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ABSTRACT

Three papers on nuclear weapons and nuclear war, based on talks given by distinguished physicists during an American Physical Society-sponsored symposium, are provided in this booklet. They include "Caught Between Asymptotes" (Philip Morrison), "We are not Inferior to the Soviets" (Hans A. Bethe), and "MAD vs. NUTS" (Wolfgang K. H. Panofsky). Areas addressed in the first paper (whose title is based on a metaphor offered by John von Neumann) include the threat of nuclear war, World War III versus World War II, and others. The major point of the second paper is that United States strategic nuclear forces are not inferior to those of the Soviets. Areas addressed include accuracy/vulnerability, new weapons, madness of nuclear war, SALT I and II, proposed nuclear weapons freeze, and possible U.S. initiatives. The final paper considers the public consciousness of nuclear war, mutually assured destruction (MAD), nuclear utilization target selection (NUTS)- a conceptual approach to nuclear war which pretends that specialized applications of nuclear weapons are possible, and others. In addition, selected discussion questions from the symposium are provided. Since courses on science and society are proliferating in many colleges/universities, it is suggested that this booklet may serve as reading material for such courses. (JN)

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Philip Morrison
Hans A. Bethe
Wolfgang K. H. Panofsky

Papers based on a symposium of the Forum on Physics and Society of the American Physical Society, held in Washington, D. C. in April 1982

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Introduction

"What else is there to talk about?"

Philip Morrison

The papers in this booklet are based on talks given by three distinguished physicists in April 1982 at a meeting of the American Physical Society (APS) in Washington, DC. The speakers—each the recipient of an award presented by the APS Forum on Physics and Society—were invited to address a special symposium organized by the Forum. Each speaker could choose his own topic. All three chose to speak on nuclear weapons and nuclear war. Through a modest amount of pre-arrangement, the three talks were more complementary than overlapping. Together, they provide authoritative and thought-provoking coverage of an issue of transcendent importance in these times.

The Leo Szilard Award of the Forum on Physics and Society recognizes outstanding accomplishment by a physicist in promoting the *use* of physics for the benefit of society in such areas as the environment, arms control, and science policy. The 1981 Szilard Award was shared by Hans A. Bethe and Henry W. Kendall. The 1982 Szilard Award went to Wolfgang K. H. Panofsky. Papers by Professor Bethe and Panofsky are included in this booklet. Henry Kendall, Professor of Physics at M.I.T., was, regrettably, unable to participate in the Awards Session that gave birth to this booklet.

The APS Forum Award recognizes outstanding accomplishment in promoting *public understanding* of issues involving the interface between physics and society. No Forum Award was made in 1981. The 1982 Forum Award went to Philip Morrison, whose paper is included in this booklet.

Courses on science and society are proliferating in colleges and universities across the country. Many of them deal with the arms race and the specter of nuclear war. It is the main purpose of this booklet to provide reading material for such courses. In trying to serve the needs of such courses, the American Physical Society, through its Forum on Physics and Society, and the American Association of Physics Teachers (AAPT) have a common interest. I thank the Forum for its sponsorship of a science-and-society series of readings, of which this is the third unit. And I thank the officers of AAPT for their ready cooperation in this project. It is AAPT that has undertaken to publish the booklet and has accepted the financial risks inherent in that undertaking.

Kenneth W. Ford

Caught Between Asymptotes

Philip Morrison

Philip Morrison is Institute Professor at Massachusetts Institute of Technology. He has had a distinguished career as a nuclear physicist, astrophysicist, and teacher. He is known for a grasp of science that encompasses many disciplines, and for his remarkable ability as a writer. His monthly book reviews in Scientific American *are fresh, entertaining, and instructive. He has been an active participant in public debate on issues of science and society—especially those related to nuclear armament—since World War II.*

To Professors Bethe and Panofsky—who are so justly admired for their power as physicists, for their good services as citizens, and for their uprightness and charm as human beings—I leave the task of addressing in analytical terms the issues of nuclear weapons and nuclear war that so urgently confront us in these times. I shall, instead, address the same subject—the same old subject, one might even say—more in a philosophical-historical vein. Some sharpness will be lost, but I hope that some perspective will be gained.

The threat of nuclear war, so gross that it numbs the intellect, must be illuminated from every angle if it is to be comprehended, if it is to sink into our collective consciousness, there to become the root of action.

My title is inspired by remarks of John von Neumann, published (in *Fortune* magazine) shortly before his death nearly thirty years ago. Von Neumann, a brilliant mathematician and father of the digital computer, was also a systematic promoter of large-scale modern weaponry. He was, at the same time, a man of clearsighted vision who recognized the terrible hazard posed by escalating weaponry. Our problem in the second half of the twentieth century, he said (I am paraphrasing), is that our weapons grow—in numbers, in accuracy, in destructive capacity—more or less monotone. They don't go backwards. But the area of the surface of the earth and the volume of its atmosphere remain fixed, gaining not an acre nor a cubic kilometer as time goes on. An extrapolation is painfully clear. We are *caught between asymptotes*, with ever diminishing room to maneuver. The distance between von Neumann's asymptotes has been halved, and halved again, since he offered the metaphor in the early 1950s.

World War III vs. World War II

We physicists understand numbers. But not even physicists can readily grasp the significance of the nuclear numbers. A "frame of reference" is lacking. Perhaps it is of some value, therefore, to compare "World War III" (defined as the use of a significant fraction of current weapons) with World War II. It is hard enough even to comprehend the awful death and destruction, the six-year cumulative total, of World War II.

What are the nuclear numbers? A few years hence, if present plans mature, there will be, in the combined arsenals of East and West, between 20,000 and 25,000 warheads capable of intercontinental distances. These will be complemented by about 30,000 warheads capable of shorter range, carried on artillery shells, torpedoes, mines, anti-aircraft rockets, and so on. In total, a panoply of weaponry, 50,000 or more nuclear-tipped devices of every size and type that man can build.

How can one assess the "size" of this pile of weapons as a destructive force? It has become conventional to translate actual megatons to "equivalent megatons"* as a way to describe the total area of damage (which is not necessarily the most relevant measure over such a wide range of sizes and purposes). The world's arsenals add to some 10 to 15 gigatons equivalent. A prodigious number, easier to write down than to understand.

Going back some thirty-five years to the late 1940s, I find an excellent effort by P. M. S. Blackett to forecast and assess the situation with nuclear weapons. Blackett's whole bent was against strategic warfare, which at that time meant the mass bombing of civilian targets. (Since then, it claims to include the "pinpoint" nuclear bombing of hardened military targets, notably missile silos. In the event it will probably revert to area destruction.) Throughout World War II, he fought against the mass bombings of Germany and Japan, and was most determined to try to show that strategic bombing was indecisive. I mention Blackett's bias because it serves to set his estimate of the military effectiveness of nuclear weapons at the most conservative end of the scale. To the atomic bombs dropped on Japan, he assigned an equivalent of only two kilotons of TNT each—strikingly low, but he had technical reasons for his estimate. (The actual energy yield of the Hiroshima bomb was about 12 kilotons, and of the Nagasaki bomb, about 20 kilotons. In terms of human casualties, the TNT-equivalent of these bombs would be greater, not less, than their actual yields.)

*See Table 2 of the following paper by H. A. Bethe.

Using Blackett's equivalence, we find that it would have taken some 100 to 150 megatons of nuclear explosives to equal in overall effectiveness the destruction wrought by the actual high explosives and incendiaries rained down in World War II from the B29s, B17s, Lancasters, and so on (I hope that your attention to old movies makes these terms real). This World War II bombardment inflicted about 1 to 1.5 million casualties—deaths and serious injuries at the two ends of the Axis.

Now (working still with equivalent megatons), we and the Soviets have about 100 times that total destructive capacity poised for war. It seems to me impossible to deny that the consequence of using any substantial fraction of these weapons would be—at least—50 to 100 million serious casualties. These casualties, let it be noted, would be more disruptive to the social fabric because they would be inflicted in a matter of hours, or at most weeks, not years. Most computer simulations of World War III give larger, probably more realistic, numbers, but I wanted to take the most conservative view.

