APPENDIX

ADDITIONAL MATERIALS FOR THE RECORD

SECRETARY OF DEFENSE

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THE POTENTIAL EFFECTS OF NUCLEAR WAR ON THE CLIMATE

A REPORT TO THE UNITED STATES CONGRESS

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PREFACE

This report to the Congress on the potential climatic effects of nuclear war has been prepared to satisfy provisions contained in Section 1107 of the Department of Defense Authorization Act, 1985, Committee of Conference, as follows:

"Sec. 1107 (a) The Secretary of Defense shall participate in any comprehensive study of the atmospheric, climatic, environmental, and biological consequences of nuclear war and the implications that such consequences have for the nuclear weapons strategy and policy, the arms control policy, and the civil defense policy of the United States.

(b) Not later than March 1, 1985, the Secretary of Defense shall submit to the Committees on Armed Services of the Senate and House of Representatives an unclassified report suitable for release to the public, together with classified addenda (if required), concerning the subject described in subsection (a). The Secretary shall include in such report the following:

(1) A detailed review and assessment of the current scientific studies and findings on the atmospheric, climatic, environmental, and biological consequences of nuclear explosions and nuclear exchanges.

(2) A thorough evaluation of the implications that such studies and findings have on (A) the nuclear weapons policy of the United States, especially with regard to strategy, targeting, planning, command, control, procurement, and deployment, (B) the nuclear arms control policy of the United States, and (C) the civil defense policy of the United States.

(3) A discussion of the manner in which the results of such evaluation of policy implications will be incorporated into the nuclear weapons, arms control, and civil defense policies of the United States.

(4) An analysis of the extent to which current scientific findings on the consequences of nuclear explosions are being studied, disseminated, and used in the Soviet Union."

This focus of this report deals with the atmospheric and climatic effects of nuclear war, and does not deal with other effects which could have environmental or biological consequences. Other effects, both the horrible immediate devastation, and long-term effects such as widespread fallout or ionospheric chemistry perturbations, have been dealt with previously. Moreover, the newly postulated climatic effects, at the possible upper extremes indicated by some analyses, would probably surpass these better understood effects.

On past occasions when other more immediate kinds of global effects have been under active assessment--and there have been several such episodes over the years--it took some time for their magnitude and implications to be assessed. This will also be true for the current issue of climatic effects. And in each previous case, the conclusion was drawn that, even were the effect to have been very widespread and very severe, the most basic elements of our policy remain sound: nuclear war must and can be prevented, and to accomplish this imperative, the United States must maintain a strong deterrent capability. This requirement remains true today. Moreover, there are two further considerations which bear on the issue of global effects of nuclear war and our deterrent policy. First, we believe the prospects are promising for significant reductions in offensive weapons. Second, strategic defense offers a path to reduce, and perhaps someday eliminate, the threat of nuclear devastation.

The report commences with a review of the current understanding of the technical issues, and then describes the implications of that understanding, concluding with a description of Soviet activities concerning the analysis of the phenomena.

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1. Technical Issues

The Climatic Response Phenomena: The basic phenomena that could lead to climatic response may be described very simply. In a nuclear attack, fires would be started in and around many of the target areas either as a direct result of the thermal radiation from the fireball or indirectly from blast and shock damage. Examples of the latter would be fires started by sparks from electrical short circuits, broken gas lines and ruptured fuel storage tanks. Such fires could be numerous and could spread throughout the area of destruction and in some cases beyond, depending on the amount and type of fuel available and local meteorological conditions. These fires might generate large quantities of smoke which would be carried into the atmosphere to varying heights, depending on the meteorological conditions and the intensity of the fire.

In addition to smoke, nuclear explosions on or very near the earth's surface can produce dust that would be carried up with the rising fireball. As in the case of volcanic eruptions such as Mt. Saint Helens, a part of the dust would probably be in the form of very small particles that do not readily settle out under gravity and thus can remain suspended in the atmosphere for long periods of time. If the yield of the nuclear explosion were large enough to carry some of the dust into the stratosphere where moisture and precipitation are not present to wash it out, it could remain for months.

Thus, smoke and dust could reach the upper atmosphere as a result of a nuclear attack. Initially, they could be injected into the atmosphere from many separate points and to varying heights. At this point, several processes would begin to occur simultaneously. Over time, circulation within the atmosphere would begin to spread the smoke and dust over wider and wider areas. The circulation of the atmosphere would itself be perturbed by absorption of solar energy by the dust and smoke clouds, so it could be rather different from normal atmospheric circulation. There may also be processes that could transport the smoke and dust from the troposphere into the stratosphere. At the same time, the normal processes that cleanse pollution from the lower-and middle-levels of the atmosphere would be at work. The most obvious of these is precipitation or washout, but there are several other mechanisms also at work. While this would be going on, the physical and chemical characteristics of the smoke and dust could change so that, even though they are still suspended in the atmosphere, their ability to absorb or scatter sunlight would be altered.

Depending upon how the atmospheric smoke and dust generated by nuclear war are ultimately characterized, the suspended particulate matter could act much like a cloud, absorbing and scattering sunlight at high altitude and reducing the amount of solar energy reaching the surface of the earth. How much and how fast the surface of the earth might cool as a result would depend on many of the yet undetermined details of the process, but if there is sufficient absorption of sunlight over a large enough area, the temperature change could be significant. If the smoke and dust clouds remained concentrated over a relatively small part of the earth's surface, they might produce sharp drops in the local temperature under them; but the effect on the hemispheric (or global) temperature would be slight since most areas would be substantially unaffected.

