the balance of reduction would be precisely even—whether it could be construed to favor statistically one side or the other—would not be the question. Once we start thinking that way, we would be back on the same old fateful track that has brought us where we are today.

Whatever the precise results of such a reduction, there would still be plenty of overkill left—so much so that if this first operation were successful, I would then like to see a second one put in hand to rid us of at least two thirds of what would be left.

Now I have, of course, no idea of the scientific aspects of such an operation; but I can imagine that serious problems might be presented by the task of removing, and disposing safely of, the radioactive contents of the many thousands of warheads that would have to be dismantled. Should this be the case, I would like to see the President couple his appeal for a 50% reduction with the proposal that there be established a joint Soviet-American scientific committee, under the chairmanship of a distinguished neutral figure, to study jointly and in all humility the problem not only of the safe disposal of these wastes, but also the question of how they could be utilized in such a way as to make a positive contribution to human life, either in the two countries themselves or —perhaps preferably—elsewhere. In such a joint scientific venture we might both atone for some of our past follies and lay the foundation for a more constructive relationship.

It will be said that this proposal, whatever its merits, deals with only a part of the problem. This is perfectly true. Behind it there would still lurk the serious political differences that now divide us from the Soviet government. Behind it would still lie the problems recently treated, and still to be treated, in the SALT forum. Behind it would still lie the great question of the acceptability of war itself, any war, even a conventional one, as a means of solving problems among great industrial powers in this age of high technology.

What has been suggested here would not prejudice the continued treatment of these questions in whatever forums and under whatever safeguards the two powers find necessary. The conflicts and arguments over these questions could all still proceed to the heart's content of all those who view them with such passionate commitment. The stakes would simply be smaller, and that would be a great relief to all of us. What I have suggested is, of course, only a beginning. But a beginning has to be made somewhere; and if it has to be made, it is best that it should be made where the dangers are the greatest, and their necessity the least. If a step of this nature could be successfully taken, people might find the heart to tackle with greater confidence and determination the many problems that would still remain.

It will be argued that there would be risks involved. Possibly so. I do not see them. I do not deny the possibility. But if there are, so what? Is it possible to conceive of any dangers greater than those that lie at the end of the collision course on which we are now embarked? And if not, why choose the greater—why choose, in fact, the greatest—of all risks, in the hope of avoiding the lesser ones?

We are confronted with two courses. At the end of the one lies hope—faint hope, if you will—uncertain hope, hope surrounded with dangers, if you insist. At the end of the other lies, so far as I am able to see, no hope at all. Can there be—in the light of our duty not just to ourselves (for we are all going to die sooner or later) but of our duty to our own kind, our duty to the continuity of the generations, our duty to the great experiment of civilized life on this rare and rich and marvelous planet—can there be, in the light of these claims on our loyalty, any questions as to which course we should adopt?

George F. Kennan, former U.S. ambassador to the Soviet Union and Yugoslavia, is a diplomatic historian and professor at Princeton's Institute for Advanced Studies. His article is adapted from an address he delivered last week after receiving the Albert Einstein Peace Prize.

(Several years ago, the founder of the Laucks Foundation formulated the following plan for peace. —ECL) :

A SIX-POINT PLAN FOR PEACE

suggested by

Irving F. Laucks

1. The President, as commander-in-chief, will order the dismantling or destruction of 2 percent of the nuclear weapons of the United States. This will not in any appreciable way diminish United States capacity to destroy any possible attackers, and the actual process of destroying some weapons, televised around the world, will demonstrate dramatically that the United States is determined to begin the process of disarmament.

2. The President will then ask other nations with nuclear arms to reciprocate by destroying 2 percent of their nuclear weapons. He will further ask them to join with the United States in forming a Federation for Peace, which will be composed of one member from each nation now possessing nuclear capability, plus two additional United Nations members.

3. The nations of the Federation for Peace will bind themselves by treaty to form an international commission to develop a plan for gradual and complete destruction of all nuclear weapons, and to supervise the step-by-step disarmament process, which might take five years to accomplish. Since warfare with conventional arms is always susceptible of escalation into nuclear war, disarmament eventually will have to include old-fashioned weapons. The knowledge of how to make nuclear weapons is widespread, and the possibility of resumption of nuclear arms production will remain a threat. However, the urgent matter for consideration is the elimination of current nuclear weaponry. As the disarmament process goes forward, manufacture of all weapons will have to be phased out and plans developed by each nation for provision of peacetime jobs for those now employed in the weapons industry. Likewise, jobs for members of armed forces displaced by disarmament will have to become available.

4. If any nation with nuclear capability refuses to participate in the gradual destruction of nuclear armament, the Federation for Peace will be empowered to act. By mutual agreement, members of the Federation will refuse trade and any other contact with non-cooperating nations. During the first stages of nuclear disarmament, military force of sufficient strength will be maintained by the Federation for Peace to meet any challenge by any nation unwilling to disarm its nuclear capability. Full general disarmament, of course, will not occur until all armed nations have joined the Federation for Peace and signed a general disarmament treaty.

