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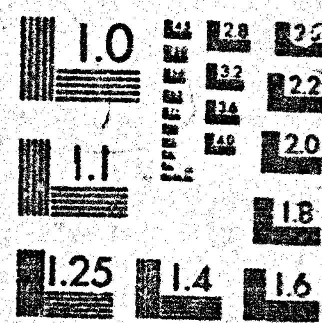

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IMPLICATIONS OF THE "NUCLEAR WINTER" THESIS

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This report assesses the potential policy implications of new findings concerning the long-term atmospheric, climatic and biological effects of nuclear war, commonly referred to as "nuclear winter." A summary of the prominent study of these effects, "The Global Atmospheric Consequences of Nuclear War," by Turco, Toon, Ackerman, Pollack and Sagan (TTAPS) is provided. Potential policy implications are examined regarding nuclear weapons strategy and deterrence, extended deterrence, targeting, C3I and damage assessment, future R&D and force modernization, strategic defense systems, arms control, civil defense and the strategic implications of U.S. and Soviet perceptions of nuclear winter. Issues and questions for further research are addressed. Keywords: An appendix on conferences and activities concerning nuclear winter and a bibliography are included.

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EXECUTIVE SUMMARY

New scientific findings indicate that massive injections into the atmosphere of dust and particularly smoke and soot resulting from nuclear detonations may have long-term atmospheric, climatic and biological consequences. These previously unappreciated potential consequences of a nuclear war--commonly referred to as "nuclear winter"--may have significant national security implications.

There are many remaining scientific uncertainties concerning these findings. In addition, the magnitude and duration of nuclear winter effects produced by the use of nuclear weapons would be dependent on the scenario of conflict, including the numbers and yields of warheads used and their height of burst, and the smoke and dust creating potential of the target areas attacked. This study assumes for purposes of analysis that nuclear winter is a possible outcome of nuclear conflict. It focuses primarily on a continuum of nuclear winter effects, but also examines the possibility of a sharp--and potentially quantifiable--threshold below which there would be virtually no nuclear winter effects and above which the effects would occur in their most severe forms.

Potential nuclear winter effects create additional uncertainties for national leaders and nuclear strategists and further complicate calculations of deterrence. Some of the possible implications for the United States of the nuclear winter findings discussed in this report are summarized below. These preliminary thoughts on implications are based on different sets of assumptions outlined in Section 1:

Strategy and Deterrence

o The possibility that the scale of an attack necessary to preempt either side's offensive nuclear forces could create nuclear winter effects could: (a) reduce both the operational and perceived significance of some strategic vulnerabilities, and (b) enhance stability.

o Concern about nuclear winter could increase the uncertainties confronting decision makers in a crisis. This concern could reduce incentives to initiate use of nuclear weapons for fear of escalation to a level of conflict at which short-term advantages gained through nuclear strikes might be negated by long-term nuclear winter effects.

o New uncertainties could be created for a nation considering retaliation for a nuclear first strike. The leaders of the attacked nation would have to predict the extent of nuclear winter effects created by the first strike on their territory (and that of other countries, including their allies) and then calculate a response that would not lead to further devastation of their own country.

o Maintenance of a credible deterrent may require consideration of potential nuclear winter effects in designing limited nuclear attack options to achieve political objectives and war termination short of full-scale conflict.

Targeting

o The U.S. could identify, categorize and set priorities for military targets based on their smoke and dust creating potential and their colocation with such areas (especially cities). U.S. nuclear weapons systems and current plans for their use could be evaluated for their smoke and dust creating potential and requirement for future weaponry could be established following a reassessment of targeting strategies based on the nuclear winter findings.

C3I and Damage Assessment

o Atmospheric opacity caused by the injection of smoke and dust into the upper atmosphere, even if it did not result in a temperature depression, might interfere with damage assessment and complicate attempts to control escalation and to terminate a nuclear war.

o A decapitating attack may be viewed as mitigating the magnitude and duration of nuclear winter effects, and thus be more attractive. Thus the possibility of nuclear winter may increase incentives for both the Soviet Union and the United States to develop and build more enduring command, control, communications and intelligence (C3I) systems that could survive a decapitation strike.

R&D and Force Modernization

o The possibility of nuclear winter suggests a hedge position in which systems with low-yield, highly-accurate warheads are preferable. Should the U.S. seek to minimize the magnitude of global atmospheric and climatic effects in the event of nuclear conflict, R&D and force modernization programs could focus on other means of limiting fires and collateral damage. This could include earth-penetrating warheads and "smart" conventional weapons for tactical, theater and strategic missions.

o Reconsideration might be given to future development and deployment of high-yield strategic systems which are more likely to contribute to the creation of a severe global nuclear winter (depending on how they are used) than lower-yield weapons.

Strategic Defense Systems

o Attrition of attacking nuclear warheads by a defense system could reduce the likelihood that a nuclear exchange would trigger a nuclear winter. A nation that successfully defended itself against nuclear attack with a strategic defense system could nevertheless create global nuclear winter effects by launching a retaliatory strike, particularly if the adversary did not have a similar ability to destroy the attacking nuclear warheads.

o For a nation facing a less than 100% effective strategic defense system, the unpredictable possibility of creating severe nuclear winter effects would increase the risks of launching a preemptive strike. The attacker might seek to overwhelm the defense system by launching vast numbers of warheads, but a greater number of warheads might penetrate the defensive system than the attacker anticipated, thus increasing the possibility that severe nuclear winter effects would result from the strike.

o Obscurance resulting from smoke and dust in the upper atmosphere could reduce defense effectiveness after the initial stages of conflict by interfering with optical sensors and other means of target acquisition as well as guidance systems.

Arms Control

o A U.S. arms control approach that sought to shape the arsenals of both sides to minimize nuclear winter effects might be unsuccessful if the Soviet Union did not also seek to do so. Even if Moscow and Washington shared concern about the possibility of nuclear winter and were willing to drastically reduce their nuclear arsenals, they could not eliminate the possibility of nuclear winter solely by setting limits on the size of their arsenals. Since the severity of potential nuclear winter effects would be determined by such criteria as warhead yields, height of burst and smoke and dust creating potential of target areas as well as by the number of warheads detonated, efforts to reduce the possibility of nuclear winter might have to include targeting restrictions, controls on fusing option and warhead yield limitations--which are unlikely subjects for bilateral discussions much less negotiations.

o As an adjunct to renewed arms control negotiations, discussions between the United States and the Soviet Union--in a "subcommission on nuclear winter effects," for example--could be useful to explore Soviet thinking on the subject of nuclear winter.

U.S. and Soviet Perceptions of Nuclear Winter

o Some analysts have suggested that the U.S. could face a situation in which U.S.--but not Soviet--leaders were convinced that nuclear winter was a serious possibility. It is doubtful, however, that scientific evidence that was sufficiently compelling to persuade the United States Government to redesign U.S. limited nuclear options to minimize nuclear winter effects would not also be compelling to the Soviet leadership. On the other hand, it is possible that an assymetry in political pressure for change could develop.

o The nuclear winter findings may present an opportunity for the United States to redefine the U.S.-Soviet strategic balance. The Soviets might perceive the U.S. to be developing credible limited nuclear options that would give the U.S. a strategic advantage. The Soviets could feel compelled to begin a new round of modernization of their forces, emphasizing more accurate, lower yield warheads and more flexible delivery systems such as small, single-warhead ICBMs. This re-evaluation could place the Soviets at a perceived disadvantage despite their massive military buildup of the last decade. It could also provide additional incentives for the Soviets to seek negotiated arms reductions to limit or prevent development of U.S. strategic advantages.

Nuclear Proliferation

o Nuclear winter findings could increase the urgency for preventing the further proliferation of nuclear weapons if future research concludes that significant atmospheric and climatic effects could result from a very small number (tens, rather than hundreds or thousands) of nuclear detonations over target areas of high smoke and dust creating potential.

Civil Defense

o The nuclear winter findings suggest that the post-war environment may become increasingly hostile to survivors for a prolonged period--weeks, or even months following a nuclear attack. The requirements for sheltering, feeding and otherwise caring for survivors of a nuclear conflict faced with a nuclear winter would be far more extensive than those anticipated under current civil defense plans which focus on protecting the population from the initial blast, fire and fallout of a nuclear attack. Necessary preparations to enable the population to cope with worst case nuclear winter conditions might involve the peacetime expenditure of an unacceptably high level of resources.

o U.S. civil defense planning might be further complicated by the prospect of a nuclear winter resulting from a nuclear conflict on foreign territory without the United States sustaining direct damage. In this case, there would be no immediate victims of blast or radiation to be cared for, and the economic and social infrastructure, including industrial production and medical services, would have remained intact initially. Prospects for survival under these conditions might be greatly enhanced by advance civil defense planning and preparations.

Although the nuclear winter findings to date may not warrant revision of the basic U.S. approach to nuclear strategy, planning and arms control, the possibility of nuclear winter effects raises many important technical and policy issues and questions. Some of these issues and questions cannot be fully considered without further scientific investigation. Others call for technical assessment by the Department of Defense, and may eventually require policy decisions. Section 3 of this report raises some questions for further research in the areas of: deterrence and warplanning, targeting, C3I and damage assessment, strategic defense systems, weapons research and development, arms control and civil defense. The report concludes with an appendix of conferences and activities concerning nuclear winter and a bibliography.

PREFACE

This report was prepared by Palomar Corporation for the Defense Nuclear Agency. It explores potential implications of new scientific findings concerning potential long-term atmospheric, climatic and biological effects of nuclear war, commonly referred to as "nuclear winter." There are many uncertainties about the nuclear winter findings that are currently the subject of scientific investigations. Nevertheless, it is assumed for this analysis that nuclear winter is a possible or probable outcome of nuclear conflict. This study is one of many policy and scientific investigations of nuclear winter currently being conducted.

One of the paradoxes of the nuclear age--and of U.S. strategic policy as it has developed over the last four decades--has been the perceived need to be able to use nuclear weapons to ensure that a nuclear war never occurs. On the one hand, U.S. leaders have feared that any use of nuclear weapons could lead to an all-out nuclear war that would threaten the survival of the United States and much of the rest of the world. On the other hand, they have believed that to prevent nuclear war the U.S. needed credible options for use of nuclear weapons to deter aggression and to terminate a nuclear conflict at the lowest possible level of destruction. Many U.S. policymakers have believed that the actual use of nuclear weapons would be inconceivable unless the survival of the United States or its allies was at stake.

This paradox is inherent in this analysis. The nuclear winter findings provide further evidence of the catastrophic nature of nuclear war and should reinforce determination to avoid nuclear conflict and to seek control of nuclear arms. At the same time, deterrence of nuclear war is believed to rest largely on an ability of the U.S. to respond to a range of serious threats. Consideration is given herein to the possibility that maintenance of a credible deterrent posture by the United States may require reevaluation of U.S. plans for limited use of nuclear weapons to account for possible nuclear winter effects. Current limited nuclear options deemed essential for deterrence may not remain credible if they could result in a severe nuclear winter that threatened the survival of the United States--even if no nuclear weapons exploded on U.S. territory. The redesigning of U.S. nuclear options to maintain the credibility of deterrence by minimizing nuclear winter effects--which is explored in this report--would not necessarily reduce the risks of escalation to all-out nuclear war nor make the use of even a limited number of nuclear weapons any less horrific.

The views, opinions, and findings contained in this report are those of the authors and should not be construed as an official Department of Defense or Defense Nuclear Agency position, policy, or decision.