However, the natural tendency of the atmosphere, disturbed or not, would be to disperse the smoke and dust over wider and wider areas with time. One to several weeks would probably be required for widespread dispersal over a region thousands of kilometers wide. Naturally, a thinning process would occur as the particulate matter spread. At the end of this dispersal period, some amount of smoke and dust would remain, whose ability to attenuate and/or absorb sunlight would depend on its physical and chemical state at the time. By this time, hemispheric wide effects might occur. Temperatures generally would drop and the normal atmospheric circulation patterns (and normal weather patterns) could change. How long temperatures would continue to drop, how low they would fall, and how rapidly they would recover, all depend on many variables and the competition between a host of exacerbating and mitigating processes.

Uncertainties also pervade the question of the possible spread of such effects to the southern hemisphere. Normally the atmospheres of the northern and southern hemispheres do not exchange very much air across the equator. Thus, the two hemispheres are normally thought of as being relatively isolated from one another. However, for high enough loading of the atmosphere of the northern hemisphere with smoke and dust, the normal atmospheric circulation patterns might be altered and mechanisms have been suggested that would cause smoke and dust from the northern hemisphere to be transported into the southern hemisphere.

There is fairly general agreement, at the present time, that for major nuclear attacks the phenomena could proceed about as we have described, although there is also realization that important processes might occur that we have not yet recognized, and these could work to make climatic alteration either more or less serious. However, the most important thing that must be realized is that even though we may have a roughly correct qualitative picture, what we do not have, as will be discussed later, is the ability to predict the corresponding climatic effect quantitatively; significant uncertainties exist about the magnitude, and persistence of these effects. At this time, for a postulated nuclear attack and for a specific point on the earth, we cannot predict quantitatively the materials which may be injected into the atmosphere, or how they will react there. Consequently, for any major nuclear war, some decrease in temperature may occur over at least the northern mid-latitudes. But what this change will be, how long it will last, what its spatial distribution will be, and, of much more importance, whether it will lead to effects of equal or more significance than the horrific destruction associated with the short-term effects of a nuclear war, and the other long-term effects such as radioactivity, currently is beyond our ability to predict, even in gross terms.

Historical Perspective: New interest in the long-term effects on the atmosphere of nuclear explosions was raised in 1980 when scientists proposed that a massive cloud of dust caused by a meteor impact could have led to the extinction of more than half of all the species on earth. The concept of meteor-impact dust affecting the global climate led to discussions at the National Academy of Sciences (NAS) in 1981. In April 1982, an ad hoc panel met at the Academy to assess the technical aspects of nuclear dust effects. At the meeting, the newly-discovered problem of smoke was brought up. The potential importance of both smoke and dust in the post-nuclear environment was recognized by the panel, who wrote a summary letter recommending that the Academy proceed with an in-depth investigation. In 1983, the Defense Nuclear Agency agreed to sponsor this investigation, on behalf of the Department of Defense. The results were published in the National Research Council report "The Effects on the Atmosphere of a Major Nuclear Exchange," released in December 1984.

Appreciation of smoke as a major factor resulted from the work of Crutzen and Birks. In 1981, Ambio, the Journal of Swedish Academy of Sciences, arranged a special issue on the physical and biological consequences of nuclear war. Crutzen was commissioned to write an article on possible stratospheric ozone depletions. He and Birks extended their analysis to include nitrogen oxides (NO_x) and hydrocarbon air pollutants generated by fires. Arguing from historical forest fire data, they speculated that one million square kilometers of forests might burn in a nuclear war. They estimated very large quantities of smoke would be produced as a result. Subsequent evaluations based upon hypothetical exchanges have yielded much smaller burned areas and smoke production. Nevertheless, their work provided insight and impetus for subsequent studies.

The first rough quantitative estimates of the potential magnitude of the effects of nuclear war on the atmosphere were contained in a paper published in Science in December 1983[(1)] generally referred to as TTAPS, an acronym derived from the first letter of the names of the five authors. This study estimated conditions of near-darkness and sub-freezing land temperatures, especially in continental interiors, for up to several months after a nuclear attack--almost independent of the level or type of nuclear exchange scenario used. TTAPS suggested that the combination of all of the long-term physical, chemical, and radiobiological effects of nuclear explosions could, on a global scale, prove to be as serious or more serious than the immediate consequences of the nuclear blasts, although no specific damage or casualty assessments were carried out for either the immediate effects or the effects of the postulated climatic changes.

While the Crutzen and Birks studies stirred some interest in scientific circles, the TTAPS study, and its widespread dissemination in various popular media, brought the problem to wide public attention. Because of its widespread dissemination, it is important to review this work in detail, and, because the salient feature of our current understanding is the large uncertainties, we will begin by discussing the nature of the uncertainties, using the TTAPS study as a vehicle for the discussion.

Uncertainties: The model used in the TTAPS study was actually a series of calculations that started with assumed nuclear exchange scenarios and ended with quantitative estimate of an average hemispheric temperature decrease. Since these phenomena are exceedingly complex and outside the bounds of our normal experience, one is forced to employ many estimates, approximations, and educated guesses to arrive at quantitative results. To appreciate the significance of the predictions derived from the TTAPS model, it is necessary to understand some of its features and limitations.

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(1) Turco, R. P. et al.; Nuclear Winter: Global Consequences of Multiple Nuclear Explosions; Science, 23 December 1983, VOL 222, Number 4630.