5. An International Court of Justice, similar to the one now in existence, but with broader powers to accept and judge cases, will be formed as the judicial branch of the Federation to decide all disputes between nations.

6. Following attainment of complete nuclear disarmament, the United Nations will be asked to form a <u>permanent</u> International Peacekeeping Force to insure that the terms of the nuclear disarmament treaty of the Federation for Peace are observed for all time. Continual inspection will be carried on to make sure that nations remain disarmed of all nuclear capability. The Federation for Peace will recognize and support United Nations international agencies now in operation, and the United Nations itself will continue to serve as a world forum.

EMP
A SLEEPING ELECTRONIC DRAGON

Our growing dependence on solid-state electronics may leave us vulnerable to a potentially devastating type of nuclear fallout

The first of two parts

BY JANET RALOFF

A nuclear bomb detonates 250 miles above Omaha, Neb. A type of "fallout" most people have never heard of bathes the entire nation, and within a fraction of a second people coast to coast find themselves without power, without telecommunications, without computers—in a word, vulnerable. The fallout is called EMP, for electromagnetic pulse. Its effects are the opposite of those of the neutron bomb: EMP cripples or kills electronic equipment but leaves humans standing—very much alive and vulnerable.

It has been estimated that roughly one millionth of the total energy of a nuclear explosion is emitted as an EMP. If the pulse from a high-altitude detonation were delivered in the opening salvo of a warring siege, the attacked population might spend precious minutes or hours reeling in chaos. Even if the defending military could respond, the civilian sector — unable to communicate well, if at all—would find recovery of vital services slow. But should the EMP shower down in "peacetime" — also a distinct possibility—a nation might find itself temporarily disabled industrially and seriously crippled economically.

Nuclear-weapons-generated EMP is by no means a new phenomenon, though for years it has had an extremely low profile outside the defense-electronics community. In fact, since the detonation of conventional high explosives sometimes produces an EMP, similar signals were expected to accompany nuclear bursts. But the extent and particularly devastating nature of the nuclear-generated signals did not become obvious until several years after the United States began its program of above-ground nuclear-weapons tests. The signals left their imprint as a series of seemingly unexplainable failures or burnouts in equipment set up to monitor effects of the nuclear tests. Analysis ultimately pointed a finger at EMP as the cause when investigation showed that induced currents and voltages produced the failures.

Around 1960, several more graphic incidents drove home the possible vulnerability of civilian and military electrical and electronics systems. One of the most famous was the simultaneous failure of 30 strings of street lights in Oahu, Hawaii, in 1962. The Hawaiian outages are now attributed to EMP from high-altitude nuclear tests 800 miles away, near Johnston Island in the Pacific. That EMP is also held responsible for having opened power line circuit breakers and for setting off "hundreds" of burglar alarms in Honolulu.

But "EMP was just sort of a sleeping spook out there," says Bill Macklin of IRT Corp. (a firm that specializes in EMP work for the military) until the electronics revolution and related computerization of industrial processes and business functions ushered in a mushrooming escalation in our potential vulnerability to EMP disruption.

The phenomenon wreaks its havoc by inducing current or voltage surges through electrically conducting materials. In some cases the surges merely trip circuit breakers, shutting down a piece of equipment or power line. In other cases, especially where semiconductor materials are involved, individual components or circuits are destroyed.

Vacuum-tube systems tend to be many times more resistant to permanent damage from EMP than are semiconductor systems, and 60-hertz motors are even more resistant than vacuum tubes. "But even motors can be damaged if connected to a very large energy-collecting structure," warns the Defense Nuclear Agency. What's more, every system or electrical complex must be evaluated individually to determine its potential vulnerability to EMP. Laboratory tests, for instance, have shown that the potential vulnerability of similar systems can vary widely depending on the type of components used, the way components are connected to each other and even on the particular manufacturer of seemingly identical parts.

In a crude sense, EMP is similar to radio waves. But it exhibits important differences. EMP waves include a broader range of frequencies and amplitudes than radio transmitters can produce, and electric fields associated with EMP can be millions of times greater than those associated with radio waves. Yet like radio waves, EMP energy is picked up by antennas and conducted to attached — or in some cases, adjacent unattached—equipment.

The actual energy raining down in an EMP pulse is not all that high, which explains why humans are not affected. In fact, EMP is presumed to be no more harmful to humans than is a flash of distant lightning. *Effects of Nuclear Weapons,* a book published jointly by the Departments of Defense and Energy, adds that dogs and monkeys showed no adverse health effects after being exposed to single EMP's or pulses administered repeatedly over a period of months. Contact with an effective EMP collector, though, such as a long wire, pipe, fence, conduit, railroad track or other large metal object, could impart a hefty shock. That's because, as a general rule, the amount of EMP that any antenna collects is proportional to its overall dimensions. And virtually every electrical conductor will serve as an EMP antenna unless it is adequately shielded.