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SECTION 1

INTRODUCTION

The destructive effects of nuclear war resulting from blast, heat and radiation have long been recognized as catastrophic. Until recently, however, the scientific and defense communities have incompletely addressed the long-term atmospheric and climatic effects of massive injections into the troposphere and lower stratosphere (upper atmosphere) of dust and particularly smoke and soot produced by fires resulting from nuclear detonations. The most prominent investigation of these effects—"Global Atmospheric Consequences of Nuclear War" by Turco, Toon, Ackerman, Pollack and Sagan (TTAPS), released in November 1983—concluded that blocking of sunlight and resultant "subfreezing continental land temperatures may be caused by fine dust raised in high-yield nuclear surface bursts, and by smoke generated in city and forest fires ignited by airbursts of all yields." These effects, the TTAPS study concluded, could have severe biological and environmental consequences, and in the worst case could threaten the survival of human and other species. The scientists also concluded that such extreme consequences could result from a relatively small-scale nuclear war, "even at the level of 100-1,000 megatons." These TTAPS findings have formed the basis of what is now referred to as the "nuclear winter" thesis. [1]

This report examines the potential implications for the Department of Defense of the TTAPS study. In Part I, this section, we summarize the nuclear winter thesis and note the significant uncertainties pointed out by the TTAPS authors as well as by other scientists and defense analysts. In Section 2 we explore some of the implications of the nuclear winter thesis for deterrence, strategy, targeting, command, control, communications and intelligence (C3I), research and development and force modernization, anti-ballistic missile systems, arms control, nuclear proliferation and civil defense. We also discuss the relevance of these implications for various scenarios of nuclear weapons use. In addition, we examine the potential impact of nuclear winter on U.S. and Soviet perceptions. In Section 3, we suggest scientific, technical and policy questions for further consideration. Finally, this report includes an appendix listing conferences, studies, articles and other activities concerning nuclear winter and a bibliography.

The Nuclear Winter Thesis

The TTAPS study used unclassified data and hypothetical nuclear exchange scenarios to study the optical and climatic effects of dust and smoke generated as a result of nuclear war. The scenarios ranged from limited to large-scale attacks and included counterforce and countervalue strikes. Computer models for the amount and vertical distribution of smoke and dust and consequent climatic effects were run and analyzed for these scenarios. According to the TTAPS report, "for many simulated exchanges of several thousand megatons, in which both dust and smoke are generated and encircle the earth within 1-2 weeks, average light levels can be reduced to a few percent of ambient and land temperature minima reach approximately -15 to -25 degrees C. Significant effects typically would last for weeks to months, during which time the smoke and dust can spread over much of the globe." [2]

The baseline case adopted for the study was a 5000 megaton exchange with 20 percent of the explosive power (yield) detonated over urban or industrial targets in the Northern Hemisphere. The explosive power in other scenarios modelled ranged from 100 to over 10,000 megatons. The 100 megaton scenario posited the detonation of 1,000 warheads of 100 kilotons each over 1,000 urban or industrial targets. The TTAPS study concluded that even this low level scenario of nuclear weapons use--if employed against target areas of high smoke and dust creating potential--could produce "major optical and climatic consequences."

For each nuclear war scenario, the scientists calculated the quantity and vertical distribution of dust and smoke generated and injected into the upper atmosphere, the elapsed time these particulates remained in the upper atmosphere, the amount of sunlight absorbed and scattered by the dust and smoke, the resultant temperature change, the extent of radioactive fallout over time, and the amount of ultraviolet light that reached the surface after the dust and smoke settled.

After assessing the results of the TTAPS study and other reports presented at the "World After Nuclear War Conference," held in Washington, DC, October 31 and November 1, 1983, the conferees major conclusions were:

- o fire, smoke, and dust could pose major problems with serious and unanticipated long-term environmental consequences
- o a harsh nuclear winter could prevail whose unbroken pall of darkness would cover the Northern Hemisphere and whose effects on the Southern Hemisphere would be greater than previously assumed
- o even small nuclear exchanges could trigger severe long-term climatic effects
- o exposure to radioactive fallout could prove worse than previous studies had indicated
- o while there would be no "Ice Age," the oceans could not provide significant relief by warming the planet
- o ozone depletion would increase exposure to ultraviolet light (UV-B)

Technical Uncertainties in the Nuclear Winter Thesis

Since the publication of the TTAPS study, some scientists have questioned the magnitude of the predicted effects, because of uncertainties about specific phenomenological parameter values used and the assumed uniformity of the smoke and dust cloud cover that would obscure sunlight. [3] They have asserted that the TTAPS study overestimated the quantity of smoke that would be generated by fires resulting from nuclear explosions and the altitude to which the smoke and dust would rise. A major study by a committee of the National Academy of Sciences (NAS), commissioned by the Defense Nuclear Agency, confirmed the possibility that a large-scale nuclear exchange could have severe atmospheric and climatic consequences. [4] The committee, which released its findings in December 1984, concluded that "although there are enormous uncertainties involved in the calculations, the committee believes that long-term climatic effects with severe implications for the biosphere could occur, and these effects should be included in any analysis of the consequences of nuclear war. However, the committee cannot subscribe with confidence to any specific quantitative conclusions drawn from calculations based on current scientific knowledge. The estimates are necessarily rough and can only be used as a general indication of the seriousness of what might occur."

The TTAPS and NAS studies and other scientific papers have pointed to unknowns and uncertainties in many variables and phenomena that will affect the magnitude and duration of atmospheric and environmental effects that could result from a nuclear war. These uncertainties include:

- o the area of urban and forest fires that would be ignited by nuclear detonations
- o the amount of smoke and soot produced by these fires
- o the vertical distribution of smoke and dust lofted into the upper atmosphere
- o the rapidity and uniformities of spreading smoke and dust in the atmosphere

- the residence times for smoke and dust in the atmosphere
- how the smoke and dust alter the radiation balance of the atmosphere (light absorption and scattering characteristics of the particulates)
- how the altered radiation balance "feeds back" and alters normal circulation of the atmosphere
- how long after the initial nuclear explosions before nuclear winter effects, if any, begin to occur.

Variables Dependent on War Scenarios

Not only are there significant technical uncertainties about the injection of smoke and dust into the upper atmosphere as a result of nuclear explosions, there are also many scenario-dependent variables of nuclear war, which would determine the particular character including the magnitude of nuclear winter effects. These variables include but are not limited to:

- total yield (megatonnage) and number of nuclear warheads detonated and length of time between detonations
- warhead yields and modes of detonation (subsurface, surface, near-surface or air burst)
- smoke and dust creating potential of target areas
- the distance between detonations
- prevailing atmospheric conditions and the season in which a nuclear war occurs

A change in one or more of these key variables will affect the nature and extent of the fires created and the amount of dust and smoke injected into the upper atmosphere. Therefore, the total yield of nuclear weapons used is a less precise indicator of nuclear winter obscuration effects than the smoke and dust potential of the target areas attacked, the yield of the warheads assigned to the targets and the modes of detonation of those warheads. A low-yield warhead detonated over a city, for example, will more likely contribute to producing a nuclear winter than a higher-yield warhead detonated over a desert or at sea.

Assumptions for this Study and Definition of Terms

For purposes of analysis, we have assumed that a nuclear winter as described in the TTAPS study is possible after some level of nuclear weapons use, and that the magnitude and duration of a nuclear winter would be dependent on the nuclear war scenario. We have used the term "nuclear winter effects" to refer to all the potential atmospheric and climatic phenomena described below that could result from a nuclear war. In analyzing the implications of nuclear winter, we have focused primarily on a continuum of nuclear winter effects, but we have also examined the possibility of a sharp--and potentially--quantifiable--threshold below which there would be virtually no nuclear winter effects and above which these phenomena would occur in their most severe forms.

The TTAPS authors initially suggested that there may be a yield threshold above which a severe nuclear winter would occur. [5] This threshold, they concluded, could be as low as 100 megatons detonated over 1000 urban/industrial targets.

The notion of a nuclear winter "threshold" has been questioned by many scientists, however, who assert that there is a greater likelihood of a continuum of atmospheric and climatic effects resulting from nuclear detonations. [6] At one end of the continuum would be relatively low accumulation and patchy distribution of smoke and dust in the upper atmosphere. Whether or not this initial accumulation of dust and smoke causes the temperature depression characteristic of nuclear winter, it could still have implications for U.S. nuclear strategy and planning as will be analyzed in Section 2. At points further along the continuum there would be a greater accumulation and spreading of dust and smoke in the upper atmosphere which could result in a more uniform cloud cover and obscuration of sunlight and in short-term temperature depression of a few degrees and regional quick frosts. These effects would worsen at points along the continuum, and at the far end there would be extreme effects, including the formation of a global blanket of smoke and dust creating near-total darkness, that could result in long-term temperature drops on the order of 15-25 degrees Centigrade. Within the spectrum of cases the atmospheric and climatic effects could produce varying degrees of darkness and cold that could last for days, weeks or months.

If only a very high level of nuclear weapons use would cause severe nuclear winter effects, then the implications of these phenomena may not be very significant. An all-out U.S.-Soviet general nuclear war is likely to create such vast short-term destruction and loss of life that the long-term atmospheric and climatic effects--whether mild or severe--would be of relatively little consequence for planning purposes. It would be yet another factor making a massive U.S.-Soviet nuclear exchange "unthinkable." Nuclear winter would have more significant implications for U.S. policy, however, if some--but not all--limited nuclear attacks could result in nuclear winter effects. This would be the case whether nuclear winter effects were a result of crossing a threshold or moving along a continuum of effects. The credibility of U.S. deterrence could be substantially weakened if U.S. options for limited use of nuclear weapons were perceived as likely to create severe nuclear winter effects, and thus not likely to be used--even in an extreme crisis. Since the nuclear winter effects of a particular limited nuclear option would be determined by the number of warheads used, the yields and modes of detonation of those warheads, the targets attacked and other factors, the credibility of deterrence might be restored by redesigning limited nuclear options that would minimize nuclear winter effects. In Section 2 of this report, we will assess the implications of possible nuclear winter effects produced by limited nuclear attacks and measures that could be taken should the U.S. seek to mitigate those effects.

If a very low nuclear winter threshold were established, many if not all limited nuclear attack options might no longer be credible. In this case, nuclear winter could become another significant factor contributing to nuclear deterrence, particularly if the Soviets also accepted this threshold--and the limits it placed on their ability to use nuclear weapons. To minimize the possibility of nuclear winter, neither side could plan to use more than a few, if any, nuclear weapons against smoke and dust creating target areas. For purposes of analysis, we have examined the possibility that the use of a very small number of nuclear weapons--tens, not hundreds or thousands--could result in nuclear winter effects. However, published research findings of the TTAPS authors and the National Academy of Sciences do not consider the potential nuclear winter effects of scenarios involving such a small number of nuclear detonations.

SECTION 2

POTENTIAL NATIONAL SECURITY IMPLICATIONS OF NUCLEAR WINTER

Potential nuclear winter effects create additional uncertainties for national leaders and nuclear strategists and further complicate calculations of deterrence.

The current arsenals of both nations already have sufficient second-strike capability to inflict damage on a scale that credibly threatens the survival of the attacker--although a coercive attack by the Soviets is still a worrisome threat scenario. The additional threat of global nuclear winter--which the TTAPS and other studies suggest is already likely to result from such a massive nuclear exchange--would probably not be considered necessary for deterrence of an all-out attack. The declared policy of the United States has been to seek credible options for lower levels of nuclear weapons use to strengthen overall deterrence, including extended deterrence for our NATO and other allies. While any use of nuclear weapons has been viewed as extremely dangerous, credible limited options for use of nuclear weapons even against Soviet targets have been perceived as necessary to maintain deterrence. It is the contention herein that nuclear options that result in significant nuclear winter effects may be less credible and thus weaken deterrence. [7]

It should be noted that we have not focused on the alternative of maximizing nuclear winter effects to enhance deterrence. While the means for doing so are relatively self-evident if the TTAPS theory is correct, it is unlikely that either the United States or the Soviet Union would plan to maximize the nuclear winter effects of their attack options--although a smaller nuclear power might. Nor would either power seek to maximize the nuclear winter effects of attacks on its own territory--by placing likely targets such as ICBMs in cities, for example.

This section examines some of the potential implications of the nuclear winter findings for: nuclear strategy and deterrence; targeting strategy and selection; nuclear command, control, communications and intelligence (C3I); future research and development and force modernization programs; strategic defense systems; civil defense planning; arms control assumptions and approaches; and crisis stability.

Nuclear Weapons Policy: Strategy and Deterrence

The possibility of nuclear winter effects suggests that "mutual assured destruction" could be a likely outcome of even a largely one-sided nuclear exchange. If we assume that the atmospheric effects could spread throughout the globe and that therefore the effects of a nuclear attack could threaten the survival of all states, an attacking nation could be effectively destroyed by its own nuclear weapons, even if there were little or no nuclear retaliation by the attacked state or its allies.