Looked at most broadly, there are three phases to the modeling problem: the initial production of smoke and dust; its injection, transport, and removal within the atmosphere; and the consequent climatic effects.

In the TTAPS model, the amount of smoke initially produced for any given scenario was probably the most uncertain parameter. This is because a large number of poorly-known variables were combined to determine the amount of smoke that could be produced from any single nuclear explosion. In actuality, the same yield weapon could produce vastly different amounts of smoke over different target areas and under different meteorological conditions. Some of the factors that must be considered--although not taken into account in the TTAPS study--include: the thermal energy required for ignition of the various fuels associated with a particular target area, the sustainability of such a fire, the atmospheric transmission and the terrain features which will determine the area receiving sufficient thermal energy from the fireball to cause ignition, the type and quantity of combustible material potentially available for burning, the fraction that actually burns, and finally, the amount of smoke produced per unit mass of fuel burned. Every target is unique with respect to this set of characteristics, and a given target may change greatly depending on local weather, season, or even time of day.

The TTAPS study did not attempt to analyze the individual targets or areas used for their various scenarios; rather, it made estimates of average or plausible values for all the parameters needed to satisfy the model. This procedure is not unreasonable and is consistent with the level of detail in the analysis, but the potential for error in estimating these averages is clearly quite large. In one case, a more detailed assessment of smoke production has recently been completed as a result of the ongoing DoD research in this area. Small and Bush[2] have made an analysis of smoke produced as a result of hypothetical non-urban wildfires which one can directly compare with the corresponding modeling assumption used in this TTAPS scenario. Bush and Small studied 3,500 uniquely located, but hypothetical targets, characterizing each according to monthly average weather, ignition area, fuel loading, fire spread, and smoke production. The results showed a significantly smaller smoke production--by a factor of over 30 in July to almost 300 in January--than comparable TTAPS results. An effort is underway to resolve this great difference. It is cited here to illustrate the very large current uncertainties in only one of several critically important parameters.

In the TTAPS analysis, smoke was more important than dust in many cases, and as a result popular interest has tended to focus on fires rather than dust. This may or may not be the correct view. If smoke is systematically overestimated, especially in scenarios that should emphasize dust production over smoke (such as attacks on silos using surface bursts), analytic results will be skewed. Additionally, uncertainties associated with the lofting of dust are large because of limited data from atmospheric nuclear tests carried out prior to 1963. This is because most tests were not relevant to the question of

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(2) Small, R.D., Bush, B. W.; Smoke Production from Multiple Nuclear Explosions in Wildlands; Pacific Sierra Research Corporation, in publication.

surface or near-surface bursts over continental geology, or the relevant measurements were not made. The range of uncertainty for total injected mass of submicron size dust, that which is of greatest importance, is roughly a factor of ten, based on our current knowledge.

After generation of smoke and dust is estimated, a model must then portray its injection into the atmosphere, the removal processes, and the transport both horizontally and vertically. The TTAPS model did not directly address these processes since it is a one-dimensional model of the atmosphere. By one-dimensional, one means that the variation of atmospheric properties and processes are treated in only the vertical direction. There is no latitudinal or longitudinal variation as in the real world. A one-dimensional model can only deal with horizontally averaged properties of the entire hemisphere. Of great significance, the land, the oceans, and the coastal interface regions cannot be treated. This is a critical deficiency because the ocean, which covers almost three-fourths of the earth's surface, has an enormous heat capacity compared to the land and will act to moderate temperature changes, especially near coastlines and large lakes. The TTAPS authors did acknowledge this limitation and pointed out that these effects would lessen their predicted temperature drops.

Because there is no horizontal (latitude and longitude) dependence in a one-dimensional model, the extent to which smoke and dust would be injected into the atmosphere over time were not estimated in a realistic way. Instead, the total smoke and dust estimated for a given scenario was placed uniformly over the hemisphere at the start of their calculation. The most certain effect of all this is that the hemisphere average temperature drops very rapidly--much faster than it would in a more realistic three-dimensional model using the same input variables.

The one-dimensional model has other shortfalls. Recovery from the minimum temperatures would largely be accomplished through the gradual removal of smoke and dust, and it was assumed that this removal rate would be the same in the perturbed atmosphere as it is in the normal atmosphere. Even in the normal atmosphere, removal of pollutants is a poorly understood process. Most pollution removal depends on atmospheric circulation and precipitation, but in an atmosphere with a very heavy burden of smoke and dust, the circulation and weather processes may be greatly altered. Some potential alterations could lead to much slower removal than normal, others to more rapid removal. Currently we have little insight into this uncertainty.

This discussion of the deficiencies of the one-dimensional TTAPS model is not meant as a criticism. A one-dimensional model is a valuable research tool and can provide some preliminary insights into the physical processes at work. The three-dimensional models needed to treat the problem more realistically are exceedingly complex and will require very large computational resources. The DoD and Department of Energy, in conjunction with the National Center for Atmospheric Research (NCAR) and other agencies, are pursuing the development of three-dimensional models to treat the atmospheric effects problem. Our work is progressing, and the first results of this effort are now beginning to appear. Though very preliminary and not a complete modeling of any specific scenario, they suggest that:

- o Substantial scavenging of smoke injected into the lower atmosphere from the continents of the Northern Hemisphere may occur as the smoke is being more widely dispersed over the hemisphere.
- o Lofting of smoke through solar heating could act to increase the lifetime of the remaining smoke and may reduce the sensitivity to height of injection.
- o For very large smoke injections, global-scale spreading and cooling are more likely in summer than in winter.