How are we to comprehend a World War III, its destruction magnified over World War II by two orders of magnitude, its time scale compressed from six years to perhaps six days? World War II decimated a generation; its political ends are, in an important way, unaccomplished; its military lessons have not been learned; and, in ways we are scarcely conscious of, it still dominates our daily behavior. If material recovery from World War II took determined and well-assisted lands from eight to ten years (psychic recovery may still lie ahead), I would estimate that it is very unlikely that material recovery from World War III could occur in less than eighty years. Adding the unknown effects on morale, and the incalculable environmental effects on soil, air, and water, I would be surprised if it would not be a century or two before the northern hemisphere found itself in anything like its present state, if indeed it ever did. Would the population have the spirit to build again the structure that had served it so poorly?

Technological society is built on productivity—output per unit input of capital or labor. So long as productivity can increase, there is no lid on production. The same rule applies to weapons. It is worth recalling that the incredible arms buildup of recent decades has been made possible by lower unit costs of destruction, by greater military "productivity." Nuclear destruction is cheaper than conventional destruction. The capital cost is lower, and so is the labor cost. In World War II, strategic bombing, at its peak, required the labor of 1.4 million men and women in the armed forces of the allies. Today, it is unlikely that as many as one-third that number are needed to manage the strategic "deterrent" of the Western alliance, a hundred times more powerful.

The Convergence of Two Trends

The present state of mutual terror—the mutual hostage relationship of the superpowers—is not unrelated to two centuries-old historical trends, trends which seem to be converging as surely as von Neumann's asymptotes.

First is the increasing size of unified units of population. True, small nations have proliferated since World War II. True also, some large nations existed long ago, brought about through occasional bursts such as that of Ghengis Khan out of central Asia, who made a kind of nation, united for warfare, that stretched halfway around the world from Vienna to Peking. But, by and large, the trend over centuries has been from smaller to larger units of population, communities bound by language, customs, behaviors, and beliefs, and perhaps mustered for common purposes by common fear of a perceived enemy. Where Los Alamos, New Mexico, now stands was once the battleground of several tribal "nations," each with its own language and customs, each holding dominion over what now might be a county. Hundreds of European rulers once divided among themselves what is now called a Common Market.

In the twenty-first century, this trend may hold hope, hope for one world. But in what is left of the twentieth century, it poses danger. The communities of several hundred million people who now face each other in fear command vast resources to apply to war.

The second trend is the exponential growth of science, and of its companion, technology. To us physicists, this is a trend of special poignancy, for as we reach farther and deeper into physical reality, as we expand the boundaries of human knowledge, so too do we make possible the application of science to ever more horrible engines of war.

Unfortunately, the second trend is overtaking the first. The ability of mankind to wipe out populations is growing faster than the unified units of population are growing. Although the powerful nations, and allied groups of nations, are larger and perhaps more resilient than they once were, they are at greater risk than ever before. The escalating technology of warfare has increased the *percentage* of a major nation's population that can be, or is likely to be, destroyed. Another pair of asymptotes squeezes mankind.

The Instrument of War as a Thing of Beauty

Can the horror of war be dulled by the esthetic appeal of the instruments of war? In a recent magazine advertisement (two pages, in color), a jet fighter is shown hugging the earth at high speed as it "flies contours"

to elude radar. In the background, dawn lights cirrus clouds over jagged mountains. It is beautiful.

It was Ruskin, I believe, who in the early nineteenth century, rhapsodized on the elegance and beauty of the ship of the line, its compact, graceful volume filled with the work of every kind of skilled artisan, its ropes the strongest, its design, its workmanship, its navigational equipment the best that money could buy. It was, in modern terminology, a superbly organized weapons system, which could capture the imagination of the poet as well as the admiral.

We can scarcely avoid looking at a ballistic missile in the same way. It lies at the leading edge of technology, a realization of nuclear physics and applied astrophysics, of hydrodynamics and thermodynamics and metallurgy, of computer science and solid-state physics, a package guided with incredible gyroscopic accuracy to within a few hundred meters of a target thousands of miles distant. Small wonder that we have our modern rhapsodists* or that the average taxpayer sees it as money well spent.

We can reflect, too, that nearly every weapons system has a nonmilitary sibling that is itself a technological marvel. A luxury liner, a supersonic transport, or a rocket to bear men to the moon commands its own esthetic response. All are devices that we build as much for the thrill of achievement as for their practical utility. The same may be true of the endless evolution of weapons.

Beyond Nuclear Weapons

From the seeds of physics have flowered war technologies of vast proportions, which, along with physics itself, have been enormously developed and systematically applied. One cannot see clearly what other technologies may lie latent in our growing knowledge of the world. I think they are there. But I cannot be sure. Perhaps there is nothing else in science that is so demanding, so evidently applicable to war, as the sudden release of nuclear energy that we have in our hands.

Yet it is worth glancing at other great advances, and asking: Do they carry the seeds of military application? Microbiology is much talked about. Its relevance to crops and to human life is plain. Geology is not irrelevant. Studies toward understanding, and therefore perhaps controlling, earthquakes have been made, enough to give a sense of foreboding. Knowledge of the atmosphere, especially the chemical kinetics of the upper atmosphere, is growing. Will man tinker with the breath

*Norman Mailer, *Of A Fire on the Moon* (Little, Brown, 1970)

of life itself? I even mention neurochemistry, a popular basis for controlling humans in science fiction. Will new advances turn fiction to fact?

It is not my purpose to suggest new weapons systems. The ones I hint at above may well never eventuate into anything. But the next generation promises more and more fundamental insights in areas outside of physics. Will every possible military application of new knowledge serve the ends of the state? Will other weapons comparable in terror to nuclear weapons be devised? And if devised, will they be deployed?

Warfare in the Third Dimension; the Erosion of Defense

1914: Darts dropped by hand from the canvas and wood aircraft of the day. 1915: Hydrogen-filled Zeppelins dropping kilopounds of bombs on the coastal cities of England. 1945: Tokyo and Hiroshima. 1982: Thermonuclear ICBMs, SLBMs, and cruise missiles by the thousands. Such has been the evolution of air war. It was Sir Hugh Trenchard, who, in World War I, suggested that erasing the boundary, flying over the coastline and over the national frontier in a third dimension, topologically distinct, was the preferred and irrestible mode of future warfare. We know very well how much misery has resulted from warfare in the third dimension, and how little military certainty.

From coats of mail and walled cities to heat-seeking anti-aircraft missiles, war has been a game in which each offensive move has been matched by a defensive countermove. But now there is a striking change. Those who wage war from the third dimension or propose to do so no longer claim the existence of a defense. Instead of defense, we have retaliatory measures, planned or anticipated, and the associated psychological stress; we have Mutual Assured Destruction (illuminated in Professor Panofsky's paper). This is the dilemma of defenselessness that further shrinks the distance between asymptotes.

Is There Reason for Hope?

In April 1947, the number of ready nuclear weapons in the world was zero. It is now, or soon will be, about 50,000. (That is four new bombs added to the world's arsenals each day for thirty-five years.) The most conspicuous feature of this buildup is, of course, that no use has been made of the weapons since the count was zero. This is at least as important as the other side of the story. The fact of no-use does not offer a naively automatic hope, but it does offer a sense of opportunity. There is indeed a profound wish and need for survival that has inhibited the use of these weapons, without yet being able to inhibit their steady growth and their

ever-present metastability as threat.

The signs of our times suggest that the decade of the 1980s is a decade of realization, a decade in which peoples everywhere are coming to understand that they face the kind of asymptote closure that I discussed at the beginning. This heightened consciousness may turn out to be no promise and bring no fulfillment, but I would prefer to be hopeful. We do know very well that the first time we saw these signs, just after World War II, the hopes were dashed.