Although a small-scale use of nuclear weapons may not create a devastating nuclear winter, an attack by the U.S. or the Soviet Union aimed at preempting the other side's nuclear forces would require a sufficiently large-scale use of nuclear weapons that it could produce severe global atmospheric and climatic effects. Thus, a first-strike which effectively destroyed an adversary's retaliatory forces might represent a Pyrrhic victory for the attacker.

U.S. deterrence policy has long been premised on the notion that nuclear forces must be able to survive a first strike and inflict unacceptable damage on the attacker in retaliation. The possibility of nuclear winter--especially if it is determined that the scale of an attack necessary to preempt either side's offensive nuclear forces would create such effects--could reduce both the operational and perceived significance of some strategic vulnerabilities. For example, the theoretical ability to preemptively destroy an adversary's land-based ICBMs might be less likely to weaken deterrence if this advantage appeared less exploitable because of the additional uncertainties and dangers of a nuclear winter. Even leaders of a nation with an effective ABM system might be self-deterred from launching a preemptive strike in a crisis for fear of triggering a nuclear winter.

Concern about nuclear winter could increase the uncertainties confronting decision makers in a crisis. This concern could reduce incentives to initiate use of nuclear weapons for fear of escalation to a level of conflict at which short-term advantages gained through nuclear strikes might be negated by long-term nuclear winter effects.

The possibility of nuclear winter effects also creates new difficulties for the nation considering retaliation for a nuclear first strike. The leaders of the attacked nation would have to assess the extent of nuclear winter effects created by the first strike on their territory (and that of other countries, including their allies) and then calculate a response that would not exacerbate these effects and further devastate their own country. Theoretically, if there were a quantifiable threshold for nuclear winter--below which there were few effects and above which a severe nuclear winter would be created--then the attacker could calculate the initial strike to be just below that threshold. The victim, assuming knowledge of the threshold, would then face suicide if it retaliated and the attacking nation could emerge having achieved its war aims.

Not only would such a strategy be very high risk, but it is unlikely that a threshold could be precisely calculated or that nuclear winter effects could be carefully controlled in carrying out a first strike. Moreover, the attacked nation would still have retaliatory options such as use of low-yield warheads against target areas of low smoke and dust creating potential. The attacking nation could never be certain that its adversary would be self-deterred from retaliating, although it might calculate that the victim would not risk the severe atmospheric and climatic consequences of "massive retaliation."

If both the United States and the Soviet Union perceived that the threat of a nuclear winter existed at a certain level of magnitude of nuclear weapons use, prospects for intra-war escalation control could be enhanced. After an initial limited nuclear weapons use, one or both nations might be self-deterred from escalation to a larger-scale exchange. The caution exercised by leaders on both sides might increase prospects for negotiating war termination. [8]

Extended Deterrence

The U.S. and the European NATO powers have long stressed different implications of the Alliance's "flexible response" strategy. For the U.S., flexible response has implied responding to Soviet aggression at any level of conflict while allowing for the possibility of preventing escalation from conventional war to the use of tactical nuclear weapons, from use of tactical to theater nuclear weapons, and finally to use of strategic nuclear forces against the U.S. and Soviet homelands. For Europe, flexible response has implied deterrence by threat of rapid escalation to use of nuclear weapons, thus ruling out the possibility of a major U.S.-Soviet war confined to European territory. At the same time, Europeans have expressed concern that U.S.-Soviet parity in strategic weapons has both weakened the "coupling" of U.S. strategic forces to European defense and increased the possibility that the U.S. would seek to limit a conflict to the European theater should deterrence fail.

Assessments of nuclear winter phenomena are not likely to lead to resolution of these basic dilemmas of U.S. extended deterrence for Europe. On the one hand, it might be determined that large-scale use of nuclear weapons in Europe would create nuclear winter effects and leave the U.S. and the Soviet Union without a meaningful homeland "sanctuary." This would seem to strengthen the link between U.S. and European security by substantially decreasing the possibility that the U.S. and the Soviet Union could escape devastation by confining a nuclear war to Europe. On the other hand, this link could be weakened if it were perceived that both U.S. and Soviet leaders would fear the possibility of creating a nuclear winter in the event of conflict in Europe, and thus they would seek to prevent escalation beyond the use of battlefield tactical nuclear weapons--such a tactical nuclear conflict could have potentially catastrophic effects for Europe without triggering a global nuclear winter. This perception could undermine the credibility of the U.S. nuclear umbrella over Europe. At the same time, this could encourage the perception in the Soviet Union that an attack on Western Europe would not necessarily escalate to a strategic exchange with the United States.

Targeting

As noted earlier, the total megatonnage of a nuclear exchange is not the sole, or even the primary variable determining the magnitude of nuclear winter effects. Rather, the smoke and dust production potential of the target areas and the yields and heights of burst of individual warheads are likely the key variables. Thus, targeting strategies for nuclear attack options are of critical importance in assessing the potential for creating a nuclear winter. Nuclear strategists are likely to expect that the immediate destruction resulting from an all-out war would be so great that long-term effects such as nuclear winter are of secondary concern. But, potential nuclear winter effects could be critical in evaluating limited nuclear attack options designed to achieve political objectives and war termination short of a full-scale conflict.

U.S. policy has long been based on the premise that in an extreme crisis, the president should have options other than an all-out nuclear strike against the Soviet Union in response to aggression. If the possibility of nuclear winter effects resulting from even limited nuclear exchanges were considered a serious danger, but the president had no means of knowing with certainty the nuclear winter potential of various nuclear attack options, the U.S. might be self-deterred in a crisis. The credibility of U.S. deterrence might be further diminished if the Soviets perceived the U.S. to be self-deterred by fear of creating a nuclear winter--especially if Soviet leaders themselves were not deterred by such concerns.

At present, in detailed attack planning, U.S. planners do not consider the smoke and dust creating potentials of given target types or of the particular warheads to be detonated at specific altitudes over those targets. There is no data base or analysis methodology for assessing these potentials. Such a data base would have to include the smoke and dust creating potential, fuel loading, and many other factors of both the target and its surrounding area, which could include a city. Also, a data base on the fire-creating effects of yields and altitudes of burst of different U.S. nuclear weapons is currently not available. Without such data bases, limited, or any other nuclear attack options could not be evaluated for their nuclear winter-creating potential.

If it were determined that nuclear weapons employment options should be formulated to minimize nuclear winter effects, U.S. nuclear planners could explore the possibilities of designing limited nuclear attack options to minimize the atmospheric and climatic effects of attack options while maximizing the potential of achieving policy goals vis-a-vis the Soviet Union. A detailed analysis would be required to determine whether critical Soviet assets could be held at risk without designating high smoke and dust creating target areas. Criteria calling for minimizing nuclear winter effects might require a re-evaluation of attack options against various classes of targets.

Based on these considerations, the U.S. could potentially identify, categorize and set priorities for military targets based on their smoke and dust production potential and their collocations with sources of smoke and dust. In addition, U.S. nuclear weapons systems and current plans for their use could be evaluated for their fire-creating potential (for example, Minuteman III warheads and planned modes of detonation over specific targets). This would enable reconsideration of which weapons should be designated against specific targets and the altitude of detonation. It might also make possible placing the highest smoke and dust producing target areas--such as cities--in withhold categories. Finally, requirements for future weaponry could be established following a reassessment of targeting strategies based on the nuclear winter findings. To minimize potential nuclear winter effects, for example, small-yield, highly accurate nuclear warheads, earth-penetrating warheads, and conventional warheads could be reserved for use against strategic targets. Any reaction to mitigate perceived nuclear winter effects would have to be evaluated also in terms of its perceived and actual effect on deterrence. Any response that was judged to have a degrading effect on deterrence would have to be balanced against the perceived benefits.

C3I and Damage Assessment

As noted in the introduction to this report, nuclear strategy also could be complicated by the short-term atmospheric effects of nuclear detonations. The injection of smoke and dust into the upper atmosphere and its retention and dispersion, even if it did not result in temperature depression, could complicate attempts to control escalation and to terminate a nuclear war.

Controlling escalation and achieving war termination are dependent in large part on accurate and timely damage assessments and effective control of U.S. nuclear forces. U.S. means for intelligence collection, after nuclear weapons use, however, may be susceptible to greater degradation than previously expected because of the atmospheric opacity caused by the injection of massive quantities of smoke and soot. At the same time, Soviet "decapitation" strikes against U.S. C3I systems could disrupt control of U.S. nuclear forces. Such disruption could prevent a controlled U.S. response for war termination at a level of nuclear weapons use below that which would create severe nuclear winter effects.

The nuclear winter phenomena could influence but not resolve the strategic debate over whether or not to preempt C3I systems in a nuclear conflict. On the one hand, it would appear desirable to avoid targeting C3I assets so the leadership of each country could maintain control of its nuclear weapons to prevent launch and retain the option of seeking war termination through direct contact with the adversary. On the other hand, fear of nuclear winter could create an incentive to launch a decapitation strike against C3I assets rather than against offensive systems. A C3I attack might be perceived as offering the possibility of preventing the launch of the adversary's nuclear forces without having to destroy all of its nuclear delivery vehicles. A C3I strike could require only a fraction of the number of warheads necessary for a counterforce attack and thus could mitigate potential nuclear winter effects. A nuclear decapitation strike would be perceived as extremely dangerous under almost any circumstances, and presumably would be considered only in extreme cases--when the risks of not taking such action are judged to be even greater than risks of acting. Such a decapitation strike might be considered if one side believed the other was preparing to launch a massive first strike.

The atmospheric effects that could lead to a nuclear winter thus may increase already strong incentives for both the Soviet Union and the United States to develop and build more enduring C3I systems or at least to incorporate nuclear winter phenomena in planning new systems that could survive a decapitation strike.

The hardening of C3I systems would likely enhance deterrence and stability by reducing confidence that a nuclear decapitation strike would be successful. If steps were not taken to harden C3I systems, then concern that these systems were even more likely to be attacked might lead to adoption of a "launch under attack" strategy or to delegate launch authority to lower levels of command. In addition, both sides may seek to develop new sensor systems that can penetrate atmospheric opacity to provide timely and accurate damage assessments.

Future R&D and Force Modernization

If future research on nuclear winter leads to a decision to take steps to minimize the severity of global atmospheric and climatic effects in the event of nuclear conflict, then an important area of concern will be force modernization programs. The objective of such programs would be to strengthen deterrence by maintaining credible limited nuclear options that would not be self-deterring.

U.S. and Soviet technological developments have made possible increasingly accurate nuclear weapons systems. These developments have reduced the perceived yield requirements for attacking hardened targets. In the future, even greater improvements in accuracy should allow for far smaller yields (10 kilotons or less) on some systems, which could further diminish collateral damage, including fires, and consequently the likelihood of generating severe nuclear winter effects. In addition, small, earth-penetrating warheads and warheads fused for air or surface bursts adjusted to minimize the smoke and dust creating potential of their detonations may be assigned to strategic missions.

Interest may also be reinforced in replacing nuclear weapons with "smart" conventional weapons for tactical, theater and strategic missions. Such weapons could include highly-accurate, long-range cruise missiles and higher-yield conventional explosives.

While the trend in weapons development has been toward increased accuracy, warhead yield has also been increased on some U.S. strategic systems. Consideration might be given to development and deployment of some lower-yield warheads, which might be less likely to contribute to creation of a global nuclear nuclear winter (depending on how they are used) than higher-yield weapons. The U.S. deterrent posture might be further strengthened if such lower-yield warheads were deployed on single-warhead ICBMs to maximize strategic flexibility and minimize potential nuclear winter effects. For example, 500 warheads on 500 delivery vehicles would provide a wider range of options for limiting nuclear strikes to minimize nuclear winter effects than would 500 warheads on 50 MIRVed systems, since all ten warheads would have to be used with each firing of a MIRVed missile.