Despite good initial progress, many basic problems remain to be solved in the areas of smoke and dust injection, transport, and removal. In order to make the results produced by these models more accurate, we must improve our understanding of the basic phenomena occurring at the micro, meso, and global scale.

One final problem should be mentioned. Dust and smoke have differing potentials to effect the climate only because of their ability to absorb and scatter sunlight. The absorption and scattering coefficients of the various forms of smoke, dust, and other potential nuclear-produced pollutants must be known before any realistic predictions can be expected. Here again there is a large uncertainty, and what we do know about pollutants in the normal atmosphere may not be correct for the conditions in a significantly altered atmosphere.

National Academy of Sciences Report, 1984: Following their preliminary review of the possible effects of nuclear war-induced smoke and dust in April 1982, the NAS came to an agreement with DNA, acting on behalf of the DoD, to support a full-fledged study. The first committee meeting occurred at the NAS in March 1983. The NAS committee adopted the one-dimensional TTAPS analysis as a starting point for their investigation. During the course of the study, virtually all of the work going on pertinent to this phenomenon was reviewed.

The result of this effort was the NAS report, "The Effects on the Atmosphere of a Major Nuclear Exchange," released on December 11, 1984.

The conclusion of the report states that:

> ". . . a major nuclear exchange would insert significant amounts of smoke, fine dust, and undesirable species into the atmosphere. These depositions could result in dramatic perturbations of the atmosphere lasting over a period of at least a few weeks. Estimation of the amounts, the vertical distributions, and the subsequent fates of these materials involves large uncertainties. Furthermore, accurate detailed accounts of the response of the atmosphere, the redistribution and removal of the depositions, and the duration of a greatly degraded environment lie beyond the present state of knowledge.
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> "Nevertheless, the committee finds that, unless one or more of the effects lie near the less severe end of their uncertainty ranges, or unless some mitigating effect has been overlooked, there is a clear possibility that great portions of the land areas of the northern temperate zone (and,

perhaps, a large segment of the planet) could be severely affected. Possible impacts include major temperature reductions (particularly for an exchange that occurs in the summer) lasting for weeks, with subnormal temperatures persisting for months. The impact of these temperature reductions and associated meteorological changes on the surviving population, and on the biosphere that supports the survivors, could be severe, and deserves careful independent study.

". . . all calculations of the atmospheric effects of a major nuclear war require quantitative assumptions about uncertain physical parameters. In many areas, wide ranges of values are scientifically credible, and the overall results depend materially on the values chosen. Some of these uncertainties may be reduced by further empirical or theoretical research, but others will be difficult to reduce. The larger uncertainties include the following: (a) the quantity and absorption properties of the smoke produced in very large fires; (b) the initial distribution in altitude of smoke produced in large fires; (c) the mechanism and rate of early scavenging of smoke from fire plumes, and aging of the smoke in the first few days; (d) the induced rate of vertical and horizontal transport of smoke and dust in the upper troposphere and atmosphere; (e) the resulting perturbations in atmospheric processes such as cloud formation, precipitation, storminess, and wind patterns, and (f) the adequacy of current and projected atmospheric response models to reliably predict changes that are caused by a massive, high altitude, and irregularly distributed injection of particulate matter. The atmospheric effects of a nuclear exchange depend on all of the foregoing physical processes ,(a) through (e)., and their ultimate calculation is further subject to the uncertainties inherent in (f)."

The Interagency Research Program (IRP): The genesis of this program stems from ongoing DoD and DoE research efforts. In 1983, both the DoD and the DoE started research on the atmospheric response phenomena. In addition to sponsoring the NAS study just discussed, the DoD portion of the program addressed a broad range of issues associated with the long-term global climatic effects of nuclear exchange. This program ($400K in FY83, $1100K in FY84, $1500K in FY85, $2500K in FY86 and continuing at appropriate levels into the future) supports research on several fronts--at numerous government laboratories, universities, and contractors.

The DoD portion of the IRP emphasizes research in (1) the smoke and dust source terms, including the definition of total ignition area, fuel loading and fire spreading, and particulate production, (2) large-scale fire characteristics, particulate lofting, scavenging, coagulation, rain-out, and atmospheric injection, (3) chemistry, including the chemical kinetics of fires and fireballs, the chemical consequences of mesoscale and global processes, and radiative properties (optical and infrared absorption, emission, and scattering), and (4) climatic effects, including the improvement of mesoscale and global climate models to incorporate better particulate source functions; horizontal advection processes; vertical mixing; solar radiation; particulate scavenging; inhomogeneities; particulate, radiative, and circulation feedbacks; seasonal differences; and particulate spreading.

The effort supported by the DoE is fully coordinated with that of the DoD and is currently funded at roughly $2M per year. The LLNL program is broad-based and includes modeling of urban fire ignition, plume dynamics, climate effects, radioactive fallout, and biological impacts. The LANL program focuses on developing comprehensive models for global-scale climate simulations. It is coordinated with complementary efforts at NCAR and NASA Ames. The IRP came into being with approval of the draft Research Plan for Assessing the Climatic Effects of Nuclear War prepared by a committee of university and government scientists. The plan was initiated by Presidential Science Advisor, Dr. George Keyworth, with the National Climate Program Office of NOAA heading the preparation effort. This program augments and coordinates the research activities currently underway in the DoD and the DoE with other government agencies. The program focuses particularly on the problems of fire dynamics, smoke production and properties, and mesoscale processes. The proposed additional research includes increases in theoretical studies, laboratory experiments, field experiments, modeling studies, and research on historical and contemporary analogues of relevant atmospheric phenomena.