Let me invoke another physicist, J. Robert Oppenheimer, a man no longer here, who has become, in a way, a mythical figure. Like many lives that have been transformed to myths, his life has seized the imagination of the informed world by his suffering, by his having gone so high and having been brought so low in service to the state.

When Oppenheimer spoke about the implacable fate of the nuclear-armed world, beginning in the fall of 1945, what he said was that the atomic bomb never offered a new argument for making a lasting peace but rather a new *opportunity* to do so. I think that opportunity, at that time, was lost. Perhaps it was illusory. Perhaps the notion of using the opportunity to exploit the new energy for economic good, to share weaponry among recent allies with deep distinctions between them, was illusion. I think, myself, that it was largely illusion. Be that as it may, enough was done so that we are still here.

But now there is a new opportunity, an opportunity to unwind the store of metastable energy and to curb self-centered nationalism. Nationalism has so much that is noble within it—I recognize that fully—but the decisive point, if we are to live, is that we have, as Oppenheimer said, "a common bond with other human beings everywhere."

I cannot end more fittingly than to read from a letter written, very probably, by Robert Oppenheimer, reporting for the Scientific Advisory Panel to the Interim Committee of the Secretary of War only two days after the end of the Japanese war, a month after Trinity. The letter ends with these words:

> We believe that the safety of this nation, as opposed to its ability to inflict damage on an enemy power, cannot lie wholly, or even primarily, in its scientific or technical prowess. It can be based only on making future wars impossible. It is our urgent and unanimous recommendation that all steps be taken to this one end. Very Sincerely, J. Robert Oppenheimer, for the Advisory Panel.

We Are Not Inferior to the Soviets

Hans. A. Bethe

Hans Bethe is Professor Emeritus of Physics at Cornell University. A powerful theorist who has worked in most of the fields of physics, he was awarded the Nobel Prize in 1967 for his pioneer work on thermonuclear energy generation in stars. He headed the Theoretical Division in wartime Los Alamos, and he has been a frequent advisor to the government since then. He has been an influential public speaker and writer on energy policy and weapons policy.

Hawks and doves agree on at least one thing: that nuclear armaments are excessive and must be reduced. But the present administration has downgraded the importance of serious arms-control negotiations by giving first priority to adding many new weapons to both the U.S. and NATO arsenals: the B1 bomber, MX missile, and Trident II missile in this country; and the Pershing II missile and ground-based cruise missiles in Europe. Without these, President Reagan and former Secretary Haig have insisted, the United States would be caught in a position of permanent inferiority. We are told that there is a serious "window of vulnerability" in our forces.

I claim that our strategic nuclear forces are not inferior to those of the Soviets. Let us look at the actual numbers.

Vehicles, Megatons, and Warheads

Table I compares the numbers of delivery vehicles of various kinds possessed by the U.S.A. and U.S.S.R. The Soviets have more intercontinental ballistic missiles (ICBMs) and more submarine-launched ballistic missiles (SLBMs), but fewer bombers. In total, the Soviets have more delivery vehicles than the U.S.A. plus Britain and France, but the difference is not significant.

In "equivalent megatons," the Soviet nuclear force is about twice that of the U.S.A. (see Table 2; "equivalent megaton" is defined there). The Soviets have put larger-yield weapons on their missiles, an advantage that is cancelled by the lower accuracy of their missiles.

The most important comparative measure of strength is number of warheads. By this measure (Table 3), the U.S.A. is somewhat ahead and is expected to remain ahead.

A single warhead can destroy nearly any target, industrial or military,

other than hardened silos. The smallest nuclear weapon in our arsenal is 40 kilotons, about three times the explosive energy of the Hiroshima bomb. (Megatons are only important as weapons of pure terror, to threaten populations.)

Accuracy and Vulnerability

Soviet accuracy has improved in recent tests. In a few years, the Soviets could, in principle, eliminate much of our ICBM (Minuteman) force in a first strike. This is the perceived window of vulnerability. (At present, they could destroy perhaps half of the Minuteman force.)

But such an attack would have no possible military advantage for the U.S.S.R. It would leave this country with 75 percent of its weapons available. In fact, it was foreseen a long time ago—in the 1950s—that the time would come when ICBMs would be vulnerable. For this reason, the U.S. nuclear force was diversified, and has remained so. As shown in Table 4, ICBMs will soon account for only one-fourth of U.S. warheads.

Of the Polaris submarines deployed in the period 1959-1967, 39 are currently in service. They are essentially invulnerable. Submarines carry half of the U.S. warheads. Destruction of the Minuteman force would not be disabling. Such a first strike by the U.S.S.R. would be madness.

In addition to submarines, we have bombers plus cruise missiles. Three-thousand cruise missiles are to be installed on 150 B52s. There is no effective air defense against cruise missiles.

Table 5 shows the present high accuracy of Soviet missiles and even higher accuracy of U.S. missiles. These accuracies will be improved in the future.

Extremely high accuracy is needed only for hard targets (silos). For most military targets, SLBMs are sufficiently accurate. Cruise missiles on bombers can have any accuracy we may want, and bombers can be on alert in time of tension, or can take off from widely dispersed airfields on warning.

Therefore our strategic forces as a whole will not become vulnerable. Our Minuteman missiles may become vulnerable, but they are only a small part of our forces. *The window of vulnerability does not exist.*

If at all, such a window may exist for the Soviets. They have put most of their strength (and warheads) on ICBMs. If ICBMs become vulnerable, the Soviets are much more vulnerable than we are. *Because of the distribution and the greater invulnerability of our forces, we are certainly not inferior, but are in fact superior to the Soviets in strategic weapons.*

The same opinion is held by military men. The Chief of Staff of each of the services was asked in 1981 whether he would trade his service—its

weapons, personnel, missions, entire range of capabilities, strengths, and weaknesses—for its Soviet counterpart service. Each of the generals and the admiral said he would not make such a trade.

Most important: Comparison of numbers is meaningless for nuclear weapons, beyond a certain minimum number. Both the United States and the Soviet Union have vast overkill capability. If you wish to destroy the other country's important military installations other than its ICBMs, a few hundred warheads are enough; to destroy the more important industrial plants, another few hundred, and in neither case do they need to have extreme accuracy. There is no justification for the many thousands of nuclear warheads that each of the two superpowers possess. Superiority or inferiority, at present levels, has no meaning.

New Weapons

We do not need the B1 bomber. Cruise missiles launched from B52 bombers can penetrate defenses to reach targets better, cheaper, and more reliably. If we need bombers in a small peripheral war, the elaborate (and costly) electronics on the B1 are not needed.

For the same reasons, we do not need the follow-on to the B1, the Stealth bomber.

Nor do we need the MX missile. President Reagan deserves credit for eliminating the "shell game" basing mode for the MX, but I cannot see *any* basing of ICBMs on land that will remain safe.

We probably do need further Trident submarines to replace some of the aging Polaris submarines. We may want the Trident II missile with its super-high accuracy, but this could be negotiable in an arms-control treaty.

The Madness of Nuclear War

There is a true window of vulnerability that is now wide open. It is that all of us, in the Soviet Union, the United States, and Western Europe, are constantly exposed to the danger of a nuclear war that might kill hundreds of millions of people, and would destroy civilization. This danger is heightened by statements like "We can survive a nuclear war" or even "We can win a nuclear war." No country can win a nuclear war; there are only losers. Chairman Brezhnev has said this clearly: "It is a dangerous madness to try to defeat each other in the arms race and to count on victory in nuclear war. I shall add that only he who has decided to commit suicide can start a nuclear war in the hope of emerging a victor from it. No matter what the attacker might possess, no matter what

method of unleashing nuclear war he chooses, he will not attain his aims. Retribution will ensue ineluctably." I am quoting Brezhnev to counter the claim by some influential people in the U.S. government that the Russians consider nuclear war winnable.

The main imperative is to see to it that there never be a nuclear war. This must have priority over comparisons of the strength of nuclear forces, which are meaningless anyway.