All nuclear explosions generate an EMP, although the intensity, duration and area over which the pulse is effective varies with the altitude of the burst. Even the mechanism by which EMP is generated may differ with the altitude at which a bomb is detonated.

Gamma rays emitted by nuclear reactions and gamma rays produced by neutron interactions with bomb residues and other materials are largely responsible for the processes that create EMP. As the gamma rays interact with materials, they produce an ionized region about the detonation point. "The negatively charged electrons move outward faster than the much heavier, positively charged ions," say Samuel Glasstone and Philip Dolan in their book, *The Effects of Nuclear Weapons.* This initially sets up a separation of charges, with regions nearer the blast point bearing a net positive charge while those farther away build a net negative charge. Charge separation creates an electric field that can attain its maximum value in about one hundred millionth of a second.

If the explosion occurred in an environment of perfectly homogeneous density, the electric field would be radial, symmetric and of equal strength in all directions, Glasstone and Dolan say. It would also fail to radiate electromagnetic energy —such as EMP—from the ionized deposition region. But for a variety of reasons (which can range from the detonation's proximity to the earth, to the configuration of the weapon or the vapor content of the air) truly homogeneous environments never exist. The result of nonhomogeneity is EMP.

In surface or near-surface blasts, the region of peak EMP hazard is restricted to a range of only about two to five miles from ground zero. For higher blasts — those occurring at altitudes up to 19 miles—the EMP-hazard range will increase to a nine-mile ground radius.

True high-altitude blasts are another matter. Unlike the relatively localized EMP effects experienced with surface bursts, high-altitude detonations — those occurring 19 miles up or higher — blanket a line-of-sight penumbra on earth. For a blast 50 miles up, the affected ground radius on earth would be roughly 600 miles; at 100 miles up, the ground radius would be 900 miles. And for an explosion centered over the country at an altitude of 200 miles, the entire continental United States (including parts of Canada and Mexico) would be drenched in a bath of EMP.

In these high-altitude bursts, gamma rays traveling upward enter an atmosphere of such low air density that they must go long distances before getting absorbed. Meanwhile, earthbound gamma rays encounter an atmosphere of increas-

COMPONENTS SUSCEPTIBLE TO EMP EFFECTS

Components Highly Susceptible to Damage
microwave semi-conductor diodes
field effect transistors
audio transistors
silicon or selenium rectifiers
power rectifier semi-conductor diodes
vacuum tubes

Components Highly Susceptible to Operational Malfunction
computers
computer power supplies
transistorized power supplies
semiconductor devices terminating in
  long cable runs
alarm systems
intercom systems
transistorized receivers and transmitters
transistorized converters
transistorized control systems
power systems control

Components Moderately Susceptible to Operational Malfunction
Vacuum tube equipment such as:
  transmitters
  receivers
  alarm systems
  intercoms
  teletype-telephone
  power supplies
Equipment with low current switches, relays, meters, such as:
  alarms
  power system control panels
  panel indicators
  status boards
  process controls
Other equipment:
  long power cables
  high energy storage capacitors or
  inductors

Components Least Susceptible to Operational Malfunction
High voltage 60 hertz equipment:
  transformers
  motors
  heaters
  rotary converters
  filament lamps
  heavy duty relays
  circuit breakers
  air insulated cables

HOW LIKELY IS A RAIN OF EMP?

Only a few years ago, nuclear war was depicted as the end of civilization: After the radioactive clouds settled, life as we know it was supposed to grind to a halt. No more. Today, military strategists speak in terms of surviving a nuclear volley, and civil-defense planners are concentrating on postwar recovery schemes to restore vital services and government once the nuclear exchanges cease. So long as strategists think the nation can survive a nuclear volley — perhaps even win one — the concept of nuclear warfare remains plausible. It becomes a real option, ghastly as that option may be.

Hence, a growing civilian interest in EMP. While the radioactive contamination and explosive effects of nuclear warfare could prove massive, there has conventionally been reason to believe some hinterlands would escape relatively unharmed. But "EMP removes the possibility of an unscathed 'hinterland,' and thereby potentially adds an entirely new dimension of damage," explains a 1972 study by Oak Ridge National Laboratory.

It's this aspect that makes high-altitude detonations so awesome. While the searing heat, radiation and explosion will probably obscure any EMP effects in most ground blasts, it will be the other way around with high-altitude explosions; EMP effects will dominate.