The IRP recognizes the need for expertise from a number of experts inside and outside of the Federal Government--many are already at work on the problem. Participating government agencies would include the Department of Defense (DNA), Department of Energy, National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), National Bureau of Standards, National Aeronautics and Space Administration (NASA), Federal Emergency Management Agency (FEMA), and the U.S. Forest Service. The IRP Steering Group is chaired by the President's Science Advisor and is composed of representatives from the Department of Defense, Department of Energy, Department of Commerce, and the National Science Foundation.

The major goals of the IRP are to accelerate the research to reduce the numerous uncertainties in smoke sources and to improve modeling of atmospheric effects. Although it is recognized that not all of the uncertainties could be reduced to uniform or perhaps even to acceptable levels, it is clearly possible to improve our knowledge of the climatic consequences of nuclear exchanges.

2. Summary Observations on the Current Appreciation of the Technical Issues

The Department of Defense recognizes the importance of improving our understanding of the technical underpinnings of the hypothesis which asserts, in its most rudimentary form, that if sufficient material, smoke, and dust are created by nuclear explosions, lofted to sufficient altitude, and were to remain at altitude for protracted periods, deleterious effects would occur with regard to the earth's climate.

We have very little confidence in the near-term ability to predict this phenomenon quantitatively, either in terms of the amount of sunlight obscured and the related temperature changes, the period of time such consequences may persist, or of the levels of nuclear attacks which might initiate such consequences. We do not know whether the long-term consequences of a nuclear war--of whatever magnitude--would be the often postulated months of subfreezing temperatures, or a considerably less severely perturbed atmosphere. Even with widely ranging and unpredictable weather, the destructiveness for human survival of the less severe climatic effects might be of a scale similar to the other horrors associated with nuclear war. As the Defense Science Board Task Force on Atmospheric Obscuration found in their interim report:

> "The uncertainties here range, in our view, all the way between the two extremes, with the possibility that there are no long-term climatic effects no more excluded by what we know now than are the scenarios that predict months of sub-freezing temperatures."

These observations are consistent with the findings in the NAS report, summarized earlier in this report. We believe the NAS report has been especially useful in highlighting the assumptions and the considerable uncertainty that dominate the calculations of atmospheric response to nuclear war. While other authors have mentioned these uncertainties, the NAS report has gone to considerable length to place them in a context which improves understanding of their impact.

We agree that considerable additional research needs to be done to understand better the effects of nuclear war on the atmosphere, and we support the IRP as a means of advancing that objective. However, we do not expect that reliable results will be rapidly forthcoming. As a consequence, we are faced with a high degree of uncertainty, which will persist for some time.

Finally, in view of the present and prospective uncertainties in these climatic predictions, we do not believe that it is possible at this time to draw competent conclusions on their biological consequences, beyond a general observation similar to that in the NAS report: if the climatic effect is severe, the impact on the surviving population and on the biosphere could be correspondingly severe.

3. Policy Implications

The issues raised by the possibility of effects of nuclear war on the atmosphere and climate only strengthen the basic imperative of U.S. national security policy--that nuclear war must be prevented. For over three decades, we have achieved this objective through deterrence and in the past 20 years we have sought to support it through arms control. Now, through the Strategic Defense Initiative, we are seeking a third path to reduce the threat of nuclear devastation.

In the remainder of this report, we will first discuss these three principal elements of our posture--deterrence, arms control, and the Strategic Defense Initiative--briefly describing each one and discussing how it relates to the issue of possible severe climatic effects. We conclude, in this regard, that these three elements, and the initiatives we are taking for each of them, remain fundamentally sound. We then explore the possibility of additional initiatives explicitly designed to mitigate climatic effects, concluding that, while some may be possible, the state of our technical understanding of these phenomena is not yet mature enough to have allowed development of specific initiatives. Finally, we review Soviet perceptions of climatic effects and their implications. We observe that Soviet perceptions are very important--indeed, that differences between their perceptions and ours would be particularly important. We conclude, however, that they have done little original work on the subject and show no evidence of regarding the whole matter as anything more than an opportunity for propaganda.

Deterrence: The evolution of U.S. strategic doctrine from the late-1940s to date is well documented. Throughout the past four decades, our policy has had to convince the Soviet leadership of the futility of aggression by ensuring that we possessed a deterrent which was sufficiently credible and capable to respond to any potential attack. Two years ago next month, the President's Commission on Strategic Forces (Scowcroft report) confirmed anew that effective deterrence requires:

- Holding at risk those military, political and economic assets which the Soviet leadership have given every indications by their actions they value most and which constitute their tools of power and control;

- Creating a stable strategic balance by eliminating unilateral Soviet advantages and evolving to increasingly survivable deterrent forces; and

- Maintaining a modern, effective strategic Triad by strengthening each of its legs and emphasizing secure and survivable command, control and communications.