Beyond this, we must greatly reduce the level of the nuclear armaments of both superpowers. This is the meaning of arms control.

SALT I and SALT II

There have been two arms-control agreements, SALT I and SALT II. SALT I is in force. SALT II was negotiated, painfully, in seven years and three administrations, and was signed by President Carter and Chairman Brezhnev, but was never ratified by the U.S. Senate. This is a pity because it was a good, carefully balanced treaty and to our advantage—the Soviets would now have fewer missiles than they actually have if the treaty were in force. Our government has withdrawn the treaty from consideration by the Senate, but, for the present, the planned arms buildup remains within the limits set by SALT II.

The trouble with the SALT agreements is not that they were unbalanced in favor of the Soviets, but that our military (and presumably theirs as well) always demanded some buildup of forces as a price for agreeing to the SALT treaties. The price for SALT II was paid (the MX), but the treaty was not ratified. In this way, strategic forces have constantly increased in spite of treaties.

The Proposed Nuclear Weapons Freeze

There are many proposals to correct this situation. The best known one is the Nuclear Weapons Freeze. There is a popular movement for the Freeze; there has been a popular vote in favor of it in New Hampshire; there is an Initiative on the ballot in California; and an opinion poll has shown that 72 percent of the American people are in favor of it. There are two Freeze resolutions in the Senate, one by Senators Kennedy and Hatfield, the other by Senators Jackson and Warner.

The Kennedy-Hatfield Freeze seems simple and straightforward, but is not well defined. Taken literally, it might mean that no change of nuclear weapons is permitted at all. This would prohibit, for example, our installation of cruise missiles on bombers. This would be a highly undesirable limitation because cruise missiles clearly constitute a second-strike

force. Both sides should be permitted to change their weapons arsenal to make it more survivable, as long as the total number and yield of nuclear weapons are not increased. For instance, the Soviets should be permitted and even encouraged to change more of their weapons from ICBMs to submarines. This is not only to their advantage but also to ours, because it would remove their incentive to use their ICBMs quickly, in one big first strike, lest they be destroyed.

The Jackson-Warner "Freeze" is far too permissive. It would allow the United States to build up all the additional weapons in the Reagan program before there is a freeze, without paying attention to what the Soviets may do in the meantime. This is no freeze at all.

Possible U.S. Initiatives

There is an important idea in the Freeze, namely that we should do something on our own initiative to stop the arms race. Negotiations with the Soviets are slow and frustrating at best, and something must be done *now* to keep the arms race under control. At the same time, we cannot afford unilateral disarmament.

A very good idea has been proposed by George Kennan, and modified by Jeremy Stone and Robert Bacher. Kennan proposed that both the U.S. and the U.S.S.R. cut their forces to half of the present level. This could be done without diminishing the security of either power. However, it is unlikely to be politically feasible. The modification by Stone and Bacher proposes that we cut our forces unilaterally by 5 percent and challenge the Soviets to do the same. Through satellite reconnaissance, we can discover whether they are actually doing this. If they are, we cut again 5 percent next year, and we continue this. In the meantime, we negotiate very seriously, with the aim of achieving Kennan's 50-percent cut in a logical and verifiable manner.

Controlling nuclear armaments is not done as a favor to the Soviets. It is done to reduce a mortal threat to America, and to the whole world. Many Secretaries of Defense have recognized that we are more secure with arms control than without it, and so have many of the Chiefs of Staff. Arms control negotiations must be undertaken no matter what the state of our relations with the Soviets are on other concerns. In fact, in times of crisis, it becomes even more important to have a good arms control agreement in force. I am happy that the arms control problem has, in fact, been decoupled from the general foreign policy of the United States toward the Soviet Union. Our delegates are meeting in Geneva to discuss the control of "theater nuclear weapons" in Europe.

Europe: Nuclear vs. Conventional Weapons

Nuclear weapons in Europe are a special problem. For decades the United States and our allies in NATO have considered nuclear weapons an effective deterrent against a hypothetical Soviet attack on Western Europe by conventional weapons. This was reasonable in the early years after World War II, when the Soviets had overwhelming superiority in conventional weapons over an exhausted Western Europe, and conversely, the United States had, first a monopoly, and later overwhelming superiority, in nuclear weapons over the Soviets.

In the long time since World War II, the situation has changed. There are two great dangers in using nuclear weapons in a hypothetical war in Europe. The first is escalation: The use of any nuclear weapon, however small, on the battlefield may lead the opponent to use a bigger one, and this may continue until megaton weapons are used. The Soviets have emphasized this many times: They consider any use by us of nuclear weapons in Europe as having crossed the nuclear threshold, and as a justification for them to use any type of nuclear weapons anywhere. Battlefield use of nuclear weapons thus involves the enormous risk of all-out nuclear war. But even if this did not happen, the use of nuclear weapons in Europe would very likely destroy much of Europe (the second great danger), because of the very high population density, and because of the enormous destructive power of nuclear weapons. Thus, in an effort to save Europe, we would destroy it. The Europeans are acutely aware of this.

In view of this situation, four highly respected former government officials—McGeorge Bundy, George Kennan, Robert McNamara, and Gerard Smith—have introduced a new proposal. They propose that we consider a declaration that we will never be the first to use nuclear weapons. The Soviets have previously challenged us to make such a declaration. Obviously, a mutual declaration would not ensure that nuclear weapons will never be used, and would not permit us to completely abandon such weapons. But it would greatly reduce the probability that they will be used.

Former Secretary Haig was quick to object that this would leave Europe open to an invasion from the East with conventional weapons, and that it would be extremely costly to bring NATO conventional weapons up to equality with those of the Warsaw Pact. This is very likely not correct.

Table 6 compares the conventional forces of East and West in Europe, along with other measures of relative strength. The Warsaw Pact nations do indeed have superiority in tanks, in the ratio of 3 to 2. But

NATO has an enormous number of "smart" anti-tank weapons, more than 10 for each Warsaw Pact tank in Europe. These are more effective and reliable than neutron bombs. Generally, the forces of East and West are well matched. Presumably, we would have to increase our conventional armaments in some areas, but I am told on good authority that this could be done for about $10 billion, a quarter of the price of the B1 bomber program alone. We may want to postpone the actual declaration of No First Use until these improvements are in place. But I believe that Robert McNamara and his associates have advocated a most important idea.

The arms race has to be stopped.

The claim that the United States is inferior to the Soviet Union in strategic nuclear armaments is wrong. The claim that the conventional forces of NATO are hopelessly inferior to those of the Warsaw Pact nations is also wrong. These claims needlessly fuel the arms race.

I have been somewhat critical of the proposed Nuclear Weapons Freeze. But it has the right spirit. The people devoted to ending the arms race must not fight each other, but must stand together. Only by ending the arms race and then decreasing nuclear armaments can the United States and the world find real security.

Table 1. Delivery Vehicles

	U.S.A.	*U.S.S.R.*
ICBMs (intercontinental ballistic missiles)	1,050	1,400
SLBMs (submarine-launched ballistic missiles)	630[a]	950
Bombers	350	140
Total	2,030[b]	2,490

a. Polaris 112
Poseidon 352
Trident II 168

b. plus 144 British and French delivery vehicles

Table 2. Equivalent Megatons[a]

	U.S.A.	*U.S.S.R.*
ICBMs	1,300	5,900
SLBMs	800	1,200
Bombers, present	3,500	900
Present total	5,600	8,000
Total according to *Nuclear War*[b]	4,100	7,100
Bombers, after cruise missiles deployed	2,700	———
Revised total	4,800	
1985 total according to *Nuclear War*[b]	4,200	9,200

a. A weapon's yield in megatons raised to the two-thirds power gives its yield in "equivalent megatons." Thus, a 2-megaton bomb contributes 1.59 equivalent megatons to the arsenal and a 0.5-megaton bomb contributes 0.63 equivalent megatons. Comparing equivalent megatons is, approximately, comparing areas that can be destroyed. (Equivalent megatons is not the right measure for comparing fallout.)

b. *Nuclear War: What's In It For You?*, a book prepared by Ground Zero (Simon and Schuster, New York, 1982), $2.95 in paperback.