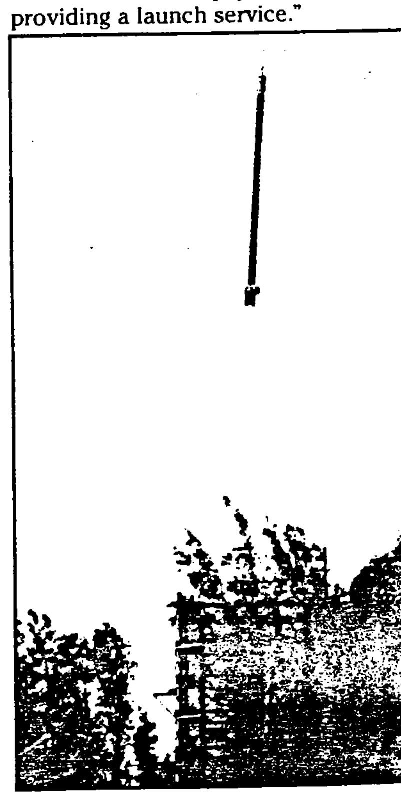
And, "In a nuclear attack, a series of high-altitude bursts is likely," notes a July 1973 report prepared by the former Defense Civil Preparedness Agency. "The source of these bursts may range from an attacker's offensive missiles detonated explicitly to produce EMP effects, to our own defensive missiles deployed to intercept offensive missiles. It seems reasonable, then, to expect dozens or perhaps hundreds of high-altitude defensive and offensive bursts spread out over a period of a few minutes or an hour."

But Bill Macklin of IRT Corp. points out that there are other possible scenarios. For instance, a small terrorist group could seek ostensibly peaceful retribution against economic threats and political aggression by unexpectedly detonating one or a series of nuclear devices in the upper atmosphere of their enemy's territory. It needn't kill anyone, but it could certainly take an enormous economic toll.

Paul Fleming of the Defense Nuclear Agency tends to discount such hypothetical scenarios, asking, "Is that a creditable terrorist action?" He suggests that it's a costly and difficult gambit with no clear payoff and adds that it may also require more technological sophistication than most poor terrorists can muster.

What worries people like Macklin, however, is the existence of firms that might sell a launch capability to anyone with money. The West German firm Otrag (Orbital Transport und Raketen Aktiengesselschaft AG), for instance, is preparing to offer just such a service and has focused its marketing on the Third World. Last month Otrag announced a fourth test of its low-cost single-stage launch vehicle from a site in Libya. A two-stage vehicle is expected to be test launched later this year, and by 1985 the company expects to be able to launch craft into orbit.

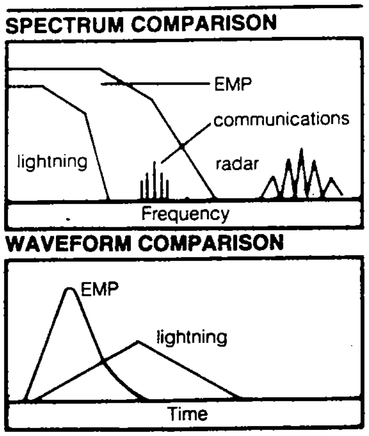
According to the March 23 AVIATION WEEK AND SPACE TECHNOLOGY, Otrag's president, Frank Wukasch, "confirmed that the test firings in Libya have led to recent charges from the government of Morocco that the revolutionary regime of Libya's Col. Muammar Qadhafi was using Otrag to acquire a capability to develop medium-range missiles." While Wukasch dismissed this assertion, NASA's Lynn Hanold told SCIENCE NEWS, "It is a fact that this company has basically said they'll launch any customer who would pay them. And there are people who are concerned they would then be open to launch something military because they're not interested in approving or passing judgment on what the payload is but just providing a launch service."

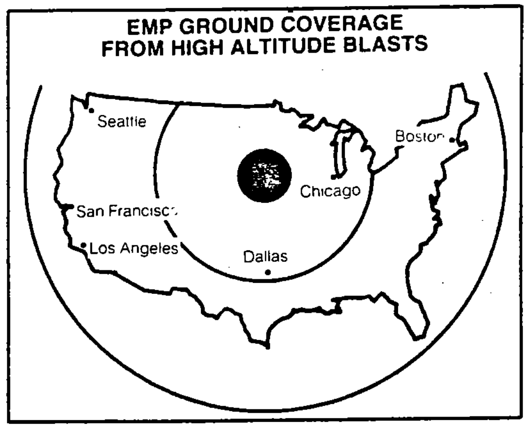


Otrag and Av. Week and Space Tech.

Otrag launch vehicle lifts off from Seba Oasis in Libya's Sahara Desert during test. Otrag hopes to have vehicles able to put satellites in orbit by 1982.