These three principles are reflected in our strategic modernization program discussed below. Consistent with meeting our essential targeting requirements which derive from these three overarching deterrence principles, we also observe other policy considerations, three of which warrant special mention because they may serve to reduce concerns about climatic effects. They are a reduction of the number of weapons and total yield, rejection of targeting urban population as a way of achieving deterrence, and escalation control. Reducing unwanted damage must be an important feature of our policy, not only because of a categorical desire to limit damage that is not necessary, but also because it adds to the credibility of our response if attacked and thus strengthens deterrence. Over the past 20 years or so, this policy and other considerations have resulted in development of systems which are more discriminating. This, in turn, has led to reductions of some 30% of the total number of weapons and nearly a factor of four reduction in the total yield of our stockpile. This direction continues today, and the prospects for extremely accurate and highly effective non-nuclear systems are encouraging.

Some analyses of climatic effects of nuclear war have assumed targeting of cities. If this were regarded as an inevitable result of nuclear attack, or as U.S. policy, it would completely distort analysis of climatic effects, but more importantly, it would perpetuate a basic misperception of the nature of deterrence. Attacks designed to strike population would, by virtue of deliberately targeting heavily built up urban centers, necessarily have a high probability of starting major fires, and consequently, of creating large amounts of smoke. We believe that threatening civilian populations is neither a prudent nor a moral means of achieving deterrence, nor in light of Soviet views, is it effective. But our strategy consciously does not target population and, in fact, has provisions for reducing civilian casualties. As part of our modernization program, we are retiring older deterrent systems (e.g., the Titan missile) which might create a greater risk of climatic effect than their replacement.

A third element of our implementation of deterrence policy which bears on a mitigation of possible climatic effects is escalation control. It is our position that, however an adversary chooses to initiate nuclear conflict, we must have forces and a targeting capability so that our response would deny either motive or advantage to the aggressor in further escalating the conflict. (Of course, the prospect of our having such a capability would help deter the attack in the first place.) This objective has already in past years resulted in development of a wide range of combinations of targeting and systems selection options. While designed to strengthen deterrence and control escalation if deterrence were to fail, these options may allow us to adjust our planning so as to reduce the danger of climatic effects as our understanding of them develops.

There are those who argue, in effect, that we no longer need to maintain deterrence as assiduously as we have, because the posited prospect of catastrophic climatic effects would themselves deter Soviet leadership from attack. We strongly disagree, and believe that we cannot lower our standards for deterrence because of any such hope. As summarized above, there is large uncertainty as to the extent of those effects; certainly today we cannot be confident that the Soviets would expect such effects to occur as a result of all possible Soviet attacks that we may need to deter. This entire area of consideration--the impact of possible climatic effects on the deterrence--is made more complex by the fact that it relates to what the Soviets understand about such climatic effects and how that understanding would influence their behavior in a crisis situation. We will probably never have certainty of either; indeed, we cannot know the latter before the event, and knowing the former is made difficult by their behavior so far, which has been to mirror back to us our own technical analysis and to exploit the matter for propaganda. (Soviet handling of the "nuclear winter" issue is discussed more fully later in this report.)

The United States has, or is now taking, specific actions which relate directly to maintaining and strengthening deterrence and reducing the dangers of nuclear war: the President's Strategic Modernization Program, arms reductions initiatives, and the Strategic Defense Initiative all bear directly on effective deterrence, and are all therefore relevant to the potential destructiveness of nuclear war including possible climatic effects. We will now discuss these in turn.

Strategic Modernization Program: The President's Strategic Modernization Program is designed to maintain effective deterrence, and by doing so, is also an important measure in minimizing the risks of atmospheric or climatic effects. It is providing significantly enhanced command, control, communications and intelligence (C^3I) capabilities which, through their increased survivability and effectiveness contribute immeasurably to our ability to control escalation. Survivable C^3I contributes to escalation control and thus, as explained above, to mitigation of damage levels (of whatever kind, including possible climatic effects) by reducing pressures for immediate or expanded use of nuclear weapons out of fear that capability for future release would be lost. The improvements to our sea-based, bomber and (with the Scowcroft modifications) land-based legs of our Triad--all intended also to improve survivability and effectiveness--are also essential to maintaining deterrence.

For nonstrategic weapons, our modernization programs have also resulted in increased discrimination through improved accuracy and reduced yield. Beyond that, we have a good beginning on a program to replace some types of nuclear weapons by highly effective, advanced conventional munitions. All of this would contribute to reduction in possible climatic and other global effects of nuclear war. The possibility of such effects, of course, adds urgency to the implementation of these programs.

Arms Reductions: It is the position of this Administration that the level of nuclear weapons which exists today is unacceptably high. As a result, to the extent it is possible to reduce nuclear weapons unilaterally--particularly where both conventional and nuclear modernization programs allow replacement of existing systems on a less than one-for-one basis--we have undertaken to do so. But it would be misleading to suggest that dramatic reductions in nuclear weapons can be achieved by unilateral U.S. initiatives without increasing the risk of nuclear attack, in the absence of any indication that the Soviet Union is undertaking similar steps, or short of a changed strategic situation resulting from highly effective strategic defenses.

Major reductions in nuclear weapons can only be achieved by negotiating mutual and verifiable reduction agreements. Agreements which only legitimate the growth, or slow the rate of increase, of existing stockpiles are not in our national interest. It is for this reason that the Administration has determined that SALT II is fatally flawed. Since 1981, the Reagan Administration has demonstrated its strong desire to break with the past pattern of calling build-ups "arms control". The arms reduction proposals we have put forward have been the most extensive ones advanced by either side for over 20 years. In the area of Intermediate Range Nuclear Forces (INF), we initially proposed the elimination of all longer-range INF (LRINF) missiles--SS-20s, SS-4s, Pershing IIs, and ground-launched cruise missiles. While this remains our goal, we are prepared, as an intermediate step, to reach agreement on the reduction of U.S. and Soviet LRINF missiles. With regard to strategic weapons, we proposed reducing the number of each side's land-based and sea-based ballistic missile warheads to 5,000--a cut of approximately 33%. We have also called for equal limitations on bomber forces and restrictions on missile throw weight. As we prepare to resume negotiations with the Soviet Union in Geneva, we reaffirm our intention to seek agreements in both areas providing for significant, mutual and verifiable reductions.