Table 3. Warheads

	U.S.A.	*U.S.S.R.*
ICBMs	2,150 - 2,250	5,500 - 6,400
SLBMs	4,750	1,750 - 1,900
Bombers, present	2,500 - 3,500	280 - 550
Present total	9,400 - 10,500	7,530 - 8,850
Bombers, after cruise missiles deployed	4,700	———
1985 estimated total	~12,000	~10,000

Table 4. Warhead Percentage Distribution

(Deliverable warheads[a], after introduction of 3,000 cruise missiles by the U.S.A.)

	U.S.A.	*U.S.S.R.*
ICBMs	26%	77%
SLBMs	53%	23%
Cruise Missiles	22%	0
Total	100%	100%
Total number	9,000	7,800

a. For this table, it is assumed that all ICBM and SLBM warheads are "deliverable," that two-thirds of the B52-launched cruise missiles are deliverable, and that a negligible percentage of weapons carried by Soviet bombers are deliverable.

Table 5. Missile Accuracy[a]

	U.S.A.	*U.S.S.R.*
ICBMs (present)	600 - 1,000 ft	1,000 - 1,500 ft
ICBMs (future)	~300 ft	?
SLBMs	1,500 ft	3,000 ft
Cruise missiles	300 ft	5,000 ft (land-based) 50 ft (ship-to-ship)
Future missiles: terrain-scan cruise missiles and perhaps eventually ICBMs and SLBMs	50 - 100 ft	?

a. The numbers are taken from *Nuclear War* (see Table 2).

Table 6. Conventional Forces in Europe and Related Measures of Relative Strength[a]

	NATO	*Warsaw Pact*
Tanks, total	28,000	63,000
Tanks in Europe	17,000	26,000
Anti-tank missiles	300,000+	?
Combat aircraft, total	10,500	10,800
Land-based aircraft in Europe	4,280	4,950
Naval aircraft	1,150	770
Ground forces in Europe	2,123,000	1,669,000
Military manpower	4,900,000	4,800,000
Annual military spending	$241 billion	$202 billion

a. Source: Defense Monitor, Vol. 11, No. 1 (1982), "Soviet Military Power: Questions and Answers," available from the Center for Defense Information, 303 Capital Gallery West, 600 Maryland Avenue SW, Washington, D. C. 20024 (single copies, $1.00; ten or more copies, $0.50 each).

MAD vs. NUTS

Wolfgang K. H. Panofsky

Wolfgang Panofsky is Director of the Stanford Linear Accelerator Center and Professor of Physics at Stanford University. His achievements span the range of fundamental physics, accelerator design, and research administration, as well as teaching, writing, speaking, and advising numerous government agencies. With an energy that matches his ability, and a keen sense of politics, he is listened to. He was perhaps the single most influential physicist in the national ABM debate of a dozen years ago.

The Public Consciousness of Nuclear War

The last years have seen a dramatic upsurge in public awareness of the threat of nuclear war. It is not totally clear why this has occurred; it may be this Administration's oratory; it may be the raised public exposure of nuclear issues brought on through the debate about ratification of SALT II; it may be the initiatives started in Europe of not wishing to become a nuclear battlefield.

In the past, testimony such as that of the Chairman of the Joint Chiefs of Staff that nuclear war casualties in the Northern Hemisphere could be in the hundreds of millions produced only a popular numbness. The statement that a single one-megaton weapon detonated over the White House would kill almost everyone within a circle of three-mile radius tended to have little impact. Such catastrophes vastly outstrip all present human experiences. The fact that the captain of a single Poseidon submarine has the lives of thirty million Russians in his hands appears as an empty statistic. Analogies with natural disasters—dam breaks, floods, earthquakes—have little meaning, since they occur in areas surrounded by sources of rescue—quite a different situation from the case of nuclear war. Possibly the campaign by the physicians which emphasizes the suffering of the living rather than counting the dead has had more impact on public consciousness. If nuclear war actually did break out on a large scale, then the consequences would be largely incalculable. The surviving medical practitioners would be unable to reduce casualties significantly.

This talk is based in large part on an article of the same title by Spurgeon M. Keeny, Jr., and W. K. H. Panofsky that appeared in the Winter 1981/82 issue of *Foreign Affairs* (Vol. 60, No. 2, p. 287), ©by the Council on Foreign Relations, Inc. Publication here is with the kind permission of the Editor of *Foreign Affairs*.

Responsible analyses of the consequences of large-scale nuclear war agree that the unknown greatly exceeds the known!

Indeed an increase in awareness is long overdue. Little concerning the danger of nuclear war and its potentially awesome consequences has changed since the mid-1960s.

The Dynamics of the Arms Race

The pattern of growth of the nuclear arsenals has followed a systematic path: Generally the United States took the initiative in introducing a new technology for delivery of nuclear weapons; the U.S. then built up deployment of such weapons and stopped at a certain level. The Soviets generally followed suit, usually three or four years later, then did not quite stop when we did, but deployed somewhat larger numbers. Today, the world's arsenal contains roughly *50,000 nuclear weapons*, almost all of these devices have explosive power which is larger than that of the two weapons which killed nearly a quarter of a million Japanese in Hiroshima and Nagasaki in 1945.

It is foolish to ask who is the good guy and who is the bad guy in causing this potentially disastrous and rationally unjustifiable situation; both the United States and the Soviets made their own decisions to acquire their nuclear weapons stockpiles following their own processes. It is more productive to understand the process which has led to numbers of weapons which, were they actually used in combat, would endanger the civilization of this world for decades and perhaps centuries to come. There is rarely a directly demonstrable military action/reaction cycle between what the Soviets are doing and what the United States is doing.

Apparently, a large number of decisions to acquire nuclear weapons are driven by the *political* motive to demonstrate power, strength, or resolve, rather than by strictly *military* requirements. In other words, nuclear weapons have become *symbols* of strength and power, rather than potentially usable instruments to resolve conflicts by force. This diversion of nuclear weapons from their *reality* as awesome instruments of war and destruction to symbols of power and strength has many inherent dangers. Once you use nuclear weapons primarily as political tools, you remove all rationale for answering the question "When is enough enough?" We have long since passed the point of military "sufficiency," to use the phrase popularized by Henry Kissinger.

The United States and the Soviets are signaling to the world that they are getting political mileage out of the acquisition of nuclear weapons. By doing so, the superpowers give powerful arguments to those nations not now possessing nuclear weapons that such weapons might also give them

political leverage. In other words, the inability of the U.S.A. and U.S.S.R. to bring their mutual nuclear arms race under control is in itself a powerful impediment against the success of the avowed policy of these two nations to stem the proliferation of nuclear weapons to the nuclear "have nots." Moreover, the nuclear non-proliferation treaty implies a solemn obligation of the superpowers to stem and reverse the nuclear arms race; the continuing buildup thus fuels cynicism about the true commitment of the U.S.A. and the U.S.S.R. to limit the spread of nuclear weapons.

In addition to the abuse of nuclear weapons as symbols of power and prestige, rather than as potentially usable weapons of war, a further factor has driven the arms race to its present insane status. This is what I call "mirror imaging." The most frequent argument heard for acquiring further weapons is not what role they would actually play in conflict, but rather that we must have them because the Russians already have them or are about to acquire them. Similarly, it is clear from the pattern of Soviet buildup that "mirror imaging" of the U.S. rather than genuine defense needs has also been a strong motive in guiding Soviet decisions.

The above remarks indicate that the nuclear arms race has really very little to do with the potential military utility of nuclear weapons. There never has been a doctrine or policy on the acquisition, deployment, and use of nuclear weapons which is free from severe internal contradictions. In other words, the absence of a clearly defined military policy for the use of nuclear weapons is one of the reasons why the arms race has produced stockpiles of such insane proportions.