As noted in the previous section, a strategic nuclear force modernization program that sought to minimize potential nuclear winter effects would include development of a more survivable and capable C3I. The national command authority would require durable wartime damage assessment capabilities to ensure control of nuclear weapons use, escalation, and the termination of conflict without creating global nuclear winter effects.

Strategic Defense Systems

Although deployment of strategic defense systems might be judged destabilizing as well as extremely expensive and possibly in violation of existing arms control treaties, efforts to destroy attacking nuclear warheads by such defense systems could reduce the likelihood of a nuclear exchange triggering a nuclear winter.

The possibility of creating severe nuclear winter effects would increase the risks of launching a preemptive strike for a nation facing a less than 100% effective strategic defense system. If the attacking nation did not face possible attrition of its forces by strategic defenses, the number of warheads necessary to accomplish its political and military goals theoretically could be calculated to determine the likely severity of nuclear winter effects created by the attack, especially if a nuclear winter "threshold" had been scientifically identified. But such a calculation would not be perceived as reliable by the attacking nation if it were confronted by a strategic defense system that would destroy an uncertain percentage of its warheads. In an effort to ensure the success of the preemptive strike, the attacker might seek to overwhelm the defense system by launching vast numbers of warheads. If a greater percentage of warheads succeeded in penetrating the defense system than the attacker anticipated, the possibility of producing severe nuclear winter effects would be increased. A relatively effective defense system could also result in a return to reliance on attacking soft targets, including cities, for retaliatory strikes, possibly increasing nuclear winter effects.

Current research under the administration's "Strategic Defense Initiative," is examining different systems for use during four different phases of ballistic missile trajectory (boost, post-boost, exo-atmospheric and terminal). It has not yet been determined whether strategic defense systems would contribute to nuclear winter effects if nuclear weapons are used to destroy incoming warheads or if these warheads are fused to detonate if attacked. The nuclear winter implications of nuclear explosions in space or at extreme altitudes in the atmosphere have also not been investigated.

Since nuclear winter effects may develop relatively slowly as the result of large-scale fires, these effects may have little (if any) consequence for ballistic missile defense in the early stages of a nuclear exchange. But the obscurance resulting from smoke and dust injected into the upper atmosphere could eventually interfere with optical sensors and other means of target acquisition as well as guidance systems and thus reduce defense system effectiveness.

While a strategic defense system could reduce the likelihood or severity of a nuclear winter, it would offer no protection from its effects once it occurred. If there were a very low threshold for nuclear winter, a nation with a defensive system that was less than 100% effective might not be able protect its population from the effects of nuclear war produced by detonations on its own soil even if a very large percentage of the attacking warheads were destroyed. In addition, a nation that successfully defended itself against nuclear attack with an defense system could nevertheless trigger a global nuclear winter with its retaliatory strike if the adversary did not have a similar ability to destroy the attacking nuclear warheads. [9] Theoretically, the nation that defended itself against most of an attacker's nuclear weapons could face the possibility that its nuclear retaliatory strike would create the severe global nuclear winter that it sought to avoid. Limited retaliatory strikes could be designed, however, to minimize nuclear winter effects.

Arms Control

A U.S. arms control approach that sought to shape the arsenals of both sides to minimize nuclear winter effects might be unsuccessful if the Soviet Union did not share the goal. While Soviet scientists have published studies of global atmospheric and climatic effects of nuclear war that parallel the U.S. nuclear winter findings, as yet there is no evidence that the Soviet political and military leadership consider nuclear winter a serious planning or operational concern.

Institutionalized discussions between U.S. and Soviet officials as an adjunct to renewed arms control negotiations--in a "subcommission on nuclear weapons effects," for example--could be used to explore Soviet thinking on the subject of nuclear winter. The results of such discussions could be reflected in the arms control terms the Soviets were willing to negotiate and in subsequent Soviet R&D and force modernization programs. It may not be necessary to await further scientific evidence before beginning such discussions.

Even if Moscow and Washington were willing to drastically reduce their nuclear arsenals, they could not eliminate the possibility of nuclear winter solely by setting limits on the number of launchers and warheads. Since the smoke and dust creating potential of target areas, warhead yields, and height of bursts are more important criteria than numbers of warheads detonated in creating nuclear winter effects, the efforts of the two sides could founder on the issues of the size of warheads and how the weapons would be used. Hypothetically, 100 one-megaton warheads used against cities might have the same atmospheric and climatic effects as 1,000 fifty kiloton warheads used against less-combustible targets. Thus, to avoid the possibility of nuclear winter if both sides used all their weapons, should the agreed upon nuclear warheads ceiling--presuming there were no greements on warhead yield--be 50 or 500 weapons apiece? For he past fifteen years only the numbers and characteristics of eapons systems and the numbers of warheads on ballistic missiles ave been subject to negotiation. For the U.S. and the Soviet nion to reach agreement on nuclear arms reductions that would harply reduce the possibility of nuclear winter, the two sides ight have to negotiate targeting restrictions, controls on using options and warhead-yield limitations--unlikely subjects or bilateral discussions much less negotiations. Targeting nd fusing options are inherently non-verifiable. Even if there ere agreed restrictions, targeting and fusing could be changed n flight or in a matter of minutes before launch.

Some unilateral and bilateral measures in arms control might e possible to reduce the likelihood of severe nuclear winter ffects should deterrence fail. Consideration could be given to egotiating reductions of weapons systems with high-yield arheads and both sides could agree to develop systems less ikely to create severe nuclear winter effects. Such weapons evelopment programs could emphasize low-yield warheads, although ow-yield warheads may not reduce nuclear winter effects in all ases, especially if there were no ceiling on the number of arheads deployed.

Even if the Soviets reject direct discussions of nuclear inter in arms control negotiations, the formulation of a U.S. rms control position should be coordinated with U.S. research and development and force modernization programs. The U.S. arms control strategy then might aim at allowing for modernization of U.S. forces to limit nuclear winter effects while seeking to limit or reduce the Soviet Union's nuclear weapons systems perceived as most threatening.

Measures that could be taken by the United States and the Soviet Union to minimize potential nuclear winter effects in the event of a nuclear war may not be in U.S. interests, however, for reasons unrelated to concern about nuclear winter. For example, while the U.S. might want the terms of an arms control agreement to allow for restructuring of the U.S. arsenal, would it want the Soviets also to deploy similar systems? Does the United States want to shape a future strategic environment in which both the U.S. and the Soviet Union have deployed arsenals with highly-accurate, very low-yield nuclear weapons which if used would minimize both immediate collateral damage and the severity of any long-term nuclear winter effects? Would such a Soviet arsenal be more able to hold more U.S. strategic assets at risk?

Even without such a radical restructuring of the strategic arsenals of the U.S. and the Soviet Union, would it be possible —or desirable— to move toward deployment of limited numbers of "nuclear winter proof" weapons on both sides while not eliminating all the larger-yield weapons systems until their life cycles are over? Would such an arms control outcome provide enough additional protection against nuclear winter in realistic limited war scenarios to justify the expense or effort? Would both sides want to maintain a reserve of "city busters" as an ultimate "doomsday machine" retaliatory threat? Further research into these and other questions would be necessary as part of any effort to include consideration of the implications of nuclear winter effects in arms control.

Nuclear Proliferation

Nuclear winter findings could increase the urgency for preventing the further proliferation of nuclear weapons if future research concludes that significant atmospheric and climatic effects could result from a very small number (tens, rather than hundreds or thousands) of nuclear detonations over highly combustible targets.

If a very low nuclear winter threshold were identified, this could provide a strong incentive for nations to acquire nuclear weapons. In such a case, a country with even a few dozen nuclear warheads and delivery vehicles could potentially gain political leverage by threat of nuclear blackmail. At the same time, a very low threshold could diminish the political value of the U.S. and Soviet nuclear arsenals. The vast numbers of weapons each country possessed in excess of those necessary to trigger a nuclear winter might be seen as far less significant politically and militarily.

If it is determined that instead of a threshold there is a continuum of nuclear winter effects, the injection of smoke and dust from dozens of nuclear detonations over high smoke and dust creating target areas would have less significant implications but would nevertheless raise new concern about nuclear proliferation. Nations which acquired nuclear weapons could not credibly threaten to set off a severe nuclear winter as they would be able to do if there were a very low threshold. Even if the threat of a nuclear winter could not be used for blackmail, the use of nuclear weapons by new nuclear nations might produce adverse global or regional atmospheric and climatic effects. These effects could include, for example, temperature depressions of a few degrees in scattered areas which may result in massive crop failures in climatically marginal agricultural regions. [10]

The potential effects of a very small number of nuclear explosions was not addressed by the TTAPS study or subsequent reports. While the 100 megaton city attack in TTAPS caused severe nuclear winter, a smaller attack could still result in a "significant" nuclear winter, according to TTAPS modeling. If future research determines that the use of fewer weapons (even if detonated over high smoke and dust creating target areas) will not inject significant quantities of soot and dust into the atmosphere then the nuclear winter findings will likely have little consequence for proliferation.

Civil Defense

The civil defense programs of the United States, and apparently those of the Soviet Union as well, have been aimed primarily at protecting the population from the initial blast, radiation and subsequent fire and radioactive fallout of a nuclear attack. An underlying assumption of these programs is that the situation for survivors of a nuclear war would improve within days or weeks as radiation levels subsided and order and the production of basic necessities were gradually restored. The nuclear winter findings, however, suggest that the environment may become increasingly hostile to survivors during the weeks, or even months following a nuclear attack.

The requirements for sheltering, feeding and otherwise caring for survivors of a nuclear conflict faced with a nuclear winter would be far more extensive (but not impossible), than those anticipated under current civil defense assumptions. Present plans for evacuation of the population from cities to rural areas would not necessarily enhance long-term prospects for survival. Evacuated survivors of the immediate blast, thermal and short-term fallout effects of nuclear weapons detonations would have to be protected against prolonged periods of cold, darkness and radiation. Sustaining these survivors for months rather than a few days or weeks as now envisioned could require construction of extensive and elaborate shelters and stockpiling of far larger supplies of food, fuel and fresh water than current preparations anticipate.

U.S. civil defense planning might be further complicated by the prospect of a nuclear winter without having sustained any direct damage to U.S. territory as a result of a nuclear conflict among other nations or on foreign territory. Present civil defense plans and preparations would be largely irrelevant, for example, in the event of a U.S.-Soviet nuclear conflict confined to Europe or a Sino-Soviet nuclear war that triggered global nuclear winter effects. There would be no immediate victims of blast or radiation to be cared for, and the economic and social infrastructure, including industrial production and medical services, would have remained intact initially. The task of civil defense in the days or weeks prior to the onset of nuclear winter conditions would be to organize protection of the population against the long-term atmospheric, climatic and biological consequences of a distant nuclear conflict. Prospects for survival under these conditions might be greatly enhanced by advance civil defense planning and preparations.

If there is a continuum of nuclear winter effects, then civil defense programs could be developed to prepare the survivors to cope with some of the problems they might face in a less severe nuclear winter environment. These programs would require research to determine the atmospheric, climatic and long-term biological conditions likely to prevail in a nuclear winter environment and possible countermeasures that could be developed to assist the survivors.

Effective civil defense measures to prepare for survival in a full-scale nuclear winter environment would be far more problematic, however. The TTAPS study predicts that the extreme darkness, cold and radiation, combined with the immediate effects of a nuclear attack, would pose a threat to human and other species. In this worst case scenario it is highly questionable whether effective civil defense plans and preparations could be made at an acceptable cost. [11] If it is determined that an extreme nuclear winter would not occur suddenly, but rather that nuclear winter effects would develop gradually along a continuum, then effective measures might be feasible for less severe atmospheric and climatic perturbations resulting from nuclear conflict. If there were a nuclear winter threshold, however, then there might be less value in augmenting U.S. civil defense programs. Below this threshold, there would be no nuclear winter effects and thus current civil defense assumptions would continue to be valid. Above this threshold, the long-term biological and environmental effects would be so devastating that even such exorbitantly expensive measures as building vast underground shelters might not ensure human survival.

The prospect that survivors of a nuclear war might face nuclear winter effects does not obviate the need for protecting the population from the initial effects of a nuclear attack.