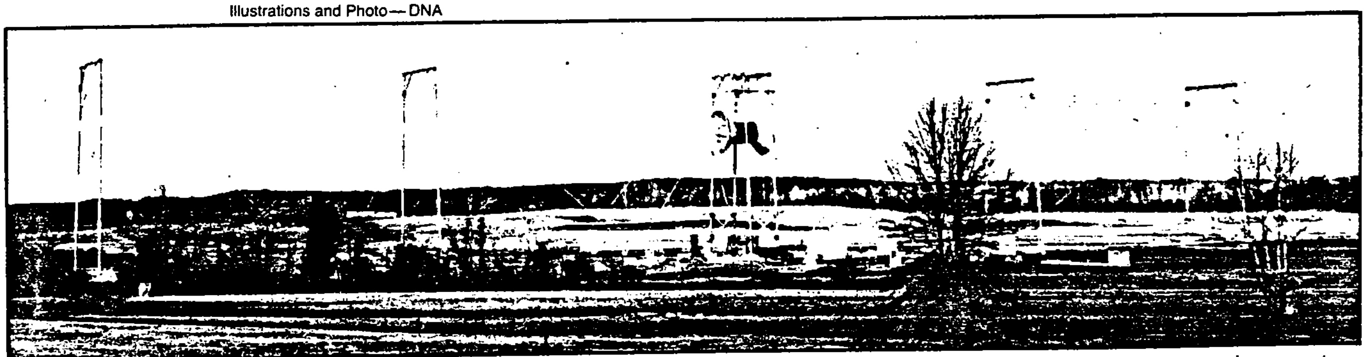
Unlike lightning, EMP delivers its energy across a broad spectrum of frequencies, including those used for broadcast communications (top). And though EMP imparts less energy than does lightning, it delivers its energy 100 times faster, usually faster than lightning arrestors can handle.





High-altitude detonations blanket wide penumbral regions on earth with EMP. Peak electromagnetic fields reach 50,000 volts per meter. Inner circle shows ground showered by EMP from blast centered above dark spot at altitude of 62 miles; outer circle shows coverage for blast 330 miles up.

Illustrations and Photo— DNA



Portable EMP simulators, like this one in Maryland, are used to test the vulnerability of components and systems in war environments.

ing density. Their inevitable interaction with air molecules sets up an EMP source region. Roughly circular, this source region may climb 50 miles in its center. Horizontally it blossoms too; how far depends on the bomb's kiloton yield and altitude at detonation.

In this EMP-generating source region, gamma rays emitted by the blast collide with air molecules, creating what are known as Compton electrons. (In 1922 Arthur Holly Compton discovered that photons such as gamma rays are able to knock electrons from orbits about the atoms to which they had been bound. The process is roughly analogous to a flying billiard ball colliding with another at rest. The recoil electron, like the initially stationary billiard ball, is generally propelled forward.) The earth's magnetic field deflects the Compton electrons, forcing them to spiral about the magnetic-field lines. "This motion causes the electrons to be subjected to a radial acceleration, which results, by a complex mechanism, in the generation of an EMP that moves down toward the earth," Glasstone and Dolan say.

The pulse crescendos to a peak, then decreases. In fact, it's the nature of this time-varying radiation to peak rapidly, then decay somewhat more slowly. Amplitude, or strength, varies widely over its broad frequency domain, which extends from about zero to 150 megahertz (million cycles per second) with 99.9 percent of the energy below 100 MHz. The rise and fall of the signal occurs more rapidly than in an equivalent-size surface burst; therefore, more of the electromagnetic energy pulsed by the high-altitude explosion falls into a higher frequency range. And for high-altitude bursts with yields of a few hundred kilotons or more, electric-field strength will vary by no more than a factor of two over most of the area showered by EMP. Maximum EMP fallout can reach 50 kilovolts per meter.

Comparing EMP with lightning illuminates some of the problems that come in designing systems to withstand a large EMP. For instance, the induction field created in association with a 100 kV/m lightning stroke is on the order of one kV/m electric field, with a high amplitude rise time peaking in one to five microseconds. In contrast, for a large, high-altitude nuclear burst, the fields radiated onto the earth's surface peak in 10 nanoseconds —roughly 100 times faster than lightning.

This fast rise time represents a double-edged sword. First, it means the spectral energy will be distributed much more broadly throughout the electromagnetic band — including the lower microwave range. Second, the rise time is so rapid that an EMP can zip through a system — destroying sensitive electronics along the way — before lightning arrestors or other defensive power-shunting switches can respond to the surge.

"In other words, EMP is sufficiently different from any other electromagnetic environment usually encountered that protection practices and components for non-EMP environments—radio-frequency interference, lightning, radar, etc. — are not directly applicable to EMP problems," explains the Defense Nuclear Agency's EMP Awareness Course Notes.

For systems whose continuous operation is deemed critical, such as military surveillance, communication and attack units, EMP protection —known in the jargon as "hardening" — becomes essential. And not surprisingly, the military has attacked the problem of hardening more aggressively than has any other industry. Just last month, at a conference in the State Department, Lt. Gen. Paul Gorman, policy and planning director for the Joint Chiefs of Staff, announced that "hardening our [communications, command, control and intelligence systems] against electromagnetic pulse ... will be one of the major strategic undertakings of the 1980s."

