

Civil defense in limited war—

Have recent developments in strategic weapons given us reason to look at civil defense in a new context?

Civil defense, once a hotly debated issue of the 1960's, has again surfaced as a topic of controversy. It reappears amid the discussions of possible new strategies being proposed by the Defense Department. In January 1974, the then Secretary of Defense James R. Schlesinger announced the intention of the US to develop long-range ballistic missiles of unprecedented accuracy. Because such weapons would have a relatively small error radius their yield would not have to be as large to be effective against military targets such as land-based offensive missiles. Hence the Defense Department has raised the possibility of a limited nuclear war with counterforce strikes (that is, against the opponent's offensive force) coupled with a program of civil defense to ensure a minimal level of civilian casualties.

We present here two different viewpoints regarding civil defense in this context. Arthur Broyles and Eugene Wigner will argue that civil defense can be effective as a defense against a nuclear attack. Sidney Drell will argue that the price of civil defense is too high in relation to the degree of protection it buys.

a debate

In favor:

Arthur A. Broyles and Eugene P. Wigner

Should the American people be protected from the effects of nuclear war? Let us first narrow that intensely studied question¹ to one that lies within the realm of physics to answer—namely, can such protection be effective? Evaluations of various evacuation and shelter systems show that they can greatly reduce the number of casualties in a nuclear encounter. Our response thus agrees entirely with the statement by V. Chuykov in the *Civil Defense Handbook* of the USSR: "Although the discussed means of destruction are called mass means, with knowledge and skillful use of modern protective measures, they will not destroy masses of people, but only those who neglect the study, mastery and use of these measures."²

The question then broadens into one with psychological and political aspects and cannot be answered precisely or completely. Nevertheless we feel that our nation's civil-defense preparations may determine the balance of power in some future nuclear crisis. Civil defense is more important than ever at a time when other nations have extensive civil-defense plans and when the balance of terror that has reigned to date is being upset by the development of new types of weapons.

The protective measures against nuclear explosions and their effectiveness can be evaluated on the basis of a wealth of data gathered by the Atomic Energy Commission in its nuclear testing program. Besides making quantitative measurements of such phenomena as blast-wave pressures, fallout intensity patterns and heat-ray intensities, the AEC constructed buildings and other structures in the vicinity of nuclear explosions and observed the resulting damage.³ This information has been used by the AEC (now ERDA) laboratories, Stanford Research Institute, RAND Corporation, the Hudson Institute, the National Research Council and other institutions to devise and determine the effectiveness of methods for protecting people. Their results are in surprisingly close agreement.

Unfortunately the general public is not well informed about such studies, probably because a large fraction of the physics community as a whole is not aware of them. And yet so much physics is involved that physicists bear a responsibility to understand it themselves and to pass on the information through the classroom and other contacts. A clear presentation of the facts is essential because it is possible, as we shall see, that a nation's civil-defense preparedness may determine the balance of power in some future nuclear crisis.

continued on next page

Opposed:

Sidney D. Drell

The strategic doctrine of "limited nuclear counterforce strikes" has been revived in the United States during the past few years. This return to a policy that was discarded more than a decade ago is accompanied by a renewed interest in extensive and organized civil-defense programs, which would require massive relocation and evacuation of populations during crises. Official government statements during the past two years allege that this combination offers the prospect of low levels of fatalities and casualties resulting from the immediate blast, thermal, radiation and subsequent radioactive fallout effects. In particular the former Secretary of Defense, James R. Schlesinger, in the Annual Defense Department Report for FY 1976 stated that "Relocation of the population from high risk areas near key military installations and the protection of the rest of the population against fallout could reduce nationwide fatalities due to fallout from a limited Soviet counterforce attack to relatively low levels well under 1 million—provided that the people in the communities that would be most exposed by fallout from such an attack make effective use of the shelters available."

The conclusion drawn from these claims and analyses is that limited nuclear war may be palatable and need not escalate to the level of an all-out nuclear exchange, which would cause unimaginable horror. In fact, on 11 September 1974, Secretary Schlesinger testified⁴ to a subcommittee of the US Senate Committee on Foreign Relations that "the likelihood of limited nuclear attacks cannot be challenged on the assumption that massive civilian fatalities and injuries would result."

Because the basis for this change in strategic doctrine is the relatively low fatality level, we must examine not only the total civil-defense implications of this doctrine but also the assumptions about the nature and effectiveness of the weapons used in the attack.

Civil defense in the larger context of an all-out nuclear strike against population centers will not concern us here, not only because it is not being proposed at present but also because most who have studied the financial and societal costs, not to mention the technical challenges, of such a program have concluded that it is not practical. But how practical and how effective is civil defense in a limited counterforce context?

The resurgence of the doctrine of limited nuclear counterforce has been spurred by progress in weapons technology—in particular, the development of accurate and reliable

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The principal sources of danger and the most effective measures against them are listed in the table on this page. (Of course a far more convincing display of the data requires something like the elaborate descriptions in the USSR handbook.) Because of the short time available for action to protect against effects of nuclear weapons, survival depends very heavily on previous planning and preparation. The effectiveness of all the protective measures would be much increased if the population were familiar with them well before the attack. The stockpiling of relatively simple tools can also help in the long-term recovery effort. Because this subject is complicated and requires extensive considerations, we shall limit our discussion to the problems of survival of the initial effects of the attack that are listed in the table.