MAD: A Condition, Not A Doctrine

As long as the United States had a dominating lead in nuclear weaponry over the Soviet Union, we considered nuclear weapons simply an extension of long-range artillery doctrine. The policy in the late 1950s and early 1960s under John Foster Dulles was the doctrine of "massive retaliation"; that is, we threatened the Soviet Union with nuclear punishment for "unacceptable behavior," wherever it might occur. As Soviet nuclear weaponry grew, this doctrine was no longer tenable because the Soviets were in a position to inflict similar punishment on the United States. This led to the situation of *mutual deterrence*, since both sides were in the position of destroying a large fraction of the population and economic assets of the adversary in response to the other side's nuclear attack. This *condition* is often called "Mutually Assured Destruction," or MAD. This MAD condition hopefully would *de facto* preclude initiation of nuclear war by either adversary.

Critics frequently attack MAD as a *doctrine* by identifying it with the

deliberate strategy of retaliating with an all-out antipopulation attack against the opening of enemy hostilities. Such a doctrine has, in fact, never existed. The often-quoted remark in President Nixon's 1970 report to the Congress on U.S. Foreign Policy, "Should a President, in the event of a nuclear attack, be left with the single option of ordering the mass destruction of enemy civilians, in the face of the certainty that it would be followed by the mass slaughter of Americans?" refers to a situation which has never been real. It has always been possible to a varying extent to commit only fractions of the total retaliatory force. Therefore, no President has ever been forced to make an "all or nothing" decision in regard to the use of nuclear forces. Nevertheless, it is correct that in recent times there has been increasing technical activity to make it possible to target and commit the nuclear forces in a more flexible manner. To repeat, the MAD doctrine as painted by its critics in its most grotesque form has never existed. However, as I shall continue to discuss, the MAD *condition* of the world is a technical-physical circumstance, and not a strategy at all.

MAD has been attacked by many critics as an unacceptable policy to guide U.S. strategy and plans. The certainly correct argument is made that the MAD situation of the world makes the civilian populations of the U.S.A. and U.S.S.R. in fact hostage to the opponent's behavior, a notion which is morally repugnant and which has been frequently rejected as an acceptable basis of warfare. Thus, we have seen a frequent recurrence of the search for strategy alternatives to MAD. Yet, one has to admit that whatever the moral repugnancy and fallibility of the MAD condition may be, it properly should be given credit for preventing the outbreak of all-out conflict between the Soviet Union and the United States or among other great powers for the longest period in recent history.

Limited Nuclear War

Starting in the 1960s, there has been a continuing debate on whether the alleged MAD doctrine is an acceptable basis for U.S. policy, or whether alternative strategies were available and should be pursued. Recently, this debate has become even more visible by pronouncements from high-ranking officials in this Administration (and, to a lesser extent in the previous one), which make it appear as if the United States has shifted to doctrines which proclaim the use of nuclear weapons for limited and selected military objectives. I consider this debate to have a profoundly misleading effect on the public regarding the alternative strategies which could be pursued as a matter of technical reality. The debate has created the impression that the outcome and scale of nuclear conflict could actually be controlled by either the doctrine of use or the specific types of nu-

clear weapons employed.

I believe that this impression is, in fact, wrong. The dangers and risks faced by humanity in nuclear conflict are largely independent of the doctrine under which the contesting parties might employ nuclear weapons, and are also little dependent on the physical nature of the weapons used. *Thus, the principal danger of doctrines which point out that nuclear weapons can be used for selective and finite objectives is not that they are correct or workable, but that they might be believed.* If national leaders are indeed convinced that nuclear weapons can be used in actual warfare for only *limited* objectives, then they might be persuaded that the potential gain would be sufficient to justify the use of nuclear weapons in particular circumstances. Thus, the failure of the policy maker to understand the truly revolutionary nature of nuclear weapons as instruments of war, combined with the enormous numbers now contained in the arsensals of the world, could lead to catastrophic consequences, not only for the belligerents themselves, but for a large fraction of the entire world.

NUTS: A Doctrine of Selective Use of Nuclear Weapons

I will call here the conceptual approach to nuclear war which pretends that specialized applications of nuclear weapons are, in fact, possible, Nuclear Utilization Target Selection, or NUTS for short. I will use the term NUTS not only for various doctrines under which nuclear weapons are dedicated to specific targets in projected nuclear wars intended to be limited, but also for the management of general nuclear war between the superpowers over a protracted period of time.

Any NUTS alternative to MAD would require that somehow the technical and human elements of a command and control structure of the belligerents be sufficiently sturdy that use of the nuclear weapons could remain restricted to the limited objectives intended. It is extraordinarily dubious that this will *ever* be possible; but it is certainly not possible today. Also, if the limited use of nuclear weapons is to remain truly limited, their damage to the surrounding civilian population collateral to the use against military objectives must be avoidable. Again, this is extraordinarily difficult, since, as we shall discuss, collateral damage to the civilian population of so-called clean, purely antimilitary attacks against specified targets is expected to be large. Finally, a necessary ingredient in counteracting MAD would be to provide an effective defense over civilian population centers against the delivery vehicles carrying nuclear explosives—the missiles, warheads, and airplanes. This is impossible to accomplish in an effective way with today's technology, and it is dubious that it will be feasible in the future.

The above remarks indicate that MAD is not a matter of strategic choice but a matter of physical fact. Yet, some of NUTS' scenarios continue to be promulgated, which I will now discuss.

Collateral Damage

The much discussed "window of vulnerability" is based on the model that the Soviets might launch a so-called surgical attack against the technically vulnerable Minuteman ICBM silos. The accuracy and number of Soviet warheads carried by their ICBMs is now such that in principle they could be launched in such a way as to destroy almost all U.S. Minuteman silos. Conversely, the United States could preemptively attack a very large fraction of the Soviet deterrent also. The suggestion is made that the Soviets might be tempted to attack Minuteman and then coerce the United States under threat of attack by the Soviet residual force into accepting surrender terms. There are many fundamental flaws in such a model. On purely physical grounds, one should recognize that if U.S. ICBMs were attacked, then, according to Defense Department calculations, some number approaching twenty million Americans and perhaps one million Canadians would be killed through radioactive fallout. A United States President faced with an anti-Minuteman attack leading to a lingering death of millions of Americans would be faced with a decision whether to retaliate that would hardly differ from his decision if New York City had been attacked. As a result, the attacker could have no assurance whatever as to whether lethal retaliation would follow. In short, this is an example where the existence of collateral damage makes it highly dubious that a NUTS scenario would remain selective.

Similar examples could be cited for many other so-called selective anti-military or "counter force" uses of nuclear weapons under discussion. In particular, the military use of nuclear weapons in Europe, which is so much discussed today, could hardly be kept isolated, a fact to which the Europeans are naturally highly sensitive. Most calculations of civilian collateral casualties inherent in the use of nuclear weapons against strictly "military" targets in Europe tend to be simplistic. It would be remarkable indeed if a potential Soviet invasion of Europe would be designed in such a way as to provide an optimum target for nuclear attack by the United States. There is no reason to expect that Soviet columns would steer clear of centers of population, taking into account the very high density of cities in Europe. In past wars, a large fraction of the European population was on the roads in the form of refugees, and under all circumstances fallout and other side effects would take their toll. In short, envisioning a war in Europe involving nuclear weapons which would not in-

volve truly massive civilian deaths and other casualties is simply an illusion.

It would be obvious, even under highly chaotic battle conditions, whether nuclear explosives of *any kind* had been used, but it would be extraordinarily difficult to determine just *what type* of nuclear device had been employed.