The public communications and power industries have been far less ambitious, however, for a number of reasons, including the cost necessary to retrofit EMP hardening to their vast networks.

But the single most vulnerable segment of society—the electronics industry—has to date largely been overlooked in terms of assessing the degree to which its products are increasing the nation's vulnerability to EMP. However, IRT Corp. has begun a rough survey of the computer's role in society with an eye toward generalizing just that. And based on preliminary data, Macklin says, "We're awed by it." From automation of food processing to the computer control of fuel and power supplies, there could be a major civil defense threat brewing, he suggests. "And I think it's an issue that [the Federal Emergency Management Agency] should be interested in," he says. To underscore that point, he will see that FEMA gets one of the first drafts of the IRT study. ☐

Next week: EMP hardening strategies.

EMP Defensive Strategies

Strategies that 'harden' electrical and electronic systems against electromagnetic pulses may save lives during a nuclear war and permit the restoration of society afterward

BY JANET RALOFF

The second of two parts

If the detonation of a high-yield nuclear weapon in the United States' upper atmosphere showered the nation with an electromagnetic pulse (EMP), how would American technology stand up? It's a question that can't be answered with any certainty today because the electronics revolution in the computerization of America is introducing an increasing EMP vulnerability to all segments of society. And that worries a multitude of defense planners.

EMP is a powerful and potentially devastating form of electromagnetic "fallout" associated with nuclear weapons (SN: 5/9/81, p. 300) and other major explosive bursts. Unlike radioactive fallout, this rain is believed harmless to living things but potentially lethal to electronics and electrical systems. It wreaks its havoc by inducing staggeringly large and rapid current or voltage surges through electrically conducting materials. And because nuclear weapons generate the most virulent form, it's not surprising that study of the phenomenon was cloaked in secrecy until the mid 1960s.

During the early 1960s, "it was so classified that if you said EMP out loud," jokes James Kerr, "you probably had to have your mouth washed out with secret lotion." Kerr, who is staff director for the Federal Emergency Management Agency's Technological Hazards Mitigation Division, said he was unable to study the effects of EMP on civil systems for his agency's federal predecessor in 1965 "because it was so classified." His goal had been the development of a guide for the protection of civilian systems and industrial facilities against wartime EMP. Kerr's guide eventually made its debut, eight years later.

What has been its impact? According to Mike King, an EMP-shielding analyst who until last July worked at the Defense Nuclear Agency in Washington, "I think, basically, that civilian industry per se has totally no regard for EMP. I guess their theory is, 'Hell, if we're going to be under a nuclear attack, why am I worried about my computer file?'" SCIENCE NEWS confirmed in interviews with several industrialists that that view is one being used to justify ignoring the hardening — or protection — of equipment against EMP within the electric power industry.

In a paper issued last December, FEMA's Russell Clanahan attempts to counter such attitudes. "Much of the destructiveness of a nuclear attack, in lives and property lost, depends on the unpreparedness of the one attacked. In a sense, ... the unwillingness to confront the situation and prepare becomes a self-fulfilling prophecy."

Perhaps if EMP protection were relatively inexpensive, there would be less resistance to hardening. But there is "a pretty impressive price tag" associated with hardening, notes Bill Macklin of IRT Corp. (a firm that has specialized in EMP work for the military). Estimates vary, but it could cost at least an extra 15 to 20 percent to build EMP protection into a new facility. And the higher cost would go not so much for added or more expensive equipment, explains Ralph Sinnott, an electronics engineer with FEMA, as for "seeing that tradesmen do the construction differently." EMP-hardening an existing facility can be notably more expensive.

Perhaps the largest controversy in EMP-hardening — one Macklin describes as being almost "theological" in nature — has developed in response to the tackling of these potentially expensive retrofit cases. At issue is whether to shield all vulnerable components in a metal box, generically known as a Faraday cage, or whether to seek out and selectively shield only the most vulnerable components.

It may not sound like a big deal, but Macklin says that while the latter, tailored approach could involve more design analysis, it could also cost "almost an order of magnitude less" than installing a Faraday cage. That becomes an attractive selling point when the economy is undergoing a fiscal belt-tightening. In addition, tailoring in smaller, selective changes to an existing system usually proves less disruptive to its users — for example, no workers tearing out existing walls, ceilings or floors — during the hardening phase. And that's another strong plus.

But this tailored approach "is very, very configuration-dependent," notes King, a strong advocate of total shielding. He explains that the vulnerability of a particular system or facility is so dependent on the exact layout of components and even the process used to manufacture seemingly identical parts that any changes in the originally analyzed system could render a specific tailored hardening scheme "for naught." And it has almost become the rule, not the exception, for firms to upgrade electronic systems with minor changes or additions that inexpensively increase the productivity or capability of the existing system.