The most obvious way of protecting against all these effects is to prevent the bombs from exploding. For example, the US might attack the enemy launch site before the missile leaves it. Such

an attack is the purpose of the "smart bombs" bemoaned by Bernard T. Feld in the July 1975 issue of PHYSICS TODAY. Or, the US might destroy the incoming missile with its own missile—the Anti-Ballistic Missile. Despite extensive debate over the ABM, it cannot be generally implemented now. As a result of the SALT I treaty, the ABM is restricted, as far as nonmilitary defense is concerned, to Moscow (with a population of 4.5 million) and Washington, D.C. (population of 1.5 million). Nevertheless, even a small ABM system could be very effective. By destroying the first wave of incoming missiles, it can give time to the people to enter shelters or to protect themselves in other, although less effective, ways.

Once a bomb does strike, the first effect is the electromagnetic pulse. This pulse threatens electric power transmission rather than human lives, although the disruption of radio transmission is of concern during an emergency.

The protection against the other effects of nuclear explosions can be pro-

vided in two ways—evacuation and shelter. Evacuation takes very much longer than the missile flight time and hence can not be considered to be a truly defensive measure. If evacuation is undertaken during a crisis, it will greatly aggravate the situation. It can be effected before provoking a showdown and serve as an aggressive move. Hence, since the advent of missiles, our country did not seriously propose it until the elaborate evacuation preparations of the USSR became known. Now it is being seriously planned as a "counterevacuation," that is, as a response to a possible evacuation of the cities of the USSR. The Ponast study, which was organized by the National Security Council,⁴ considered a nuclear attack in which the USSR aimed two thirds of its destructive force at civilian targets. This attack would destroy 45% of the US population under present circumstances. The preparation for the "counterevacuation" would cost about \$500 million—one day's welfare expenditure—and would reduce the popula-

H-Bomb major immediate effects

EFFECT	CAUSE	DAMAGE	DEFENSE
ELECTROMAGNETIC PULSE	Expanding charged particles from bomb explosion	Damage to electronic equipment up to hundreds of miles; power stations at shorter ranges	Special protective equipment related to lightning security devices; no effects on humans
PROMPT NUCLEAR RADIATION	Nuclear reactions during bomb explosion	Normally less than blast	(Normally negligible compared to blast)
HEAT RADIATION	Radiation from the hot fireball generated by the explosion	Fires ignited a few tens of miles but greatly reduced by clouds or smog and dampness	Eliminating exposed inflammable material; shelters including large public buildings
BLAST WAVE	Expansion of hot bomb material pushes air into a wave of wind and high pressure	Destruction of buildings as well as serious injuries to people from flying objects and falling buildings from five to ten miles	Evacuation blast shelters; reinforced public buildings
FALLOUT	Radioactive products of nuclear fission mixed with vaporized earth	Heavily wind dependent; can be the order of one hundred miles	Sheltering by large public buildings or special shelters for a few days or weeks until the radiation level has died down



Peking tunnel shelters double as storage vaults for vegetables (left) or as conference halls (right). The authors argue that such shelters can



be effective in reducing US casualties in the event of a nuclear attack to about 5.5 % of the total population. Figure 1

tion loss to 11%. Because the USSR population is less crowded into cities than ours, their losses would be smaller yet—less than 5% according to our calculations.⁵ This loss is half of that experienced by the Soviets in World War II.

Shelter design

The defense measure advocated in the US, and installed by the Chinese, is the provision of shelters. The technical problem is to design a shelter with maximum blast resistance, minimum access time and minimum cost. The Chinese appear to have conquered the problem, as shown in figure 1. US scientists, during a 1970 study at the Oak Ridge Civil Defense Project,⁶ estimated that effective shelters could be built at a cost of \$23 billion. In similar conclusions four years later, the Ponast study found that a \$35-billion investment—very much larger than that needed for preparation for counterevacuation and one tenth of one year's federal expenditures—would reduce the casualties caused by an attack by the USSR to 5.5%.⁴ For this reason we can not possibly accept Feld's conclusion in *PHYSICS TODAY* that "there is no defense against nuclear weapons, now or in the foreseeable future." Actually, as we have just described, the effectiveness of shelters should not be surprising: If shelters were ineffective, the expenditure on their construction by the government of China, the government of a nation much poorer than ours, would be entirely unjustifiable.

A third intermediate arrangement for

defense, also indicated already in the Soviet handbooks on civil defense,² is to move most city dwellers away from densely populated areas but not as far as the pure counterevacuation proposes. Instead, the Soviets would build "expedient shelters" using materials at hand. Rather ingenious designs, which can be built by untrained prospective occupants, give a blast resistance of 30 pounds per square inch. A sample plan is shown in figure 2. Such a system, not significantly more expensive than the simple evacuation plan (not much over \$500 million, according to the Ponast study) could reduce the fatalities as well as does the elaborate and rather expensive shelter system referred to above. However neither one can provide protection against a sudden attack.

In the design of shelters, prompt nuclear radiation can generally be ignored in comparison with the blast wave unless the blast protection is very good or the weapon is very small. The reason is that prompt-radiation effects decrease much more rapidly with distance than do blast effects. To see this, note that the blast pressure in pounds per square inch from a W kiloton explosion at a distance r in kilometers is given approximately by

$$p = \frac{1.6 W^{2/3}}{r^2}$$

The intensity of the prompt radiation decreases more rapidly than $1/r^2$ because of the absorption by air. Thus, according to the equation, blast shelters designed for 100 psi will be effective against a 1-megaton weapon for distances greater than about $1\frac{1}{4}$ km. The area within which the pressure exceeds a given amount is inversely proportional to this pressure. Thus the area where the pressure exceeds 5 psi—the pressure often considered as the survival pressure for unprotected people—

is twenty times the area for 100 psi.