As to how nuclear arms reductions bear on nuclear-induced climatic changes, the relationship is two-fold: they can strengthen deterrence--the most direct way available to us today of dealing with the possibility of severe climatic effects--and they can mitigate the effects to some extent if deterrence were to fail. However, nuclear arms reductions which may be achievable in the near term are not likely to be able to reduce significantly the consequences of a nuclear war in which a large proportion of the then existing nuclear forces would be used and in which active defenses would be non-existent or ineffective.

It is worth noting in this context, that proposals which would "freeze" development of modernized systems would also stop what has been a continuing trend in our capability--development of systems which are more discriminating and thus more restrictive in both local and global effects. We must avoid constraints that would force us to use weapons of high yield or unconfined effects.

<u>The Strategic Defense Initiative and Arms Control</u>: It is essential to keep potential benefits of arms reductions clearly in view when assessing what one seeks to accomplish through that process. Our objectives in arms reductions are to preserve deterrence in the near-term and begin a transition to a more stable world, with greatly reduced levels of nuclear arms and an enhanced ability to deter war based upon the increasing contribution of non-nuclear defenses against offensive nuclear arms. This period of transition could lead to the eventual elimination of all nuclear arms, both offensive and defensive. A world free of nuclear arms is an ultimate objective to which we, the Soviet Union, and all other nations can agree. The Strategic Defense Initiative research program enhances our efforts to seek verifiable reductions in offensive weapons through arms control negotiations. Such defenses would destroy nuclear weapons before they could reach their targets, thereby multiplying the gains made through negotiated reductions. Indeed, even a single-layer defense may provide a greater mitigating effect on atmospheric consequences than could result from any level of reductions likely to be accepted by the USSR in the near term.

In addition to its design objective to destroy nuclear weapons in flight, the Strategic Defense Initiative would further serve to remove any potential for environmental disaster by moving away from the concept of deterring nuclear war by threat of retaliation and, instead, moving towards deterrence by denial of an attackers political and military objective. Defenses can provide such a deterrent in two ways. First, by destroying a large percentage of Soviet ballistic missile warheads, an effective defense for the U.S. and our Allies can undermine the confidence of Soviet military planners in their ability to predict the outcome of an attack on our military forces. No rational aggressor is likely to contemplate initiating a nuclear war, even in crisis circumstances, while lacking confidence in his ability to predict success.

Second, by reducing or eliminating the utility of Soviet shorter-range ballistic missiles which threaten all of NATO Europe, defenses can have a significant impact on deterring Soviet aggression against our Allies. Soviet SS-20s and shorter-range ballistic missiles provide overlapping capabilities to target all of Europe. This capability is combined with a Soviet doctrine which stresses the use of conventionally-armed ballistic missiles to initiate rapid and wide-ranging attacks on crucial NATO military assets. By reducing or eliminating the military effectiveness of such ballistic missiles, defense systems have the potential for enhancing deterrence not only against intercontinental nuclear attack, but against nuclear and conventional attacks in Europe as well.

Some critics claim that the SDI program would cause the Soviet Union to increase numbers of weapons in an attempt to overcome the defense. This is related to the argument advanced over a decade ago that, by rendering ourselves totally vulnerable to Soviet weapons we would be able to negotiate limits on those weapons. This logic has, of course, been disproven by events; despite the fact that the U.S. made itself fully vulnerable, the U.S.S.R. increased the number of its weapons fourfold since the signing of the ABM Treaty in 1972. The guarantee that all Soviet weapons would reach their U.S. targets apparently did not give the Soviets an incentive to negotiate an equitable SALT II agreement, it encouraged them to build more weapons. Defenses would have the opposite effect; they would reduce the military and political value of ballistic missiles thereby increasing the likelihood of negotiated reductions. The prospect that powerful emerging technologies will reverse the cost leverage which offensive forces have heretofore had over defenses will further improve the likelihood of negotiated reductions.

Thus, by preventing the detonation of thousands of nuclear warheads, and, by paving the way for the elimination of those warheads by making them obsolete, the Strategic Defense Initiative may provide an answer to both the short-term and potential longer-term consequences of nuclear war.

Civil Defense: The basic goal of civil defense in the United States is to develop and maintain a humanitarian program to save lives in the event of major emergency, including a nuclear war. As to changes in our Civil Defense posture, the Federal Emergency Management Agency believe that until scientific knowledge regarding climatic impacts of nuclear conflicts is more fully developed it would be impractical to develop cost-effective policies regarding civil defense, or to change existing policies.

The particular staff elements within the Federal Emergency Management Agency responsible for civil defense planning are being kept abreast of the issues relative to possible climate effects as they develop and will be prepared to take appropriate action as soon as the relevant research now underway is complete.