But there is an even more interesting aspect to the tailored versus Faraday cage debate. "While the tailored guys all agree that the [Faraday cage] approach will work," King says, "not everybody agrees that the tailored approach will." What's more, he says, even advocates of the tailored approach think that when building a new system or facility, it will cost less to shield it in a Faraday cage. So while shielding with a Faraday cage "is not only the soundest way to go," King claims, "it turns out — and I'm doing a lot of work in this area — that it appears also to be the cheapest way to go over the life-cycle" of a system.

Debate over the topic is so intense and vital to issues of cost and hardening effectiveness that the Defense Nuclear Agency will convene a big working symposium on the issue in a few months.

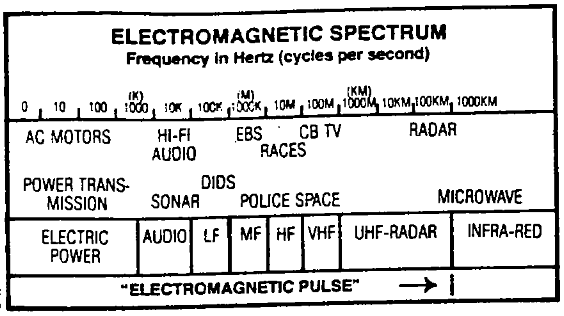
One issue on which there is seemingly no argument is that technology now exists to EMP-harden any vulnerable system.

But just because something uses electronic parts doesn't mean that the system is vulnerable. And an impressive survey to narrow down when and why something is vulnerable has been conducted over the past 25 years, largely with Defense Department funding. Many of those studies are still classified, although their results are pouring into the open literature.

For instance, communications equipment using bipolar transistors with self-contained batteries and loop antennas are not susceptible to direct EMP damage. Similar equipment using stick antennas up to 40 inches long is also safe. However, electronic equipment using field-effect transistors could be damaged if the connected antenna is more than 30 inches long. The general implication of these studies, notes the Defense Department in one of its attack-environment manuals, is that mobile communications equipment — including walkie-talkies and the common transistor radio — are relatively survivable in an EMP environment. But radio-transmitting stations will be vulnerable unless expressly hardened for EMP.

"It sort of boiled down to," says Kerr, "if there's no antenna, there's no problem." For example, computers are one of the most vulnerable systems to EMP. But a computer "is not much more vulnerable than a piece of marble," unless and until it's attached to an antenna, the FEMA research director said. And every metal object represents a potential antenna to collect radiated EMP signals and focus them into more massive ones.

That's one reason why FEMA has elected to EMP-harden radio-broadcast stations throughout the nation. Televisions, with their large rooftop antennas and power cords, are prime candidates for EMP damage. But transistor radios aren't, and it has been estimated that 80 percent of the population has access to them. So if, and when, the Emergency Broadcast System is called into use for warning the public about a nuclear attack, an EMP-hardened network of AM and FM radio stations could



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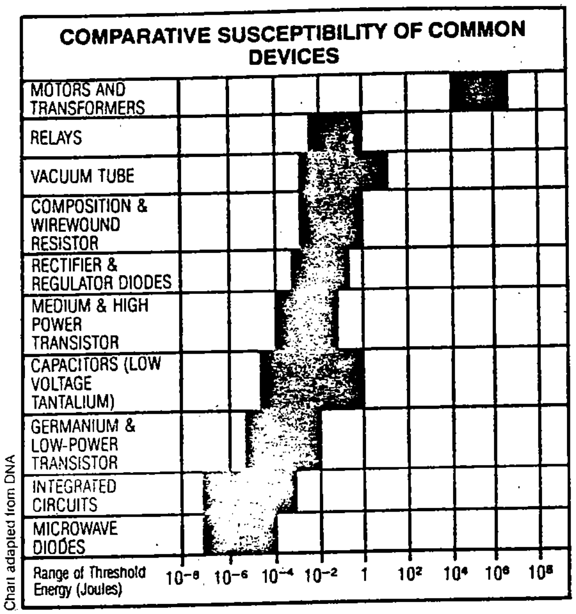
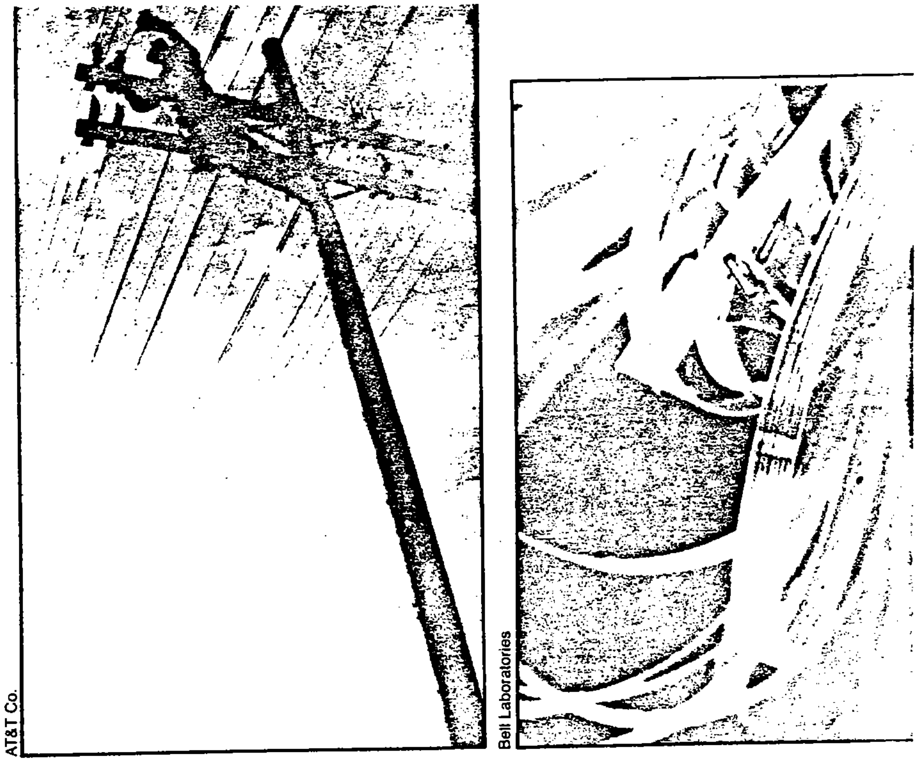