The effects of blast decrease more rapidly with bomb yield than do those from prompt nuclear radiation. For very small nuclear weapons, prompt radiation can be more harmful than the blast. Thus for a 1-kiloton bomb, neutron and gamma radiation at 750 meters are 700 and 400 R if no protection is provided. The blast pressure at that distance is 5 psi—quite tolerable. Indeed the mid-lethal blast pressure for a well instructed person, who knows how to protect himself from flying objects, is well in excess of 30 psi.

Blast shelters are designed not only to diminish the air pressure to which a person is subject, but also to protect him from flying objects. A properly designed blast shelter will also place sufficient mass between a person and the outside fallout particles to shield him adequately from the radiation. One foot of earth cover reduces radiation perpendicular to it by a factor around ten, and more than that for slanting rays. Shelters also provide cover against heat radiation and external fires. Two feet of earth will provide adequate protection from actively burning fire.

Global consequences

Worldwide effects from the detonation of a nuclear explosion naturally demand as much concern as the immediate effects. Many wonder whether the global consequences such as fallout might not be so severe as to deter any nation from even precipitating an attack. The most recent investigation of this question, the Nier report by the National Academy of Sciences,⁷ verified previous conclusions that world-wide fallout produced in a nuclear attack would not be sufficient to deter the attack. It found, however, that the de-

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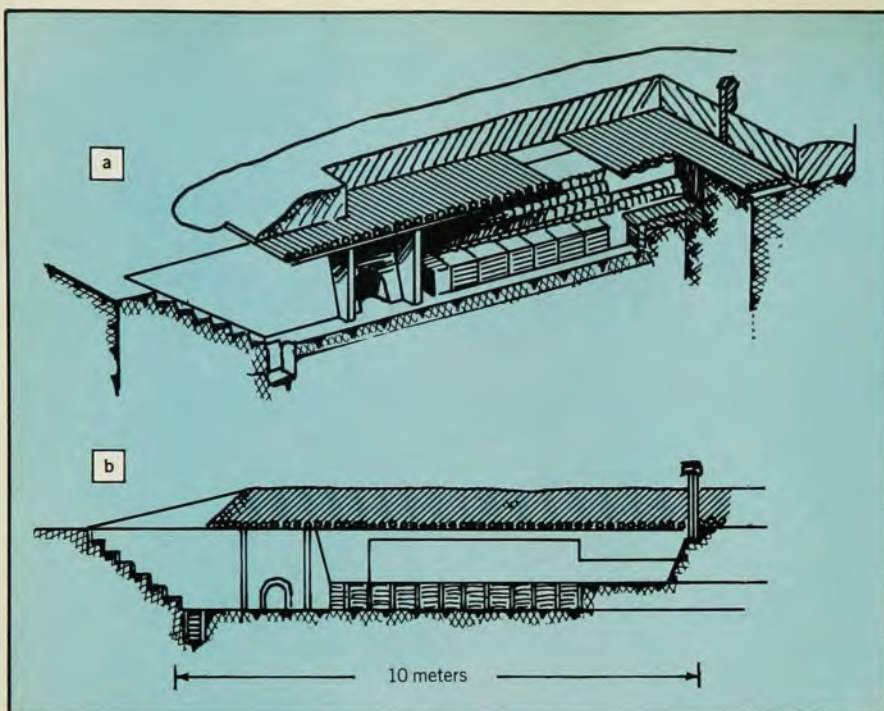
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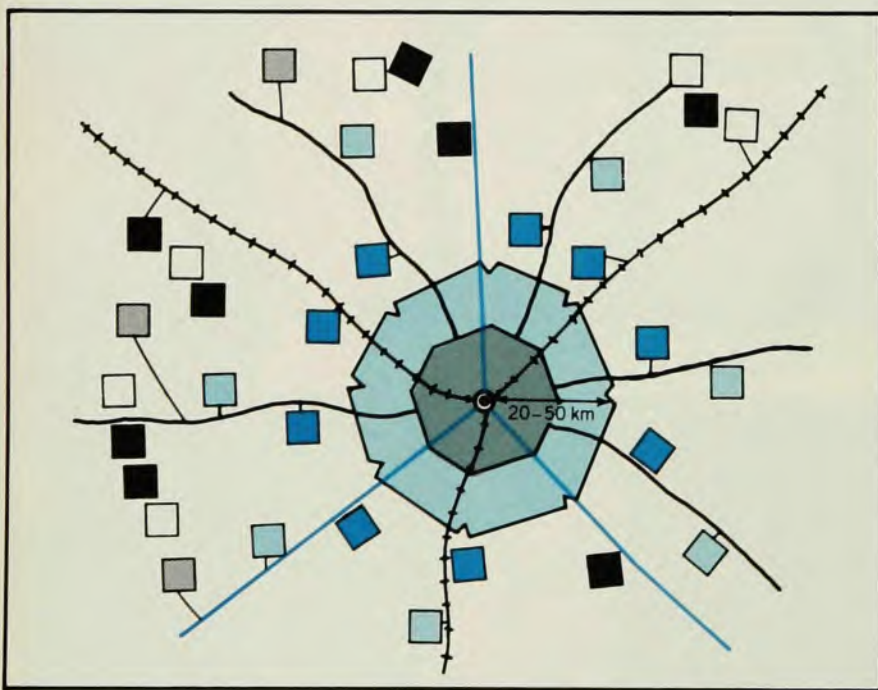
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Hasty shelter plan of the Soviets is a dugout in dense soil with a ceiling of pine poles. The plan shows the general view (a) and cross section (b). From reference 2. Figure 2