The Neutron Bomb

This fact lends some perspective to the debate about the so-called neutron bomb. This device, more precisely called an enhanced radiation weapon, has been touted by its proponents as a specialized and "humane" means of attacking invading tank crews selectively, while leaving friendly populations and structures largely intact. The opponents of the device protest that deployment of the neutron bomb makes it easier to make the decision to initiate the use of nuclear weapons. On technical grounds both of these positions are false. *All* nuclear weapons kill through blast, heat, prompt radiation, and many delayed effects, including fallout. An enhanced radiation weapon only increases the relative lethality of the prompt neutron radiation accompanying the initial explosion. For instance, a 1-kiloton enhanced radiation weapon proposed for deployment in Europe still has an explosive power of 1,000 tons of TNT—much greater than that of any blockbuster used in World War II. Its neutron radiation has been enhanced to correspond to what would be an "ordinary" 10-kiloton nuclear explosive. Its radius of damage either by neutrons or blast cannot be too sharply defined for any number of reasons, quite apart from the fact that the accuracy of aim is limited and that outright erroneous targeting can occur.

Defense Against Nuclear Weapons

Significant protection of the population against massive nuclear attack remains technically infeasible. Elementary considerations indicate that the offense will win in the contest between offense and defense in the nuclear age. This conclusion stems from the unprecedented destructiveness of nuclear weapons. The problems of defense against conventional, chemical explosives and defense against nuclear explosives are drastically different. If 10 percent of the airplanes carrying *conventional* weapons were lost during each bomber attack, this would be intolerable for the attacker, since his airplanes would be diminished to about one-third after 10 attacking waves. In contrast, should an attack with *nuclear* weapons be contemplated, then if only 10 percent of the attacking airplanes

penetrated, such an attack would be devastating due to the enormous damage wrought by even a single nuclear explosion. Not only must a defense against nuclear attack be essentially impenetrable, but it must also be all-covering. In targeting population or the economic assets of an enemy country, the attacker can presumably choose where and when to strike. As a result, all responsible analyses continue to indicate that with existing and foreseeable technology, the cost of a meaningful defense of population and industry is a great deal higher than the increase in cost which would be borne by an attacker to defeat that defense.

Notwithstanding this technical conclusion, there continue to be totally irresponsible articles in various media hinting that great "breakthroughs" are just around the corner, which foreshadow the evolution of an impenetrable defense. I assure you that neither laser weapons nor particle beams, which are the items most frequently mentioned in this respect, offer such a prospect in the foreseeable future.

The above remarks about defense pertain both to active defense (the attempt to intercept incoming nuclear weapons) and to passive defense (protection of the population through civil measures). Currently, the civil defense program of the Soviet Union is roughly ten times larger than that of the United States. Yet neither the U.S. nor Soviet programs are of sufficient size to offer much protection in a large nuclear conflict. The Soviets have shelters which might protect as much as ten percent of their population. There is no evidence that the Soviet Union has provided extensive industrial hardening, and the Soviet population is even more concentrated in urban centers than that of the U.S.

There have been extensive claims that the Soviet Union might evacuate most of its urban population into the country and thereby protect its people from general nuclear war. Although, to my knowledge, there have never been any urban evacuation exercises in the Soviet Union, true believers point to the alleged existence of evacuation plans. Such plans, if they did exist, could not be practically executed. Civil evacuation would require prestocked food supplies and either preconstructed shelters or the capability of the evacuees to dig their own shelters expeditiously. Neither alternative is real. There would have to be major transportation resources, which the Soviet Union does not possess and which, particularly in winter, would be extremely difficult to use under any circumstances. Evacuation would take days, or even weeks, and would give us a clear signal of the Soviet intent for war.

Communication and Control

A necessary ingredient of a NUTS nuclear warfighting capability, in particular if it is envisaged that nuclear war would protract over an extended period of time, would be an extremely reliable and resistant communications, command, control, and intelligence assessment system. There is universal agreement that the current U.S. so-called C^3I system does not nearly meet such a requirement. There is disagreement whether a system could *ever* be built which could provide the necessary reliable information flow assessing the state of the battlefield and transmitting fully authenticated command and control information during a nuclear war. As a matter of practical history, it has been very difficult to give the acquisition of such a reliable and capable control system sufficient priority in the continuing military procurement cycles.

One must recognize that the decision makers in control of authorizing the use of nuclear weapons will be under extraordinary stress once nuclear hostilities break out. If you combine this fact with the highly unreliable information which they might receive under nuclear war conditions, and the necessity of exercising tight control over the actual use of nuclear weapons, the conclusion is inescapable that it is extremely unlikely that a limited and selective nuclear conflict under a NUTS strategy will, in fact, lead only to a limited and selective use of weapons.

Arms Control is the Only Answer

Thus, I conclude that in fact we are fated in the foreseeable future to live in a MAD world. This fact is inherent in the tremendous power of nuclear weapons, the size of the nuclear

stockpiles, the collateral damage associated with the use of nuclear weapons against military targets, the technical limitations on defense of population and industry, and the great difficulties and uncertainties involved in the efforts to control the conduct, and prevent the escalation, of nuclear war.

There is no reason to believe that this situation could change in the foreseeable future. The circumstances which cause the MAD condition are far too profound and the pace of technical military development far too slow to overcome the fundamental technical considerations that underlie the mutual hostage relationship of the superpowers. Thus, MAD and NUTS are not alternative strategies which can be chosen at will as a matter of policy by either the United States or the Soviet Union, or both; rather, MAD is a condition underlying the current world situation, and

a NUTS strategy is not only technically infeasible but extremely dangerous if either the U.S. or the Soviet Union believed to the contrary and acted accordingly. It has been the continuous ambiguity, internal contradictions and vacillation of doctrine in the futile search for a NUTS alternative to the MAD condition of this world that has prevented the United States from defining when "enough is enough."

I conclude that, should nuclear weapons of any type be detonated in a conflict by any power, in any theater of war, under any doctrine, then vast segments of the populations and resources of the belligerent countries and their neighbors will be in gravest danger. Only drastic limitations and reductions of the nuclear stockpiles accomplished through restraint and successful measures of arms control can remedy this situation. We must alter our national priorities toward this end, or the future indeed looks grim.

Selected Discussion

Cruise Missiles

QUESTION: Professor Bethe said that cruise missiles on bombers are stabilizing and desirable. But are not cruise missiles too small to be detected easily, and therefore destabilizing?

BETHE: One must distinguish between cruise missiles on bombers and land-based cruise missiles. Cruise missiles on bombers are, I think, highly desirable because they provide an invulnerable force in addition to submarines, and I would not mind if the Russians at a later date had such cruise missiles, too. Also, these are detectable because they are on the very detectable bombers, and the bombers look different once they have the cruise missiles on them. Cruise missiles deployed on the ground in Europe are a different matter. Those I consider highly undesirable. Like any land-based weapon, they are vulnerable, and even more so in Europe than in the United States. On the other hand, one can make cruise missiles without nuclear warheads, and those might be very good devices against tanks. So, if I were the Secretary of Defense (which I hope I never will be), I would advocate deploying cruise missiles on the ground only with conventional warheads, never with nuclear warheads. Then I would invite the Russians to come and inspect any one of them that they want to.

What Can Physicists Do?

QUESTION: Pogo said, "We have seen the enemy, and he is us." Are we physicists our own enemy because of our apathy? Should physicists, emulating the physicians, embark on a major program of public education, starting with themselves? What can physicists do?

MORRISON: Physicists can and should do a lot. The last two years or so have shown an extraordinary upturn in interest and concern for issues of nuclear war. At MIT, for example, we have a lively faculty group which organized recently on its own initiative. It has a speakers bureau; it has publicized itself and is training itself, going through a whole series of discussions with that smaller number of us who

have been there and have been concerned for many years. It is getting invitations. As education about nuclear war gains momentum, there will be disappointments and failures. But I do not see apathy at this time. Quite the contrary. A few years ago, we could not get anybody to talk about the question. Now, most everybody at least wants to listen, and many want to talk.

Sufficiency

QUESTION: When talking about the sufficiency of our strategic armaments, we tend to start from where we are and ask how much armaments might be reduced. Would it not be better to work from the bottom up, asking what level of threatened destruction in the Soviet Union is required to deter that nation, and what level of weaponry is required to maintain that threat?