Chart adapted from DNA



Aerial lines of conventional telephone systems (above left) make good antennas for picking up EMP surges, and the equipment connected to them is vulnerable to interruption by EMP's. Fiber optics (above right), which are coming into use for communications, do not contain the electric and electronic components susceptible to this kind of surge, and so are invulnerable.

within 10 to 15 minutes broadcast the President or local leaders nationally.

Already FEMA has EMP-hardened 150 to 200 of the 600 radio stations it has targeted to make up its voluntary emergency broadcast network, Sinnott told SCIENCE NEWS. However, since the stations with the biggest broadcast coverage were hardened first, roughly half of the nation is already within earshot of an EMP-hardened station. Completion of the network is expected within three to five years.

Sinnott says that the EBS-network stations will be equipped with backup power-supply systems, usually diesel generators, and fueled to last several weeks. And the anticipated need for that backup electrical power points to what is perceived as potentially one of the least prepared of the nation's industries.

If a high-altitude nuclear blast bathed the nation in EMP, "my gut feeling is…our power systems would probably not be available," says King, whose former employer, the Defense Nuclear Agency, maintains a more than passing interest in that subject. DNA has run "EMP awareness courses" for electric-utility executives and engineers. Still there appears to be a widespread prevailing attitude that lightning arrestors used throughout that industry are more than adequate to tackle the energy delivered by a nuclear EMP.

That's true, concedes King: "Some of the lightning arrestors are more than capable of handling the energy; but they are not fast enough." He explains, as do countless reports and manuals printed by FEMA over the past decade, that a lightning arrestor has to be quick enough to respond to a pulse. The devices—which short out circuits leading into sensitive power-controlled equipment—are designed to handle lightning pulses, which King points out are about three orders of magnitude slower in their rise times than EMP. The result is that an EMP can flash through the circuit, wreaking havoc, long before the circuit can short. While some studies suggest equipment damage could occur, the most likely result of an EMP exposure would be to trip circuit breakers across the nation. Companies with insufficient electric-load-shedding capabilities would be forced to shut generating stations down. "And you're talking 12 to 24 hours to get them back on line," King says. "That's not a damage situation, it's a functional upset. But the effect is the same."

And the net effect is that much if not most of the U. S. power grid would be shut down for hours to days, depending on the frequency with which successive EMP pulses arrived.

"It is necessary to distinguish a rather striking contrast between civil and military approaches" to coping with potential EMP disruptions, explains a 1975 Defense Department study, *Electromagnetic Pulse and Civil Preparedness*. "While the nearly universal military approach has been to harden systems of interest, this is not a feasible civil measure." Military attack and communications systems cannot afford to shut down, even momentarily, during attack periods, whereas "[c]ivil preparedness systems can afford to be out of action for periods running from minutes to days." So while some attempt has been made to harden civil systems, such as the Emergency Broadcast Network, another common strategy has been to analyze likely damage should an EMP occur and then to develop contingency plans to cope. These plans could include storing spare parts that would most likely need to be replaced or simply compiling directions for manually taking over formerly automated activities until repairs can be made.

A number of critics worry, however, that the electric-power industry has been too complacent about the threat of its potential vulnerability to take even these measures. And while the military has aggressively sought to EMP-harden its most important facilities and weapons over the past 15 years, it is quite dependent on several civil systems that appear potentially still quite vulnerable to EMP—notably the nation's electric-power and telecommunications industries. As one EMP analyst points out — in the event of war, these military dependencies on non-EMP-hardened networks could prove an Achilles heel to national defense. ☰

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