Soviet evacuation scheme illustrates their detailed planning. Safe zone is outside light colored region surrounding populated district of city (dark color). Map shows districts for relocation of workers of plants that do not stop their operation (dark colored squares) and for those that temporarily suspend operation (light color). Also shown are relocation sites for evacuees (light gray) and for plants and organizations (open squares). Black squares are existing communities. Colored lines denote operational control limits. Figure 3

pletion of the ozone layer could be more serious. Increased radiation might force people to adopt special protection against sunburn, and it would lead to an increase in the skin-cancer rate by a factor of almost two. The depletion of ozone would also upset some ecological

systems in important ways. Although this study calls for additional research to answer some remaining questions regarding world-wide effects, Philip Handler, President of the National Academy, makes the following statement in his letter accompanying the Nier report:

"At the same time, the governments of the United States and of other major nuclear powers should be alert to the possibility that a geographically distant, populous other nation might determine that the degree of short-term damage to itself in this report, would be 'acceptable' and that, since long-term recovery would be highly likely, might conclude that its own self-interest is compatible with a major nuclear exchange between other powers."

In other words, we cannot count on global effects in themselves as deterrents.

Even though civil-defense measures can be effective as population protection, the US lags behind many nations of the world in building such systems. The Chinese have installed extensive blast shelter systems; the Russians have preferred an evacuation procedure that removes the city population to outlying areas where hasty shelters are to be constructed from materials at hand. A sample evacuation plan from the USSR handbook is shown in figure 3. Admittedly, this system would lose effectiveness if another nation initiated the war: It takes two or three days to evacuate cities and to build emergency shelters. However, if such time is available, the USSR system is cheaper and probably more effective than the Chinese blast shelters. The Chinese, however, can occupy their shelters in a very short time and thus be prepared for an attack with very little warning. Evidently the Chinese are afraid that someone will attack them with little notice, while the Russians believe that they are in a position to determine when the nuclear exchange will come and that they can carry out their evacuation and construction in time.

Political aspects

The United States, on the other hand, has essentially no civil-defense system. This lack is deliberate, and the reasoning behind it is clearly evident in the hearings before Congress on military matters.^{8,9} Our leaders recognize that, if the nuclear powers have the capability of destroying the opposing nuclear attack forces, they will be tempted to strike first. If they wait, their own weapons may be destroyed first and they would be defenseless. Thus the US, until quite recently, carefully designed its nuclear strike force to be effective against the population of an opponent but ineffective against his weapons. We also did not protect our people. This inaction assured him that we would not attack first and therefore, that he need not strike a preventive blow.

The trouble with our strategy was that the Soviets, and more recently the Chinese, have not accepted this "balance of terror." The Soviets' large mis-

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siles are effective against our land-based missiles and their killer submarines can attack our Polaris submarines. In addition, our population is so exposed that it is doubtful we would accept the casualties required to participate in any stage of nuclear war through a second, third, or any strike with our missiles. Perhaps such considerations led Secretary of Defense James R. Schlesinger to propose the addition to our arsenal of missiles that would be effective against sheltered enemy

ICBM's.⁸ However we are disappointed that Washington has not given strong support for measures that will protect the US population from the effects of a nuclear war.

As a final remark we wish to add that it disturbs us greatly that passionate opponents of the protection of our own civilians against nuclear attack do not oppose, and do not even mention, the elaborate preparations of the USSR in this direction. The Soviet handbook on civil defense is circulated in millions of

copies. (It has been carefully studied at the Oak Ridge National Laboratory.) The USSR gives instruction on civil defense in the high schools, they carry out exercises in their factories and, most distressingly, they have made elaborate preparation to evacuate their cities preceding a confrontation. If the opponents of the civil defense feel that these preparation are not even worth mentioning, why do they consider the protection of our own civilians objectionable and even provocative?

Drell: continued from page 45

MIRV's (multiple independently targetable reentry vehicles), which enable a single missile to attack several different targets with high accuracy. These MIRV's can selectively attack hardened military targets such as underground silos containing the fixed land-based ICBM forces and at the same time can cause relatively low casualty levels. Indeed this combination of factors forms the basis for the military value and strategic credibility that are claimed for such an attack.

Of course the effect of weapons against both military targets and civilians depends critically on such factors as the numbers and yields of incoming warheads, their height of burst and the level and extent of civil-defense protection. One example described by Secretary Schlesinger in his Senate testimony envisioned an attack against all the fixed ICBM's—1000 Minutemen and 54 Titan missiles—with a single one-megaton warhead incident on each silo and with the warhead fuzed to detonate in air at the optimum height of burst. The attack would result, he claimed, in fewer than 800 000 dead and 800 000 injured or ill from radioactive fallout.

The fatality levels for such an attack are calculated by making certain assumptions about the civil-defense protection provided in terms of the protection factors of various shelters. These numbers are the reciprocals of the fraction of radiation that penetrates the shelter. Thus the existing civil-defense program requires that, for a shelter space to be identified as such and stocked, it must have a protection factor of 50–100. That is, it must shield against all but 1–2% of the radioactive fallout. This factor is equivalent to a dirt cover of approximately two feet or a concrete wall of about 16 inches. By

comparison,³ a single-story residence has a protection factor of three, and a residential basement, a factor of 25.