This prospect does, however, call for a reexamination of current assumptions about the post-attack environment. Additional preparations under some conditions might give the survivors a better chance of coping with less severe long-term atmospheric, climatic and biological effects of nuclear war. The necessary preparations to enable the population to cope with worst case nuclear winter conditions, however, might involve the peacetime expenditure of an unacceptably high level of resources.

Strategic Implications of U.S. and Soviet Perceptions of Nuclear Winter

The possibility of nuclear winter would likely increase the uncertainties for both the U.S. and the Soviet Union in considering use of nuclear weapons in a crisis. Some analysts have suggested, however, that the U.S. could face a situation in which American—but not Soviet—leaders were convinced that nuclear winter was a serious possibility.

In this case, if the Soviets believed that the U.S. was self-deterred from employing its limited nuclear options by fear of producing severe nuclear winter effects, U.S. deterrence could be weakened. The Soviets might perceive the U.S. as less likely to respond militarily to Soviet use of conventional forces, especially if possible U.S. responses risked escalation to nuclear weapons. The Soviet Union thus could be less reluctant to use military force on its periphery or to engage in military actions in the Third World.

The U.S. strategic position could be further weakened if the Soviets were not self-deterred from limited use of nuclear weapons to achieve policy goals because they did not believe that such uses of nuclear weapons would produce nuclear winter effects. The Soviets could gain leverage over the U.S. and exacerbate strains between the U.S. and its allies as the credibility of extended deterrence was reduced.

The above may not be the most likely scenario of U.S. and Soviet perceptions of nuclear winter, however. It is unlikely that U.S. leaders would believe that nuclear winter were possible and Soviet leaders would not. A decision to redesign U.S. limited nuclear attack options to minimize nuclear winter effects would have to be based on very compelling--and probably public--scientific findings. It is doubtful that Soviet scientific research on nuclear winter would contradict U.S. findings. Even if Soviet and U.S. findings differed on critical questions such as the level of nuclear weapons use likely to produce substantial nuclear winter effects, the Soviets would not necessarily believe that their results were conclusive. The Soviets would take seriously official U.S. statements indicating concern about minimizing potential nuclear winter effects when they detected evidence of this concern in U.S. force modernization programs and arms control approaches.

If the U.S. declared that it was taking steps to minimize potential nuclear winter effects of some of its limited nuclear options, doubt might be cast on the credibility of Soviet options for limited nuclear attacks, including potential counterforce attacks on U.S. ICBMs. By its actions as well as its words, the U.S. would be redefining the criteria of strategic capability--to the disadvantage of the Soviet Union. After the Soviets had spent tens if not hundreds of billions of rubles in the last decade modernizing their strategic forces and surpassing the U.S. in many measures of strategic capability, the United States program aimed at minimizing nuclear winter effects would be calling into question the value of that effort. A Soviet counterforce strike on U.S. ICBMs with SS-18s might no longer be a credible threat in a crisis because both sides would know it could lead to a global nuclear winter.

The Soviets might perceive the U.S. to be developing credible limited nuclear options that would give the United States a strategic advantage. The Soviets could feel compelled to begin a new round of modernization of their forces, emphasizing more accurate, lower yield warheads and more flexible delivery systems. They could view the U.S. as seeking to use the nuclear winter findings along with the Strategic Defense Initiative program to place new pressures on the Soviet Union to gain political leverage as well as strategic advantage.

In sum, the U.S. might be in a position to redefine the U.S.-Soviet strategic balance based on the nuclear winter findings. This reevaluation could place the Soviets at a disadvantage despite their massive military buildup of the last decade. It could also provide additional incentives for the Soviets to seek negotiated arms reductions to limit or prevent development of U.S. strategic advantages.

SECTION 3

ISSUES AND QUESTIONS FOR FURTHER RESEARCH

Although the nuclear winter findings to date may not warrant revision of the basic U.S. approach to nuclear strategy, planning and arms control, the possibility of nuclear winter effects raises many important technical and policy issues and questions. Some of these issues and questions cannot be fully considered without further scientific investigation. Others call for technical assessment by the Department of Defense, and may eventually require policy decisions. The following points, while not exhaustive, are intended to pose questions for further research and assessment while suggesting some of the elements that may remain unchanged.

Deterrence and Warplanning

The basic logic of nuclear deterrence is not likely to be altered by a new understanding of long-term atmospheric consequences of nuclear war. The ability to inflict unacceptable damage on the adversary after sustaining a first strike will likely continue to affect perceptions and thus peacetime and crisis deterrence even if nuclear war becomes more "unthinkable" because of the possibility of nuclear winter.

As long as nuclear weapons exist, even if both sides perceive a nuclear winter to be a possible outcome of a nuclear exchange, it is likely that to maintain deterrence, both the U.S.

and the Soviet Union will prepare to wage a nuclear war if deterrence fails. But the nuclear winter findings could lead to a reevaluation of the criteria and means of minimizing damage to one's country while at the same time achieving wartime goals. The U.S. is likely to seek to minimize the immediate destruction of U.S. territory by nuclear weapons even if a nuclear winter could eventually engulf the entire Northern Hemisphere or even the whole planet. The question therefore is not whether to plan for the possibility of using nuclear weapons, but rather whether potential nuclear winter effects should, or should not, affect such planning. Defense officials and nuclear planners are likely to be guided by the assumption that the less damage suffered by their society (including the military) in a nuclear exchange the better chance it will have of coping with the long-term effects of the use of nuclear weapons. The possibility of setting off a nuclear winter may increase the importance of war termination after relatively small nuclear exchanges and influence targeting options to minimize attacks on smoke and dust creating target areas such as cities. Specific issues and questions for targeting, damage assessment and C3I, strategic defense systems, and weapons research and development, arms control and civil defense are examined below.

Targeting

The TTAPS and other studies indicate that the key variables in determining the likelihood that nuclear explosions will trigger nuclear winter effects are:

- o smoke and dust creating potential of the targets and target areas
- o total yield
- o number of warheads used
- o time duration of the exchange
- o distance between explosions
- o yields of warheads and the heights of burst over particular targets

Based on these factors:

* Should the U.S. identify, categorize and set priorities for military targets based on their smoke and dust creating potential and their collocation with such areas?

* Should plans be reevaluated for attacking industrial targets, command and control centers and political control assets based on considerations of smoke and dust creation? Should energy targets be rated by this criterion, for example, and their priorities be reconsidered?

* Should some targets be placed in withhold categories to minimize collateral fires or dust? Should the U.S. consider various other means of reducing fires created by heat and blast?

* Should the U.S. consider a restructuring of target priorities and reexamine the yield, height of burst and accuracy of warheads assigned to specific targets? For example, could smaller, more accurate, earth-penetrating warheads--or even conventional warheads--be substituted in some cases?

* Should targeting for limited nuclear options and other attack options for controlling escalation be reevaluated?

* Is the option of targeting political leadership less credible because of collateral nuclear winter effects likely

be created by attacks on key party, military and security icilities in highly combustible areas?

* Would the particles in the smoke and dust layer affect RV :curacy or possibly damage warheads (fratricide on a massive :ale)? Would the atmospheric circulation patterns for the area : attack be altered in ways that are unpredictable and would :astically affect accuracy?

* Would the force multiplier effects of attacking C3I 'stems (preventing the launch of nuclear weapons without :stroying each weapon individually) suggest that an even greater :emium on C3I preemption may be a result of concern to minimize iclear winter effects?

* How would the prospect of nuclear winter affect the iclear strategies and force modernization policies of Britain, :ance and China?

3I and Damage Assessment

U.S. plans for controlling escalation and war termination :e dependent in part on accurate and timely damage assessments. iis ability to assess damage would be even more essential if :cision makers were trying to limit the nuclear winter effects :oduced by the total nuclear exchange as well as to control icalation and terminate conflict. U.S. means for intelligence illection, however, could be susceptible to degradation by irtial or total opacity of the atmosphere.

* How long after initial nuclear attacks would obscuration : potential intelligence targets begin to occur? At what rate iuld large quantities of soot and dust accumulate?

* How soon after a nuclear exchange could the developing iclear winter effects be assessed (on one's own territory and i the territory of the adversary)?

* How would the severity of damage assessment degradation : affected by changes in the time frame of nuclear weapons use, iat is, from most weapons used in a matter of hours to a more :otracted use of nuclear weapons?

* Would the nuclear winter obscuration effects inhibit our ability to control escalation and terminate conflict by weakening or neutralizing damage assessment and other intelligence collection capabilities?

* If a blanket of smoke and dust neutralized U.S. space-based platforms for damage assessment, are there alternative means for intelligence collection currently available for wartime use? Could new intelligence collecting means be developed and deployed that could "see" through nuclear winter effects?

* How would the progressive increase of atmospheric opacity (over several days) affect escalation control in a protracted conflict?

* Would C3I be so degraded after a Soviet counter-C3I attack that the degree of obscurance would be a moot point?

* Would the Soviets likely follow a multi-salvo strategy rather than a shoot-look-shoot strategy and thus not require real-time target damage assessment? If so, are the Soviets less vulnerable to disruption of their strategy by nuclear winter effects interfering with C3I?

* If the Soviets' rely primarily on air, ground and naval reconnaissance rather than space assets for theater conflict in Europe and Asia, would this provide them with an advantage over U.S. forces in protracted conflict in a nuclear winter environment?

* How would nuclear winter effects degrade military operations, for example, target acquisition? Would the disruption of overhead reconnaissance by nuclear winter effects provide protection for military activities on the ground, at sea and in the air following initial nuclear strikes?

Strategic Defense Systems

If nuclear winter obscuration effects would develop relatively slowly as the result of large-scale fires, these effects would not have significant consequences for defense systems in the initial stage of a nuclear conflict. Concern about minimizing nuclear winter effects, however, could affect U.S. policy on developing and deploying defense systems to destroy an adversary's missiles and warheads in flight to limit the number of nuclear explosions on U.S. territory.

* Should nuclear winter effects be considered in evaluating strategic defense research and development? Would strategic defense systems be degraded by large-scale accumulation of soot and dust in the atmosphere (degraded detection of launch; degraded detection and tracking of incoming warheads; degraded damage assessments; degradation of effectiveness of laser weapons systems)?

* Would warhead explosions in any or all of the phases of ballistic missile flight--the boost, post-boost, exo-atmospheric or terminal--contribute to nuclear winter effects?

* Would the ability to greatly reduce the number of nuclear weapons exploding on U.S. territory and thus mitigate nuclear winter effects in the United States reinforce the value of ballistic missile defense?

Weapons Research and Development

Should the United States decide to develop and deploy weapons systems that would make possible minimizing nuclear winter effects, criteria could be established for current and future R&D programs. In this case, R&D would likely focus on design and production of some flexible weapons systems with high accuracy and low-yield nuclear and conventional warheads. Earth-penetrating warheads could also be developed, including some moderate to high-yield weapons for buried targets. Such R&D programs could support ongoing efforts to further diversify the mix and flexibility of U.S. strategic systems.

* Should even greater efforts be made to decrease the yield and increase the accuracy of nuclear warheads to reduce nuclear winter effects? Should very low-yield warheads--one to ten kilotons--be developed for strategic missions and used for surface bursts or earth penetration to minimize the height at which dust and soot are injected into the atmosphere?

* Should R&D programs also focus on development of conventional weapons for strategic missions to reduce reliance on nuclear weapons?

U.S.-Soviet Arms Control

The possibility of nuclear winter is unlikely to fundamentally alter the arms control process or the outcome of any nuclear arms control negotiations. While the prospect of a nuclear winter may stimulate greater public pressure for negotiating U.S.-Soviet nuclear arms control limitations and reductions, the primary concerns of both the U.S. and the Soviet Union are likely to remain unchanged. In addition to seeking to avoid nuclear war, the two sides are likely to continue to be concerned about the impact of an agreement on the actual and perceived strategic balance and on each side's current and planned weapons programs. Desire to minimize nuclear winter effects may reinforce arms control approaches that favor placing limitations on systems with high-yield, low-accuracy warheads.