BETHE: I question the value of that exercise, because our ultimate aim should be to get away from the idea of deterrence based on a threat to population. I agree with the NUTS concept in one respect: namely, that it is better to attack military targets than civilian population. If nuclear weapons make any sense at all militarily (and I do not think they do), their deterrent role could be to prevent a Russian invasion of western Europe. The targets, in that case, would be military installations only.

PANOFSKY: There is no clear definition of sufficiency (notwithstanding the fact that Mr. Kissinger used the term many times). It is simplistic to say we have so many megatons and can kill so many people and that's sufficient. We are talking for the deterrent role about the number of survivable megatons after presuming an initial strike against our weapons by the other side. I think it is clear that we are vastly over-armed even for the most conservative interpretation of a deterrent role. This is witnessed by the fact that the vast majority of our nuclear weapons are targeted against objects of very limited economic or military importance. Even if the Kennan proposal to cut weapons in half were implemented, we would still live in a MAD world. But a very important success of that cutback would be that we would much more

clearly be doing what we say we are doing: namely, using our arsenal for deterrence. There would then be fewer superfluous weapons around for which people could invent doctrines of use.

MORRISON: A book that I worked on* addressed this question by considering modes of reducing weapons, preserving "sufficiency" at every stage. It was our view that the submarine deterrent should be retained, but with a slow reduction of its warheads; also that bombers and land-based missiles should be reduced step by step, in a long protracted way, in order to send a strong signal and not demand an immediate response from the other side. The safety of the United States would, as far as we could see, only be increased by this process, which would end in a very much smaller number of missiles than we now have.

Anti-Ballistic Missile (ABM) System

QUESTION: There is again talk of developing an ABM. What are its advantages and disadvantages?

PANOFSKY: There are two ultimate roles for ABM. One is "area" defense; the other is "hard-site" defense. Area defense means an umbrella over population and industry. Hard-site defense is to protect the deterrent—that is, to try to counteract the basic vulnerability of land-based ICBMs.

In my talk, I said that ABM is essentially hopeless for area defense, and I gave an overall assessment of why that is so. (The claims on behalf of area defense by *Aviation Week and Space Technology* and other magazines are not made correct by constant repetition.)

Hard-site defense is a much more complex and technical matter. For the shell-game basing mode of MX, one can talk about shuttling an ABM defense along with the MX missile. Or one can talk about defending a fixed silo. Skipping all the complexities, I can simply say that with present technology, the calculated numbers for ABM are bad. Technical feasibility is all right, or *may* be all right,

* *Winding Down*, The Boston Study Group (W. H. Freeman, re-issued 1982).

but it is clear from the calculations that the cost of the defense is higher than the cost of the offense to overpower it or the value of the assets defended. So the ABM question is not a feasibility question and not even a very important question. Because of the cost ratio that favors the offense, the ABM is just another ingredient fueling the arms race.

No-First-Use Pledge

QUESTION: Would a pledge of no-first-use of nuclear weapons increase or decrease the chance of war occurring in Europe?

PANOFSKY: Please note that Bundy, Kennan, McNamara and Smith did not propose to make a no-first-use declaration immediately. They proposed to make sure that the conventional defense of Europe becomes more adequate, *after* which there should be a no-first-use declaration. I believe this is eminently sensible. There is vast disagreement about how large the effort would have to be to strengthen "adequately" the conventional defense of Europe. Some believe, as indicated in Professor Bethe's talk, that it would take only a minimal effort. General Haig and others believe to the contrary. So how long it would take to get to a state in which a no-first-use declaration could be made is debatable, and is, in fact, being debated. In any event, since the Soviets and the U.S. have approximate nuclear parity, the credibility of our use of nuclear weapons in Europe is quite dubious, irrespective of a no-first-use declaration. If there were an invasion of Europe, and even if the conventional defense were inadequate, would an American president really order the use of nuclear weapons and endanger the United States?

Reconversion of the Arms Industry

QUESTION: For arms reduction to succeed, will it be necessary to "buy off" the arms industry—that is, to subsidize the reconversion from armaments to civilian products?

BETHE: I heard an answer to this question from the vice president of a machinists' union. His union is as much involved in the arms race as any union. He said that economic recession as the result of arms reduction is nonsense. A billion dollars spent in civilian industry creates more jobs that a billion dollars spent on weapons. Many unions would support reconversion of the arms industry.

PANOFSKY: Remember that the arms race is remarkably symmetrical between East and West. Institutional pressure for expansion of the arms industry to an ever larger percentage of total economic activity is quite apolitical—equally true in socialist and capitalist countries. The arms industry is not to "blame" for the arms race. Reconversion will be an equal problem on both sides.

Accidental Use

QUESTION: The discussion has been focused on whether a government would rationally use nuclear weapons. What is the possibility of an accidental firing or a deliberate but unauthorized firing?

MORRISON: These are, of course, both possible. But it seems to me that the overwhelming danger lies rather in the emotional and misjudged political actions of leaders who have a centralized command. A single errant weapon *might* trigger escalation, but I consider it unlikely, unless it happened at the wrong time in a moment of crisis and was misinterpreted.

PANOFSKY: One of the limited successes of arms control that we do have is a hotline. Both the Soviet Union and the United States are determined to damp out the effect of any such unauthorized firing. The hotline was part of SALT I, and was recently quietly upgraded by mutual agreement.

Verification

QUESTION: Most proposals for arms reduction require mutual verification. How good are satellites for verification? Would the Russians permit us to come in and see what they have, and would we permit them to come in and see what we have?

BETHE: It is generally agreed that our satellites can reliably find the locations of missile silos in other countries. Also, satellites can determine the number of launches, the number of submarines, and the number of bombers with reasonable accuracy. A ten-percent error is of no consequence. What difference does it make whether the Soviets have 1,200 launchers or 1,300 launchers? If weapons were reduced to half, or even less than half, of present levels, satellite verification would still be quite adequate. Many years ago, when the Arms Control and Disarmament Agency was beginning its work, 200 missiles were believed to be a good goal. You can conceal ten or twenty weapons, but it is difficult to conceal 100. A negotiated force of 200 missiles on each side is enough for verifiable security.

PANOFSKY: The adequacy of verification depends, of course, on what you are trying to verify. One of the more ill-conceived recent proposals is to negotiate about verification (including mutual inspection) more or less in the abstract. I think it is essential that, when you negotiate an arms control agreement, verification be made an integral part of the negotiation. Verification must be "adequate" for each kind of weapons system. There should be a relationship between the confidence in the method of verification and the level of evasion that is tolerable. As Professor Bethe said, you don't care about 5 or 10 percent. For some things, you don't care at all. In the biological warfare convention, for instance, a treaty was enacted even though verification is extremely poor. Both sides agreed to that because it was recognized that biological warfare is inherently as dangerous to the side that uses it as to the side against which it is used. In dealing with verification, it is important to avoid generalities and deal with specifics.

Role of the United Nations

QUESTION: Is the United Nations' consideration of disarmament likely to be effective? Will the third world be able to exert pressure on the superpowers to actually do something

rather than just talking and posturing?

MORRISON: I consider the General Assembly's June 1982 special session on disarmament a very important phenomenon. A residual juridical and diplomatic initiative by various nations might arise out of it. It is extremely unrealistic, looking at the structure of the world today and of the UN in particular, to expect that any decisive influence could be exerted on either of the superpowers by other nations. Nevertheless, as a device for mobilizing world opinion, the special session is valuable. Indeed, I consider it—and especially its resonances across the United States—one of the most important events of the year in the United States. [*Added in press*: Almost one million serious people came to march in New York City during the session.]

PANOFSKY: I don't disagree that the UN special session on disarmament can add very substantially to the pressures that are developing worldwide for arms control. But in the United Nations' framework, there is simply no good mechanism to translate these general pressures into concrete proposals. That can be accomplished only through hard work by the negotiating partners.

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