In the attack described by the Secretary, the Department of Defense assumed that for 30 days roughly 35% of the US population remained in designated shelters with protection factors of 50–100, that 20% sought residential-basement protection and that the remaining 45% were protected by the average residential protection factor of 3. These calculations were stopped after this thirty-day period and thus do not include the final 6% of the fallout nor the long-range effects.

However, the Secretary did not describe the military effects of this attack, which was designed to cause such low civilian casualty levels. Straightforward calculations show that the nuclear attack assumed in the above calculations would destroy well under one half of our fixed ICBM force if carried out by missiles with the targeting accuracies projected for the Soviet ICBM force. This conclusion follows even if we assume that the Soviet missile systems have a perfect 100% reliability, which is surely a gross overestimate, particularly when you recall that we are talking of a massive attack coordinated in time so that all 1054 US ICBM silos are hit essentially simultaneously. I can see no practical military value to such an attack. On the contrary it would surely invite lethal retaliation.

In response to these and other DOD calculations on collateral civilian damage related to counterforce attacks, the Senate Foreign Relations Committee in September 1974 asked Congress's Office of Technology Assessment to review the DOD analyses. A panel convened by OTA for this purpose raised questions about the sensitivity of the DOD analyses to various assumptions, including a range of possible weather conditions, civilian protection factors and parameters of the incoming attack.⁸ The DOD responded with more calculations, which showed that the expected fatalities are indeed very sensitive to the nature of

the attack and can vary by large factors. In particular, the DOD now finds that fatalities in the range of 10 to 20 million will result from prompt effects and fallout alone if the attack is delivered by the nuclear weaponry of today or of the near future and is designed to destroy the majority of the attacked ICBM force.⁸ Figure 1, which is based on DOD calculations, illustrates the fatalities as a function of the percentage of ICBM silos destroyed. (Note that the DOD reduced the civil-defense protection factors assumed for the last two attacks by 25% relative to that described earlier; otherwise, with identical protection factors, one would expect the one-megaton ground burst to cause more fatalities than two 550-kiloton bursts—one in air and one on the ground.) Even at the highest level in figure 1 a healthy retaliatory force of some 210 ICBM's would remain as well as all the SAC bombers and missile submarines.

Naturally the predictions of figure 1 are subject to such uncertainties as the weather and winds at the time of attack, and are sensitive to the degree of civil-defense protection and to the ability to provide medical care to the ill or injured. Nevertheless, one can clearly not contemplate an effective strategic attack designed to decimate our ICBM force in terms of casualty levels of one million civilians, but rather must consider it in terms of upwards of tens of millions, even assuming extensive protection of the population.

The price of civil defense

The most recent DOD reports also make clear that civil defense would be a central element of our policy of flexible response, with emphasis on limited nuclear counterforce. Indeed the justification for the civil-defense budget was expressed in the report for FY 1976 largely in terms of its role as a necessary adjunct of our policy emphasis on flexible response. The DOD report also argues that we must have the same population-evacuation options as the Soviet Union for two reasons:

Sidney D. Drell is deputy director of the Stanford Linear Accelerator Center. This text is adapted from his testimony presented on 18 September 1975 to the Subcommittee on Arms Control, International Law and Organization of the US Senate Foreign Relations Committee.

- ▶ "to be able to respond in kind if the Soviet Union attempts to intimidate us in time of crisis by evacuating population from its cities," and
- ▶ "to reduce fatalities if an attack on our cities appears imminent."

This position marks a major shift in emphasis of the civil-defense program since the 1974 Annual DOD Report, when it was largely justified by Secretary of Defense Elliott Richardson to help recovery from peacetime disasters. I personally endorse this previous objective and furthermore I support the existing program of identifying and stocking shelters as a prudent insurance program against a wide range of incidents, including the accidental launch of nuclear weapons, a severe nuclear-reactor accident or natural disasters such as hurricanes. However, a comprehensive civil-defense program involving both sheltering and evacuating the population on a very large scale is a different thing. Undoubtedly it can be demonstrated to have a great lifesaving potential in the event of a nuclear attack against specific military targets. But the issue is in essence an issue of the price one has to pay for a civil-defense program in relation to the degree of protection one buys against specified attacks: What price in our priorities, values and style as a society? What price in dollar costs?

Investment in a civil-defense program could, as one function, protect the population from the blast, thermal and radiation effects in the immediate vicinity of a nuclear explosion—roughly within a radius of four miles for a blast of one megaton. Such protection against the close-in effects is either impossible or tremendously costly.

Another function of civil defense is to reduce casualties from fallout generated at distances well beyond several miles. This effect of dangerous fallout levels, extending many hundreds of miles downwind from nuclear explosions, plus the long-range effects of radioactive contamination to extensive areas, differentiates nuclear war from all other previous experience. The range and extent of the threat to life of radioactive fallout depends critically on many factors including the height of burst (that is, whether or not the fireball from an explosion near Earth's surface scoops up and spreads an enormous cloud of radioactive debris); the fraction of fission yield in the bomb design and the weather.

The biological effect of fallout is measured in terms of the standard dosage unit of the roentgen-equivalent mammal (the rem). Whole-body exposures to less than 100 rems cause blood changes but no disabling illness. Experience following the Hiroshima and Nagasaki blasts shows that doses of 100 to 200 rems cause a certain amount of ill-

ness including fatigue and perhaps some nausea, but are rarely fatal. However, levels of about 450 rems of whole-body exposure can cause severe illness and produce a 50% fatality rate. This scale is the basis for assessing how much protection must be provided for an effective civil defense. As is shown in figure 2, an unsheltered person as far away as several thousand miles downwind from an attacked missile field or military base would be exposed to an expected 600 rems.