Some analysts studying the nuclear winter question have expressed concern that Soviet leaders may not take nuclear winter seriously, even if the U.S. concludes that some changes in nuclear strategy and planning are warranted as a result of the nuclear winter findings. Assymetrical perceptions and strategies could prevent the successful avoidance of nuclear winter effects in the event of a nuclear war. Arms control negotiations may provide a forum in which Soviet views of nuclear weapons effects could be better understood.

Specific arms control issues and questions raised by the nuclear winter findings include:

* What, if any, is likely to be the effect of the TTAPS findings on Soviet perceptions and positions in the arms control process?

* Should the U.S. design arms control proposals that allow both sides to modernize their nuclear arsenals in the direction of deploying smaller, more accurate weapons or other "technology" approaches to mitigating nuclear winter?

* How should the nuclear winter findings affect U.S. arms control approaches for INF and strategic systems, including the assumptions and goals behind negotiating positions, the weapons mixes to be preserved in U.S. forces, and the restructuring of Soviet forces the U.S. would like to affect? In SALT I and SALT II, for example, the U.S. structured the agreements to allow for modernization programs, including MIRVs, cruise missiles, the B-1 and the MX. Since SALT I, the U.S. has become increasingly concerned about the Soviet MIRVed ICBM threat to its land-based missiles and has sought to at least limit the number of warheads on Soviet ICBMs, and if possible to reduce the number of SS-18s and the overall Soviet throw weight advantage.

* Is there a contradiction between the goals of minimizing nuclear winter effects in the event of war and maintaining and improving crisis stability? Crisis stability could be weakened in some cases if the types of offensive weapons systems developed and deployed--such as small-yield, highly accurate warheads--appeared more "usable" in a crisis (and there were incentives for first use). Similarly, strategic defenses that destroyed nuclear warheads could reduce the chance of nuclear winter but increase instability.

* If a nuclear winter "threshold" were determined (including the mix of weapons, warhead size, and other factors necessary to cross the threshold) and the U.S. and the Soviet Union agreed to reduce their strategic and theater nuclear forces to a level "below the threshold," could such a major reduction be credibly verified? How would parity be determined at a significantly lower level of weapons systems?

Civil Defense

The possibility of a nuclear winter makes the obstacles to survival in a postwar environment appear even more formidable than earlier foreseen. But the prospect of long-term atmospheric effects produced by nuclear explosions does not completely obviate the need for protection of the population from the initial blast, fire and fallout of a nuclear attack—or from less severe nuclear winter effects such as short-term temperature depressions of a few degrees. It is likely that both the U.S. and the Soviet governments will continue to plan for providing some protection for the population from those effects, even if the survivors of the nuclear exchanges might face worst-case nuclear winter effects. The question for civil defense planners is whether they should alter or add to their programs to provide the survivors with the necessary tools and information to have a better chance of coping with the increasingly hostile post-war environment they may encounter.

If limited nuclear winter effects are possible and survivable, then the U.S. may want to consider augmenting its existing civil defense program that focuses on immediate blast effects and fallout. Some of the civil defense issues and questions raised by the nuclear winter findings follow:

* Is current U.S. civil defense planning either irrelevant to or inadequate for protection from nuclear winter effects?

* Would a civil defense program that adequately prepared the nation to survive severe nuclear winter effects be prohibitively expensive (hundreds of billions of dollars) and of questionable efficacy? Would such civil defense preparations be vulnerable to nuclear attack?

* If an effective civil defense program to assist survivors in the struggle against nuclear winter effects would be prohibitively expensive, should the U.S. take some steps to cope

with nuclear winter effects on a lesser scale (for example, sponsor research into crops that are less vulnerable to temperature changes and begin storage of large quantities of food to assist survivors through the initial months of deprivation)?

* Does the prospect of a nuclear winter reduce the strategic value of civil defense and eliminate any advantages held by the Soviet Union if the Soviet civil defense program, though more extensive, is based on the same assumptions and plans as the U.S. program?

* If the Soviets were to concentrate their civil defense efforts on preparing to survive nuclear winter effects, would they build on what they have, make extensive modifications, or scrap their existing programs?

* Do plans for evacuation of civilians from cities in a nuclear war become irrelevant if a nuclear winter will eventually descend on the survivors in the rural areas?

* What types of environmental and biological research should the U.S. sponsor and should any of this research be conducted jointly with scientists from the Soviet Union or other countries?

SECTION 4

REFERENCES

1. The TTAPS study was published in Science magazine as "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions," December 23 1983; complementing the TTAPS study in the same issue of Science is Dr. Paul R. Ehrlich et. al.'s "Long Term Biological Consequences of Nuclear War"; see also Carl Sagan, "Nuclear War and Climatic Catastrophe: Some Policy Implications," Foreign Affairs, Winter 1983-84; the nuclear winter thesis is also examined in the book, The Cold and the Dark, Norton, July, 1984, and in the article, "The Climatic Effects of Nuclear War," Scientific American, August 1984. The findings of these and other scientists were first publicly presented at a "World After Nuclear War Conference" held in Washington, DC, October 31 and November 1, 1983. A paper delivered at the conference by Soviet scientists V.V. Alexandrov and G.L. Stenchikov, entitled "On the Modelling of the Climatic Consequences of the Nuclear War," presented findings similar to those of the TTAPS study. The TTAPS study was preceeded by several other investigations of the subject, including the the 1975 National Academy of Sciences report, "Long-Term Worldwide Effects of Multiple Nuclear Weapon Detonations," studies published in the Swedish journal Ambio (1982), and discussions at the "Third International Conference on Nuclear War" in Erice, Italy (August 19-23, 1983). See the special issue of Ambio, "Nuclear War: The Aftermath," Volume XI, Numbers 2-3, 1982, and specifically, the article by Paul J. Crutzen and John W. Birks, "The Atmosphere After a Nuclear War: Twilight at Noon."

2. TTAPS, "Global Consequences of Nuclear War," October 24, 1983 (Original manuscript submitted to Science for publication), p. 1.

3. Edward Teller has argued that several factors may prevent the occurence of a nuclear winter. In an article published in Nature, Teller wrote that firestorms that loft smoke to a high altitude are very rare and depend on dense concentrations of fuel and precise weather conditions that allow all available oxygen to be consumed. See "Widespread After-Effects of Nuclear War," Nature, August 23, 1984. Calculations by scientists at Lawrence Livermore support Teller's theories. In one computer simulation of a detonation of a single-megaton explosion, Physicist Joyce Penner found that a column of smoke rose six miles into the sky, but that half the smoke dropped quickly into the troposphere. Penner estimated that the 50% that remained aloft contained nearly three times the condensation needed to produce rain. See Time, December 24, 1984. S. Fred Singer considers the possibility of a "nuclear summer" in "The Big Chill? Challenging

a Nuclear Scenario," Wall Street Journal, February 3, 1984. The nuclear summer theory has been investigated by a team of climate modelers. Their research has shown that climatic-effects projects are extremely sensitive to the way that key parameters are modeled. By replacing the normally "fixed" or static sun with one that appears to move across the sky, they were able, in some cases, to turn a nuclear winter into a nuclear summer. These results were cited by Dr. Edward Teller at a conference co-sponsored by the National Bureau of Standards and the Defense Nuclear Agency. See Science News, Vol. 126.

4. National Academy of Sciences, "The Effects on the Atmosphere of a Major Nuclear Exchange," Committee on the Atmospheric Effects of Nuclear Explosions, Commission on Physical Studies, Mathematics and Resources, National Research Council, December 11, 1984.

5. The concept of a nuclear winter "threshold" was included in the TTAPS Science article. The authors noted that "one can envision the release of ~ 1×10^6 tons of smoke from each of 100 major city fires consuming ~ 4×10^7 tons of combustible material per city. Such fires could be ignited by 100 Megatons of nuclear explosions. . . . such a low threshold yield for massive smoke emissions, although scenario-dependent, implies that even limited nuclear exchanges could trigger severe after effects." See also Carl Sagan's article in Foreign Affairs, for reference to "sub-threshold wars." (p. 277) In the article Sagan also noted that "it seems clear that the species is in grave danger at least until world arsenals are reduced below the threshold for climatic catastrophe." (p. 284) Reference is also made to a nuclear winter threshold in The Cold and the Dark, which describes a "threshold region in which, it now appears, nuclear winter could be triggered" (pp 26-28, 106-107).

6. Some people have referred to these lesser, "patchy" effects leading to a severe nuclear winter as "nuclear autumn." For references to patchy rather than uniform nuclear winter effects and a continuum of conditions see: Michael C. MacCracken, "Nuclear War: Preliminary Estimates of the Climatic Effects of a Nuclear Exchange," Lawrence Livermore National Laboratory, paper presented at the Third International Conference on Nuclear War, Erice, Italy, August 19-23, 1983; Curt Covey, Stephen H. Schneider and Stanley L. Thompson, "Global Atmospheric Effects of Massive Smoke Injections from a Nuclear War: Results from General Circulation Models," National Center for Atmospheric Research, Boulder, Colorado, January 6, 1984; and Michael C. MacCracken, Annotated Outline, "Atmospheric Calculations on Nuclear Winter," Lawrence Livermore National Laboratory, June 11, 1984, pp. 5-8.

7. The smallest megatonnage exchage examined in the TTAPS study, as noted in Part I, was a scenario involving the use of 1,000 warheads of 100 kilotons each against 1,000 urban/industrial targets. This scenario, which the TTAPS authors acknowledged was most likely to occur only as part of a larger exchange, produced significant nuclear winter effects. While such an attack scenario involved a limited number of nuclear weapons, it would not constitute a credible limited nuclear attack option. Nuclear attacks on 100 major cities would not be perceived as limited and would be almost certain to invite large-scale retaliation against the attacker's cities. Thomas Powers argues that this scenario "contradicts too many principles of nuclear strategy." "If American war planners elected to 'limit' a war to 100 megatons," he argues, "they would stay away from cities, which are generally targeted only in the final, all-out phases of war plans. If the planners decided to hit 1,000 urban targets (an attack virtually certain to bring all-out response), they would use a lot more than 100 megatons and would target a lot of other things as well." Thomas Powers, "Nuclear Winter and Nuclear Strategy," The Atlantic, November 1984.

8. This point was made by Leon Goure in his statement before the House Subcommittee on Natural Resources, Committee on Science and Technology, "Some Potential Strategic Implications of the 'Nuclear Winter' Hypothesis," September 12, 1984.

9. Goure, Leon, statement before House Subcommittee on Natural Resources, Committee on Science and Technology, "Some Potential Strategic Implications of the 'Nuclear Winter' Hypothesis," notes that the nuclear winter findings "appear to enhance the utility of strategic defense of both military and strategic targets." He argues that "given that stratospheric dust produced by the detonation of large yield nuclear weapons on hard targets such as missile silos slows the return to ambient climatic conditions, the pursuit of damage limitation may be better served by the strategic defense of such targets than by counterforce strikes."

10. The National Academy of Science has estimated that a one degree temperature drop in the Northern Hemisphere could end wheat production in Canada. Although some plant species are particularly resistant and can withstand severe temperature fluctuations, many major food crops such as corn, rice and soybeans are particularly unresilient. National Academy of Science 1975 Study, op. cit., pp. 93-94; Paul Ehrlich et al., in Science, op. cit., discuss the sensitivity of rice and sorghum to cold temperatures and notes that exposure to a temperature of only 13 degrees C. at a crucial time can inhibit grain formation because the resultant pollen are sterile. Additionally, corn and soybeans are very sensitive to temperatures below 10 degrees C.; Richard Turco has noted that scientists are recognizing that

agriculture may well be the most sensitive biological system to be affected by cold temperatures, Defense Science Board panel on Atmospheric Obscuration, July 17, 1984; Sidney Winter detailed the susceptibility of agriculture to nuclear winter effects before the Joint Economic Committee on July 12, 1984; see also Sagan, Foreign Affairs, op. cit., pp. 265-66; and The Cold and the Dark, op. cit., pp. 54-56.

11. One analyst has estimated that "serious" preparedness measures would involve expenditure rates of ten to one hundred times higher than current expenditures on civil defense. See Sidney G. Winter, "Economic Consequences of Nuclear War," testimony prepared for the Joint Economic Committee, July 12, 1984, p. 4.