As we have shown, much of our long standing policy and our current initiatives move in a direction such as to reduce the probability of severe climatic effects even though they were instituted before such effects were under investigation. Specifically, we are maintaining a strong deterrence augmented by necessary force modernization and verifiable, mutual arms reductions. We are continuing the development of accurate, discriminating systems designed to achieve their military objectives with the least nuclear yield possible. We have implemented and are constantly refining options for escalation control. We have, long ago, rejected the targeting of population as a means of securing deterrence. Finally, we have begun the Strategic Defense Initiative which has as its ultimate goal the obsolescence of nuclear weapons. All these things work first to deter nuclear war--the best way of avoiding the effects at issue--and second, to reduce these effects were deterrence to fail.

Possible Further Initiatives: As we have already pointed out, reducing unwanted damage must be an important feature of our policy. It would be entirely consistent with our policy and recent practices to continue to make weapons more discriminating, to reduce their yields by improved accuracy where possible, and in other ways to minimize effects not directly related to target damage, so as to both enhance the credibility of our deterrent and to reduce unwanted destruction, including the potential for ameliorating possible climatic and other environmental effects. In fact, we are pursuing such objectives in general, though programs are in various stages of development.

Beyond these continuing trends, with regard to targeting and the detailed characteristics of the nuclear forces, which pertain both to deterrence and to limiting damage, as our understanding of climate effects improves it is prudent to develop other measures intended to reduce those effects if deterrence were to fail. Besides possibly adding targeting options to those which already exist to limit damage, some technical developments might also contribute. For example, highly accurate, maneuverable reentry vehicles and earth penetrating weapons, both of which might be useful in strengthening deterrence, could reduce yields and in other ways limit the starting of fires. In the farther future, for selected missions, nonnuclear systems, if feasible, might replace some strategic nuclear systems, as we have begun to do for non-strategic systems.

Today, however, we have inadequate knowledge to evaluate possible measures. As the analytical methods for assessing climatic effects become more accurate and we gain confidence, they can be used to predict what kind of changes will in fact reduce the dangers of nuclear war. For example, some have suggested that reducing the height of burst of the nuclear explosions could reduce the area of thermal effect and, therefore, the amount of material burnt. However, at lower heights of burst, increased fallout might be worse than any mitigation of long-term change in the climate. Where such trade-offs are involved, we need better information before deciding.

4. Soviet Activities on Climatic Effects

Soviet science spokesmen and media have claimed that Soviet scientists had independently confirmed the probability of severe long-term atmospheric effects as a consequence of nuclear exchange. Initially, their claim was accepted in the West; however, an examination of open Soviet publications specifically discussing this prediction shows their claim to be unfounded.

In their writings on the "nuclear winter" hypothesis, Soviet scientists have neither used independent scenarios nor provided independent values of the essential parameters characterizing the key ingredients (soot, ash, and dust) on which the hypothesis principally depends. Instead, Soviet researchers--and on this subject, it is hard to tell the difference between scientific workers and propagandists--have uncritically used only the worst-case scenarios and estimates from other work. They have taken these estimates and merely adapted them to borrowed mathematical simulations of state-of-the-art multi-dimensional models of global atmospheric circulation modified to instantaneously simulate long-term global effects after an exchange. For example, the primary atmospheric circulation model used by the Soviets in the case of the widely publicized study by Soviet researchers V. Aleksandrov and G. Stenchikov, is based on a borrowed, obsolete, U.S. model. Thus, given the sources of inputs and methods for their "studies," their findings do not represent independent verifications of the hypothesis.

Further, Soviet reports tend to stretch the conclusions well beyond what even their uncritical, worst-case assessments support, embellishing statements of technical analyses with conclusions that any use of nuclear weapons at all will lead to the disappearance of the human race or similar propagandistic statements the Soviet Union has made on and off for years, even before these atmospheric phenomena surfaced.

The Soviet scientists have contributed very little to the international study or understanding of this phenomenon. This shortfall has not gone unnoticed by other non-Soviet scientists, some of whom have characterized their analyses as "crude" and "flawed." Time after time their presentations contain exaggerated claims, which are criticized by their foreign colleagues following the formal briefing, but subsequent presentations do not reflect any change, even though in private the Soviets acknowledge the exaggeration.

This is not to say that, over the years, the Soviets have not published studies that have examined various effects and phenomena (dust, fires, soot, etc.) of nuclear detonations; they have. However, the Soviets have made little use of such findings in their public discussions and models of the phenomenology associated with the current climate effects hypothesis. They have not been forthcoming in providing information that might have been of use with regard to reducing the uncertainties associated with the assumptions made in their work. Repeatedly, they ignored an American request for information derived from Soviet pre-1963 nuclear tests and large-scale fires. The flow of useful technical work has been almost all one-way. It is worth noting that Soviet interest in this topic provides them with some degree of additional access to U.S. scientists (and their technology) who are involved with super-computers, software model development, and global and mesoscale climate phenomenology.

If the Soviets see this issue as a matter that might substantially affect their policies, strategy, or force structure, those views have so far been hidden from us. It is important that, whatever the outcome of the scientific work regarding climatic effects of nuclear war, the understanding should be commonly held by all of the nuclear powers and help to reduce the risk of nuclear destruction. Unfortunately, recent Soviet performance and statements on the subject do not appear supportive of establishing a truly common understanding, either on the phenomena themselves or on their implications for the strategic relationship between the two powers. If the Soviet leadership does believe that the possibility of severe climatic effects is important, then this issue will add its weight, along with the many other imperatives which the United States and the people of the world feel so strongly, to produce a truly constructive approach toward a world in which the fears aroused by such horrors as nuclear war or the so-called "nuclear winter" will be a thing of the past.