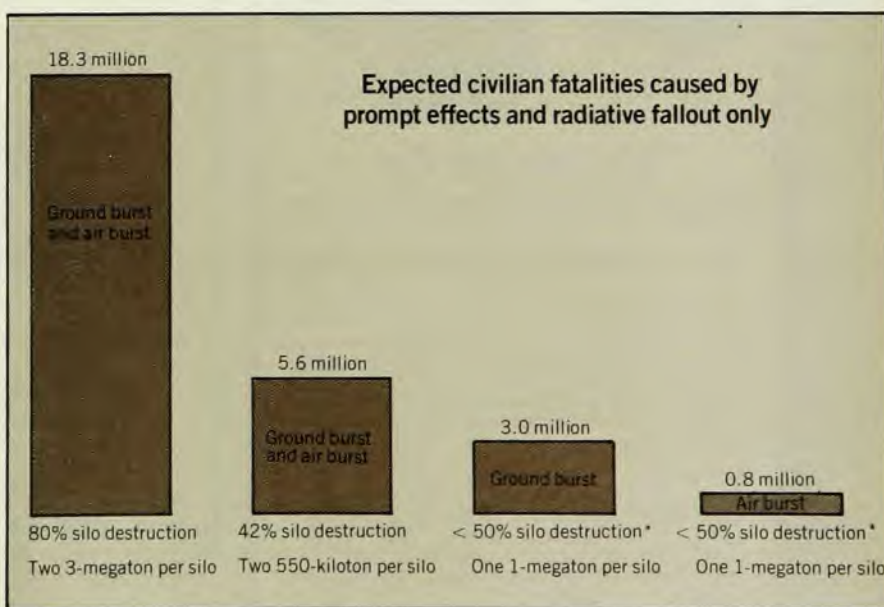
The time scale of the radioactive fallout is also of great importance in considering protection. For how long a period of time after an explosion must one be sheltered from fallout in order to survive? For typical burst altitudes in the atmosphere a human body totally and completely shielded from fallout during the first hour immediately following a nuclear explosion will still receive 45%, or almost half, of the total fallout if exposed thereafter. Twenty percent of the total dose is deposited after the first day, and a person emerging after four weeks of complete protection from fallout will still be subject to 6% of the total dosage. The decrease in rate of fallout follows a $1/T^{1.2}$ law, and evidently the required time scale for protection is measured in weeks.

This discussion of fallout effects shows the required physical parameters of civil-defense shelters. Few dispute the technical facts concerning the means to protect large populations for one to four weeks after an attack from the physical effects of blast, fire, radiation and fallout. However, major social parameters and costs are also involved because identified shelter spaces and

evacuation plans do not by themselves make an effective civil-defense program, in my judgment. A total system must be organized and interwoven extensively into civilian life through training programs, rehearsals, and volunteer activities. The pre-attack shelter organization envisioned by the 1962 Office of Civil Defense Guide planned that a shelter accommodating 100 civilians would require an operating cadre of 25, of which 10–12 would need prior training. This number constitutes 10% of the sheltered or 20% of the adult population.

To recruit the required large cadre of trained personnel the government would have to look beyond existing community safety personnel such as policemen and firemen. Perhaps the military reservists and National Guard units could play a central role in organization and training, but they would still have to rely on a large functioning organization involving a much larger number of trained civilians.

One task of trained personnel would be to operate communications systems over large distances in order to deal with shortages of food, water and medical supplies. They would also have to know how to use radiation dosimeters, because in the immediate post-attack period the fallout levels can vary greatly from one locale to another. Like the snow, radioactive debris accumulates where driven, depending on wind and weather conditions as well as on the location and shadows of tall buildings. Local pockets of relative safety may exist amid areas with lethal levels of radioactivity. Finally the trained cadre would have to provide leadership in the



Casualty toll varies with the type of nuclear attack, among other parameters. All the calculations were done by the DOD in its analysis "Sensitivity of Collateral Damage Calculations to Limited Nuclear Scenarios," sent to the Senate Foreign Relations Committee on 11 July 1975, except for the two with asterisks, which are by the author.

Figure 1

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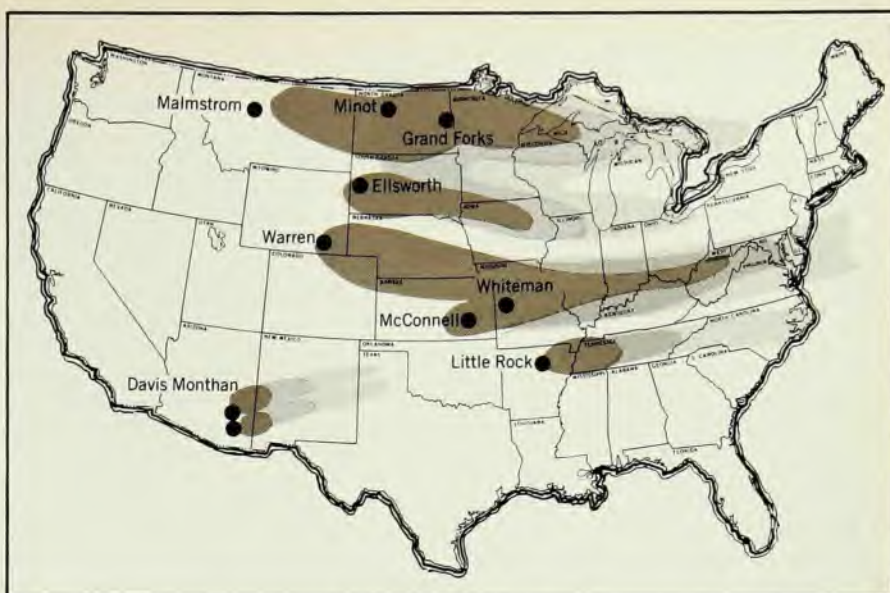
long period of extreme social duress after the attack and would have to reestablish requisite services for a society with a large proportion of ill and injured citizens.