12. The Soviet Academy of Sciences, in May 1983, formed a group called, "The Committee of Soviet Scientists for the Defense of Peace and Opposition to the Nuclear Threat" which delivered a paper at the October/November conference in Washington. The Soviet paper, which parallels the TTAPS findings, is co-authored by V.V. Alexandrov and G.L. Stenchikov, and is entitled "On the Modelling of the Climatic Consequences of the Nuclear War," The Computing Centre of the Academy of Sciences, Moscow, USSR, 1983.

13. See the special issue, "Nuclear War: The Aftermath," Volume XI, Numbers 2-3, 1982, specifically, Paul J. Crutzen and John W. Birks, "The Atmosphere After a Nuclear War: Twilight at Noon."

14. The nuclear winter thesis has been assessed in several other conferences, including: an international seminar conducted by "the Scientific Committee on Problems of the Environment" (SCOPE) in Paris on October 22-24, 1984 (earlier sessions of SCOPE were held in Leningrad on May 15, 1984, New Delhi (February 1984), Stockholm (November 1983), and London (March 1983). SCOPE, whose headquarters is in London, intends to publish a comprehensive report on the implications of nuclear winter in June 1985; an American Association for the Advancement of Science (AAAS) workshop, "Long-Term Environmental and Biological Consequences of Nuclear War," AAAS Annual Meeting in New York, May 29, 1984; a Stanford University "Workshop on Biological and Ecological Research on the Effects of Global Thermonuclear War and Nuclear Winter," Stanford, California, June 11-13, 1984; "Nuclear Deterrence: New Risks, New Opportunities," University of Maryland Conference, September 5-7, 1984; The National Bureau of Standards Conference on "Large [Nuclear War] Scale Fire Phenomenology," Gaithersburg, Maryland, September 10, 1984; and the University of South Carolina Conference, "Nuclear Winter and the Prevention of Nuclear War," Institute of International Studies, November 29-December 1, 1984.

15. Congressional hearings on the climatic consequences of nuclear war, as well as on the specific topic of nuclear winter, include: Committee on Science and Technology, U.S. House of Representatives, "The Consequences of Nuclear War on the Global Environment," September 15, 1982 (House Report, together with minority and dissenting views, August 3, 1983); "U.S.-Soviet forum on the Climatic Effects of Nuclear War," sponsored by Senators Kennedy and Hatfield, December 8, 1983; Joint Economic Committee hearings on "The Consequences of Nuclear War," July 11-12, 1984; and the Committee on Science and Technology, U.S. House of Representatives, Subcommittee on Natural Resources, Agricultural Research and Environment, "Hearings on the Climatic, Biological and Strategic Effects of Nuclear War," September 12, 1984.

16. See the Congressional Record--House, p. H 10230, September 26, 1984.

17. For a summary of the Federation of American Scientists activities, see the F.A.S. Public Interest Report, Volume 37, No. 1, January 1984; for Physicians for Social Responsibility activities, see their Spring 1984 PSR Newsletter, especially "The Risks of Nuclear War: New Data, New Technology."

18. The Center has also published an issue of "The Nuclear Winter News," September 1984 and has distributed copies of the April 1984 issue of the Bulletin of the Atomic Scientists which details the conference findings.

19. See U.N. #A/C.1/39/L.22 "Resolution on Nuclear Winter," introduced by India, Mexico, Pakistan, Sweden, Uruguay and Yugoslavia; and #A/C.1/39/L.69/REV.1, "Studies on Climatic Effects of Nuclear War Including the Possibility of Nuclear Winter," introduced by Belgium, Canada, the Federal Republic of Germany and Japan.

APPENDIX A

CONFERENCES AND ACTIVITIES CONCERNING NUCLEAR WINTER

The findings of TTAPS and other scientists were first presented at a "World After Nuclear War Conference" held in Washington, DC, on October 31 and November 1, 1983. The conference was sponsored and attended by prominent scientists and academics as well as by representatives of diverse public interest groups. Two technical papers were presented, one by Dr. Carl Sagan of Cornell University entitled the "Global Atmospheric Consequences of Nuclear War" (the TTAPS study), and a second, by Dr. Paul R. Ehrlich of Stanford University, which represented a consensus of forty biologists who attended a meeting on the "Long-Term Worldwide Biological Consequences of Nuclear War," held in Cambridge, Massachusetts on April 25-26, 1983. The World After Nuclear War Conference received considerable press and public attention, enhanced by a satellite link-up with physicists and biologists in the Soviet Union. [12]

The global atmospheric consequences of nuclear war had been examined previously: in the 1975 government-sponsored report by the National Academy of Sciences' entitled "Long-Term Worldwide Effects of Multiple Nuclear Weapon Detonations"; in the Swedish journal Ambio [13]: and at the "Third International Conference on Nuclear War" held in Erice, Italy (August 19-23, 1983) [14]. But it is generally acknowledged that the TTAPS study raised new questions regarding the potential long-term consequences of uclear war by placing more emphasis on the climatic effects of moke and soot in the atmosphere.

The U.S. Congress has also shown considerable interest in he potential implications of nuclear winter. In addition to umerous Congressional hearings [15], the FY-85 Defense uthorization Act required that a report on nuclear winter indings and policy implications be submitted to Congress. A eport was submitted on March 1, 1985. This report is to assess the atmospheric, climatic, environmental and biological onsequences of nuclear war and the implications that such onsequences have for the nuclear weapons strategy and policy, he arms control policy, and the civil defense policy of the nited States." [16]

Public interest groups that have demonstrated interest in he nuclear winter thesis include: the Council for a Livable orld, which worked closely with the organizers of the World fter Nuclear War Conference and has published an information ooklet called "The Nuclear Winter" based on Dr. Carl Sagan's onference presentation; the National Resources Defense Council NRDC) which has organized a "Project Nuclear Winter" and has ublished a booklet entitled "Nuclear Winter, Silent Spring" (1984); the Federation of American Scientists which helped to rganize the Kennedy-Hatfield U.S.-Soviet forum (December 8, 983) and the Joint Economic Committee Hearings (July 11-12, 984); and Physicians for Social Responsibility which conducted anels entitled, "Nuclear War and Survival" that have used the echnical evidence of the TTAPS findings. [17]

In addition, a "Center on the Consequences of Nuclear War" 'as established in December 1983 to disseminate the scientific 'indings that were presented at the October/November 1983 World ,fter Nuclear War Conference. The Center is located in lashington and provides the most recent scientific studies, .nformation and materials (print and audio-visual) of the nuclear 'inter thesis to organizations and the media. The center has lisseminated several thousand copies of the two Science magazine ırticles. [18]

In addition to the international interest generated by the ;COPE meetings (see footnote 3), it should also be noted that the Inited Nations has had two resolutions introduced that express interest in the nuclear winter thesis. [19]

APPENDIX E

BIBLIOGRAPHY

Conferences and Academic/Scientific Papers

1. Alexandrov, V.V. and Stenchikov, G.L., "On the Modelling of the Climatic Consequences of the Nuclear War," The Computing Centre of the USSR Academy of Sciences, Moscow, USSR, 1983.

2. American Association for the Advancement of Science (AAAS), "Long-Term Environmental and Biological Consequences of Nuclear War: Does it Matter?," recording conferance held in New York, May 29, 1984; presentations include: Richard P. Turco, "Smoke, Dust and Radioactivity Produced by Nuclear Explosions"; Stephen H. Schneider, "Climatic Effects of Emission Scenarios"; David Pimentel, "Agricultural and Biological Impacts of Nuclear War Scenarios"; Charles A. Zraket, "Implications for Military Planners"; Brent Scowcroft, "Reactions of Noncombatant Nations to the Nuclear Winter Scenario."

3. Bierly and Mirabito, "The U.S./USSR Agreement on Protection of the Environment and its Relationship to the U.S. National Climate Program," Bulletin of the American Meteorological Society, January 1984, 11 pgs.

4. Conrad, Michael, "Adaptability Theory as a Framework for the Study of Nuclear Winter," Stanford Conference, June 1984, 7 pgs.

5. Covey, et. al., "Global Atmospheric Effects of Massive Smoke Injections from a Nuclear War: Results from General Circulation Model Simulations," Nature, 308, March 1984.

6. Crutzen, Paul J. and Birks, John W., "The Atmosphere After a Nuclear War: Twilight at Noon," Ambio, Vol. XI, #2-3, 1982.

7. Ehrlich, et al., "Long Term Biological Consequences of Nuclear War," Science, December 23, 1983, 10 pgs.

8. Knox, Joseph B., "Global Scale Deposition of Radioactivity from a Large Scale Exchange," Lawrence Livermore National Laboratory (LLNL) Document #89907, 18 pgs.

9. Luther, Fredrick M., "Nuclear War: Short-Term Chemical and Radiative Effects of Stratospheric Injections," LLNL Document #89957, 21 pgs.

10. MacCracken, Michael C., "Nuclear War: Preliminary Estimates of the Climatic Effects of a Nuclear Exchange," LLNL Document #89770, 23 pgs.

11. MacCracken, Michael C., "Annotated Outline of Atmospheric Calculations on Nuclear Winter: Status Report," Stanford Conference, June 11, 1984, 13 pgs.

12. National Academy of Sciences, "Long-Term Worldwide Effects of Multiple Nuclear Weapon Detonations," 1975.

13. National Academy of Sciences, "The Effects on the Atmosphere of a Major Nuclear Exchange," Committee on the Atmospheric Effects of Nuclear Explosions, Commission on Physical Studies, Mathematics and Resources, National Research Council, December 11, 1984, 193 pgs.

14. Penner, Joyce E., "Tropospheric Response to a Nuclear Exchange," LLNL Document #89956, 13 pgs.

15. Sagan, Carl, "Nuclear War and Climatic Catastrophe: Some Policy Implications," Foreign Affairs, Winter 1983-84.

16. Stommel, Henry, "The Year Without a Summer," Scientific American, Vol. 240, June 1979, pgs. 176-86.

17. Stothers, Richard B., "The Great Tambora Eruption in 1815 and Its Aftermath," Science, June 15, 1984, p. 1191.

18. Tarter, Bruce, et al., "LLNL Study of the Global-Scale Physical Effects of a Nuclear Exchange: Preliminary Findings," August 15, 1984.

19. Thompson, et al., "Global Climatic Consequences of Nuclear War: Simulations with 3-D Models," Draft Submitted to Ambio on December 16, 1983, 33 pgs.

20. Turco, Toon, et al. (TTAPS), "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions," Science, December 23, 1983.

21. Turco, et al. (TTAPS), "The Climatic Effects of Nuclear War," Scientific American, August 1984.

Articles, Books, and Reports

22. Angier, Natalie, "Debate Over a Frozen Planet," Time, December 24, 1984, 2 pgs.

23. "Soviet Study Says Weapons of One Sub Could End All Life," Baltimore Sun, August 27, 1984, p. 2.

24. Barton and Paltridge, "Twilight at Noon Overstated," Ambio, Vol. 13, No. 1, 1984, 4 pgs.

25. Begley, et al., "Nuclear War: The Long View," Newsweek, November 7, 1983, 1 pg.

26. Broad, William J., "U.S. Weighs Risk That Atom War Could Bring Fatal Nuclear Winter," New York Times, August 5, 1984, p. 1.

27. Carrier, Geroge F., "The State of the Science," also commentaries by Michael M. May, Albert Gore, Jr., George W. Rathjens and Ronald H. Siegel, Theodore A. Postol, Richard L. Wagner, Jr., "Strategic Significance," Issues in Science and Technology, Winter 1985, p. 112.

28. Center on the Consequences of Nuclear War, "Nuclear Winter News," September 1984.

29. Clawson, Patrick, letter to the editor, Foreign Affairs, Spring, 1984, 2 pgs.

30. Cohen, Sam, "Nuclear Winter vs. Nuclear Reality," Colorado Springs Gazette-Telegraph, August 15, 1984.

31. Council for a Livable World, "The Nuclear Winter," pamphlet, 1984.

32. Crutzen, Paul J., "A Nuclear Winter," Ambio, Vol. 13, No. 1, 1984, 4 pgs.

33. "U.S. Plans to Discuss 'Nuclear Winter' With Soviets," Defense Daily, July 16, 1984, p. 70.