Beyond the training of these special leaders, the plans for massive population relocation and evacuation out of high-risk areas near the possible counterforce target system require a heightened level of public awareness and concern, and a willingness to rehearse the evacuation plans. Without them, surely a chaos spawned by panic will ensue at the time of implementation. How can one draw public attention, much less commitment, to such plans without "overselling" them by a sustained escalation of apprehensions from the mood of today *vis-a-vis* the dangers of nuclear exchange between the US and the Soviet Union? Is not such an escalation of apprehensions more to be feared than desired as the US and Soviet Union move further from the brink of a nuclear conflict due to misunderstanding, misapprehension or mistake and strive mutually at SALT for a more stable nuclear balance at lower levels of nuclear armaments? Indeed one of the lessons of the civil-defense shelter exercises in 1961 and 1962 was that the large expenditures for civil defense and the general dislocations accompanying a major shelter program could only be sold to the American public by presenting the very real threat of nuclear war.

Strategy

Consideration of civil defense as an element of strategy has been given renewed importance by the new emphasis on fighting a limited nuclear war. This policy changes our nuclear doctrine of the past decade, which has been dominated by the recognition that once a nuclear weapon is detonated on US or Soviet territory there would be substantial probability that nuclear exchanges could not be terminated before both nations were destroyed and the casualties numbered hundreds of millions. The new strategic doctrine raises the issue of whether this unpleasant "balance of terror" and mutual hostage relationship might be changed by the adoption of new tactics and the development and purchase of new weapons for fighting limited nuclear wars at acceptably low casualty levels. I believe such a policy would cause the following deleterious effects:

- ▶ **Harm to strategic stability.** The development of a new missile force designed specifically as hard-silo killers would fuel concern on both sides about the vulnerability of the fixed ICBM's to a preemptive first strike. It would emphasize the importance of striking first and could thereby destabilize a crisis situation. Furthermore the development and rehearsal of civil-defense



Fallout patterns for an attack on US ICBM silos (black dots). Two inner contours show radiation doses of 450 and 200 rems for a person with a protection factor of 3. In the lightest colored regions strontium-90 contamination exceeds 2 microcuries/meter². Data are for a winter day and will vary with wind patterns. (From R. L. Garwin, reference 8.)

Figure 2

plans involving evacuation and relocation of large populations could be viewed with alarm by an opponent as preparation for executing a first strike.

- ▶ **Harm to SALT talks.** The development and testing of the required new missiles will create pressures against quantitative reductions in the numbers of strategic forces and against such verifiable qualitative restraints as missile test-flight quotas and limits on the rate of deployment of new systems that would slow down the pace of progress in the arms race.

- ▶ **Waste of resources.** The plans justified by this year's rhetoric may materialize into the multibillion-dollar weapons systems of the next decade unless the rationale behind them is rejected.

- ▶ **Shift of values.** Implementation of an extensive civil-defense system through massive training will affect the priorities of our society and will require heightened concern about nuclear war,

which would counter the progress that has been made toward reduced international tensions.

Finally, what will prevent the eventual escalation of an initially limited nuclear war to an all-out nuclear holocaust? Once nuclear weapons are used in war at all it will be very difficult, if not impossible, to verify yields, sizes, numbers and types of the nuclear explosions on both sides. However, the one technically unambiguous fact is whether or not nuclear weapons have been used at all. Therefore it is wisest for the US to adopt as a national policy the highest possible nuclear threshold. We should maintain a gap between nuclear and non-nuclear warfare that is as clear and wide as possible, and resist the temptation to develop doctrines and civil-defense programs that understate, on dubious technical and strategic premises, the collateral damage and the casualty levels of nuclear conflict.

Broyles and Wigner reply to Drell

Our own discussion is principally concerned with the technical question of whether defense against nuclear weapons is possible. We feel that as physicists we should be able to judge the extent to which such defense is possible and we also feel that the physics community at large should have a degree of familiarity with this problem. Sidney Drell's article is less concerned with the physical problem than with the more important but less precisely ascertainable one concerning the political implications and consequences of a vigorous civil-defense effort—a subject to which only the last section of our own article

refers. Nevertheless, we would like to comment, first, on a problem of physics concerning which our opinions differ.

We differ with Drell in our estimation of the radiation danger from fallout after a reasonably long sojourn in shelter, let us say two weeks. First of all we calculate that the total radiation dose from the fallout after two weeks amounts to less than 7% of the total radiation of the fission products from 1 minute on to infinity. In addition, the radiation becomes softer as time goes on, so that it becomes easier to protect against it. More importantly, the radiation after two weeks is stretched out

over a rather long period—six months or so. Although the damage done to Man by 10% of this radiation is not reversible the damage done by the remaining 90% appears to decrease by 2½% per day. As a result, by the end of the half year, the effect of the radiation received in the early period after emergence from the shelter has decreased to 11% of its initial magnitude. Altogether, the damage caused by the radiation received after the two-week sheltering period hardly exceeds 4% of the damage that a person outside would receive in the initial two-week period. Even more importantly, because the radiation intensity after two weeks is only one thousandth of its intensity at one hour after the explosion, after two weeks the shelter can be abandoned for reasonably long periods. Thus survivors can possibly clean up surroundings or, in extreme cases, move to a less contaminated location. We conclude that the danger from the fallout radiation can be easily guarded against after a period of two weeks from the time of the explosion and that the emergence from the shelter after that period produces much less difficulty than indicated in Drell's article. We do not wish to deny, of course, that it is even better if no nuclear explosion takes place.

The second, still somewhat technical, point to which we wish to take exception is the statement that "Protection against the close-in effects (blast and heat) is either impossible or tremendously costly." The gross national product per person of China is a small fraction of ours, yet most visitors to their land return greatly impressed by the very effective and easily accessible civil-defense shelters that were proudly shown to them. More concretely, the implementation of the counter-evacuation plan would cost \$2.50 per person and the Chinese-type shelters \$175 per person (or \$35 per person per year, because their construction may take about five years). Surely, neither of these figures can be called "tremendous;" yet they would really buy each of us a great deal of security and would discourage attacks or threats of attacks—an equally important accomplishment. In fact, the Swiss civil-defense book says that the most important accomplishment of civil-defense preparations is that they will never have to be used.

On the other hand, we agree with Drell that an unlimited nuclear exchange between the USSR and the US would result in more than one million casualties on both sides. But in our opinion, we must strive for an approxi-

mately equal casualty rate—not 2 or 3% in the USSR and about 45% here. We also note that as Drell points out, the US Secretary of Defense believes that nuclear attacks on military targets may be feasible. Unfortunately the Soviet government may share this view.

Our last objection to Drell's statement is nontechnical and is in the spirit of his own article. He says "Furthermore, the development and rehearsing of civil-defense plans involving evacuation and relocation of large populations could be viewed with alarm by an opponent as preparation for executing a first strike." If that is so (and we believe it is) we do not understand the failure of his article to mention the USSR development and rehearsal of civil-defense plans involving evacuation and relocation of large populations. Evidently, he is not concerned by these plans and does not view them with alarm; he does not even think that they are worth mentioning. What he sees with alarm is that we may duplicate these efforts, that we put an end to the situation in which we may have to face an enemy who can destroy fifteen times more citizens in the US than we can destroy of his. Frankly, this current situation is what alarms us and is what we wish to terminate.

Drell replies to Broyles and Wigner

Although Arthur Broyles and Eugene Wigner frequently allege that the Soviets have extensively interwoven a civil-defense program into their society, to the best of my information no evidence exists that they have in fact exercised a civil-defense system capable of massive population relocation or evacuation. A large number of emigrés from many parts of the Soviet Union have been received in the West; had there been any widespread civil-defense rehearsals in the Soviet Union we surely would have heard about them by now. The Soviets have indeed written much on the subject and have given their population a more intensive exposure to civil defense. Apparently they have spent much more money on plans and organizations and involved small numbers of people with key skills in exercises. However, I believe that in view of the unprecedentedly large scale of the nationwide disaster we are considering, an effective civil-defense program must also include, as one of its essential components, full-scale rehearsals and survival living exercises involving the population.

Selective quotations from civil-defense manuals are not reliable guides to the effectiveness of a civil-defense program. If it were, we might cite from their manuals the removal of anti-Western polemics in the 1974 edition. We



might also cite the fact that their civil-defense manuals for 1970 and 1974 (see reference 2 for the former and ORNL-tr-2845, 1975, for the latter) contain elementary substantive errors such as the translation, from US sources,³ of miles directly to kilometers without the conversion factor of 1.6 in giving ranges of destruction from given bomb yields. Furthermore, the Soviet analysis of

minimum requirement for air supply in shelters has not changed from old manuals. Thus the US editor of the translation is led to comment, in the preface, that "The Soviet Union has not conducted mass shelter living experiments or even simulated ones as has been done in the US." The editor then comments further: "We believe that this is the most serious flaw in the whole Soviet Civil Defense planning." In my judgment, plans and manuals, on one hand, and an effective operating system, on the other, are very different things!

In referring to the Nier report Broyles and Wigner stated that it "verified previous conclusions that worldwide fallout produced in a nuclear attack would not be sufficient to deter the attack." In fact the report contains no such conclusion, nor does it address questions as to what will or will not deter war. Its task was the much more narrow one of considering the consequences of a nuclear conflict "by examining, independently, possible effects upon, respectively, the atmosphere and climate, natural terrestrial ecosystems, agriculture and animal husbandry, the aquatic environment and both somatic and genetic effects upon humans," as remarked by Handler in his letter of transmittal. In my reading of the Nier report I was more impressed by how extensive are the unknowns that will de-

termine the scale of the disaster resulting from a major nuclear conflict and by how little can be predicted with confidence.

I believe there is no basis in fact for the statement by Broyles and Wigner that "the Soviets' large missiles are effective against our land-based missiles and their killer submarines can attack our Polaris submarines." This allegation is also at variance with assessments given by our civilian and military leaders. To quote Secretary Schlesinger, for example, in the Annual Defense Department Report for FY 1976, "Our sea-launched ballistic-missile force provides us, for the foreseeable future, with a high confidence capability to withhold weapons in reserve."

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