34. Ehrlich, Anne, "Nuclear Winter," Bulletin of the Atomic Scientists, April 1984, 14 pgs.

35. Ehrlich, Paul, "The Nuclear Winter," The Amicus Journal, Winter, 1984, 7 pgs.

36. ----------, "North America After War," Natural History, March 1984, 3 pgs.

37. ----------, "When Light is Put Away, Ecological Effects of Nuclear War," The Counterfeit Ark: Crisis Relocation for Nuclear War, 1984, 13 pgs.

38. ---------, et al., The Cold and the Dark: The World After Nuclear War, Report of the Conference on the Long-Term Worldwide Biological Consequences of Nuclear War, W. Norton & Company, New York, 1984.

39. Evans, Joseph P., "The Big Chill," Commonwealth, April 20, 1984, p. 231.

40. Federation of American Scientists, F.A.S. Public Interest Report, Volume 37, No. 1, January 1984.

41. Garn, Jake, "Nuclear Weapons: The Case for Weapons Reductions and Defense," Christian Science Monitor, August 21, 1984, p. 20.

42. Goodman, Ellen, "National Nuclear Follies: FEMA and the Farmers," Boston Globe, November 10, 1984.

43. Grover, H.D., "The Climate and Biological Consequences of Nuclear War," Environment, May 26, 1984.

44. Haaland, Carsten, "Nuclear Winter and National Security," Journal of Civil Defense, February 1984, 3 pgs.

45. Hanson, Christopher, "Nuclear Winter Idea Puts 'Freeze' on War," Chicago Tribune, September 9, 1984, Section 6, p. 3.

46. Harwell, Mark A., Nuclear Winter: The Human and Environmental Consequences of Nuclear War, Springer-Verlag, New York, 1984.

47. Hilts, Philip J., "Nuclear Winter . . . Confirmed by Soviet Scientists," Washington Post, November 2, 1983, 1 pg.

48. ---------, "Scientists Say Nuclear War Could Cause Climatic Disaster," Washington Post, December 9, 1983, 1 pg.

49. ---------, "U.S. Begins Study of Possible Climatic Disaster in Nuclear War," Washington Post, May 29, 1984, p. 6.

50. Holden, Constance, "Scientists Describe Nuclear Winter," Science, November 18, 1983, 2 pgs.

51. Horne, A.D., "Nuclear Climate More Lethal Than Predicted, Soviets Say," Washington Post, December 9, 1983, 1 pg.

52. Horowitz, Dan and Lieber, Robert J., letter to the editor, Foreign Affairs, Spring, 1984, 2 pgs.

53. Katz, Jonathan, "Nuclear Winter Effects Not Settled," letter to the editor, New York Times, January 5, 1985.

54. Kearny, Cresson H., "On a 'Nuclear Winter'," letters in Science, Vol. 227, January 25, 1985, p. 227.

55. McGrory, Mary, "Biologists Paint an Icy Picture . . .," Washington Post, November 1, 1983, 1 pg.

56. McWilliams, Rita, "Hill Told Money Won't Buy Nuclear Survival," Washington Times, July 13, 1984, p. 4.

57. Natural Resources Defense Council, "Nuclear Winter, Silent Spring," 1984.

58. "Winter Kills," editorial, The Nation, August 30, 1984.

59. National Academy of Sciences, "Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations," 1975.

60. "Nuclear Winter, Star Wars," editorial, New York Times, December 14, 1984.

61. "The Winter After the Bomb," editorial, New York Times, November 1, 1983, 1 pg.

62. "Nuclear Winter and Its Smoke," editorial, New York Times, August 19, 1984.

63. "Nuclear Winter Study Could Help," editorial, Omaha World-Herald, July 24, 1984.

64. Physicians for Social Responsibility, "The Risks of Nuclear War: New Data, New Technology," PSR Newsletter, Spring 1984.

65. Plous, Scott, "Will Deterrence Survive a Nuclear Winter?," Science, July 20, 1984, p. 268.

66. Powers, Thomas, "Nuclear Winter and Nuclear Strategy," The Atlantic, November 1984, p. 53.

67. Quester, George H., "New Risks, New Opportunities," Baltimore Sun, August 21, 1984, p. 15.

68. Raloff, Janet, "Beyond Armageddon," Science News, November 12, 1983, p. 314.

69. Rensberger, Boyce, "National Academy of Sciences Backs Nuclear Winter Theory," Washington Post, December 12, 1984.

70. Rogers, Ed, "Devastating 'Nuclear Winter' Could Follow Atomic War, NRC Says," Washington Times, December 12, 1984.

71. Sagan, Carl, "The Nuclear Winter," Parade, October 30, 1983, 3 pgs.

72. ----------, "Nuclear War and Climatic Catastrophe: Some Policy Implications," Foreign Affairs, Winter 1983-84, 35 pgs.

73. ----------, "The Chilling Aftermath of a Nuclear War," letter to the editor, Wall Street Journal, February 16, 1984, 1 pg.

74. ----------, The Nuclear Winter," Science Fiction Magazine, March 1984, 7 pgs.

75. ----------, "A Nuclear Theory That Can't Be Tested," letter to the editor, New York Times, December 29, 1984.

76. Schneider, Stephen H., Notes from a presentation on "Climatic Effects of Smoke and Dust Scenarios After Nuclear War," includes historical material from The Coevolution of Climate and Life, May 29, 1984, 7 pgs.

77. Sehlstedt, Albert, "International Study is Urged on Nuclear War, Atmosphere," Baltimore Sun, September 13, 198[illegible], p. 14.

78. Seitz, Russell, letter to the editor, Foreign Affairs, Spring 1984, 2 pgs.

79. Shabecoff, Philip, "Grimmer View Painted of Nuclear War Effects," New York Times, October 31, 1983, 1 pg.

80. Simon, Herbert, "Mutual Deterrence or Nuclear Suicide," Science, February 24, 1984, 1 pg.

81. Sinclair, Ward, "Crops Seen Nuclear Survivor," Washington Post, December 6, 1983, 1 pg.

82. Singer, S. Fred, "The Big Chill," Wall Street Journal, February 3, 1984, 1 pg.

83. ----------, "On a 'Nuclear Winter'," letters in Science, Vol. 227, January 25, 1985, p. 356.

84. Smith, R. Jeffrey, "NRC Panel Envisions Potential Nuclear Winter," Science, December 21, 1984, p. 1403.

85. "The Meaning of Nuclear Winter," editorial, St. Louis Post-Dispatch, July 18, 1984.

86. Strout, Richard L., "The Arresting Issue of Nuclear Warfare," Christian Science Monitor, January 6, 1984, p. 15.

87. ---------, "Modern Dinosaurs in a Nuclear Winter," Christian Science Monitor, December 21, 1984, p. 14.

88. Sullivan, Walter, "Specialists Detail 'Nuclear Winter'," New York Times, December 26, 1983, p. 15.

89. Teller, Edward, "Widespread After-Effects of Nuclear War," Nature, August 23, 1984, p. 261.

90. Torsney, Janet, "Nuclear Winter and Nuclear War," The Interdependent, January/February 1984, 2 pgs.

91. TTAPS, "On a 'Nuclear Winter'," letters in Science, Vol. 227, January 25, 1985, p. 356.

92. "Military Experts Accept 'Nuclear Winter' Scenario," Washington Post, July 12, 1984, p. 32.

93. Zuckerman, Edward, "The End-of-the-World Scenarios," New York Times, November 24, 1984, p. E17.

Congressional Testimony and Materials

94. Committee on Science and Technology, U.S. House of Representatives, "The Consequences of Nuclear War on the Global Environment," September 15, 1982 (House Report, together with minority and dissenting views, August 3, 1983).

95. Congressional Requirement for a Report on Nuclear Winter, Congressional Record, House, p. H10230, September 26, 1984.

96. Emery, David F., "Consequences of Nuclear War," Statement before the Joint Economic Committee, July 11, 1984.

97. Gayler, Noel, "Consequences of Nuclear War," Statement before the Joint Economic Committee, July 11, 1984.

98. Gould, Stepen J., "The Biology of Nuclear Winter," Statement before the House Subcommittee on Natural Resources, Agricultural Research and Environment, September 12, 1984.

99. Goure, Leon, "Some Potential Strategic Implications of the 'Nuclear Winter' Hypothesis," Statement before the House Subcommittee on Natural Resources, Agricultural Research and Environment, September 12, 1984.

100. Hecht, Alan, Statement before the House Subcommittee on Natural Resources, Agricultural Research and Environment, September 12, 1984.

101. Murray, Russell, Statement before the Joint Economic Committee, July 11, 1984.

102. Office of Technology Assessment, "The Effects of Nuclear War," May 1979.

103. Postol, Theodore A., "Possible Military and Strategic Implications of Nuclear Winter," Statement before the House Subcommittee on Natural Resources, Agricultural Research and Environment, September 12, 1984.

104. Teller, Edward, Statement before the Subcommittee on Natural Resources, Agricultural Research and Environment, September 12, 1984.

105. Wagner, Richard L., Statement before Joint Economic Committee, July 11, 1984.

106. Warnke, Paul C., "Consequences of Nuclear Warfare," Statement before the Joint Economic Committee, July 11, 1984.

107. Winter, Sidney G., "Economic Consequences of Nuclear War," Statement before the Joint Economic Committee, July 12, 1984.

International Views and Press Reaction

108. Aleksandrov, V.V., and Stenchikov, G.L., "On the Modelling of the Climatic Consequences of the Nuclear War," The Computing Centre of the USSR Academy of Sciences, Moscow, USSR, 1983, 53 pages.

109. Barnaby, Frank, "Is the South Safe?," South, January 1984, p. 11.

110. Foreign Broadcast Information Service (FBIS), Daily Report, Soviet Union, "Scientists Warnings on Nuclear War Effects Surveyed," July 15, 1983, 9 pgs.

111. -----------, on U.S.-USSR Symposium on Nuclear War Results, December 13, 15, 30, 1983, 4 pgs.

112. -----------, Soviet Union, May 18, 1983, 7 pgs.

113. ----------, Soviet Union, May 19, 1983, 10 pgs.

114. ----------, Soviet Union, May 20, 1983, 7 pgs.

115. ----------, Soviet Union, May 23, 1983, 9 pgs.

116. ----------, Soviet Union, "Leningrad Seminar Forecasts Nuclear War Results," June 6, 1984, p. AA6.

117. ----------, Soviet Union, "Weather Seminar Delegate Cites Nuclear War Effects," June 19, 1984, p. CC11.

118. ----------, Soviet Union, "U.N. Conference on Disarmament Held in Leningrad," June 19, 1984, p. AA8.

119. ----------, Soviet Union, "Congress Hearings Held on Nuclear War Outcome," July 12, 1984, p. A6.

120. ----------, Soviet Union, "Academy Computer Director Writes on 'Nuclear Winter'," (JPRS-UMA-84-066), August 3, 1984, p. 23.

121. ----------, Soviet Union, "Scientists on Global Consequences of Nuclear War," August 6, 1984, p. AA6.

122. ----------, Soviet Union, "Environmental Dangers of Nuclear War Noted," October 4, 1984, p. CC6.

123. ----------, Soviet Union, "Moscow TV Cites NBC Commentary on Nuclear Winter," (JPRS-UMA-84-066), October 22, 1984, p. 8.

124. ----------, Soviet Union, "Academician Views Arms Issues, Nuclear Winter," November 8, 1984, p. AA5.

125. ----------, Soviet Union, "Lyutyy Comments on U.S. 'Nuclear Winter' Report," December 13, 1984, pp. AA-10-AA-11.

126. ----------, Western Europe, "Erice Conference on Effects of Nuclear War Ends," August 24, 1984, p. A1.

127. Garcia, Jorge, "Alto a la Guerra Nuclear," The Excelsior (Mexico), May 30, 1984, p. 8A.

128. "A Cold, Dark, Starving World," Globe and Mail, November 2, 1983, p. 1.

129. Myers, Norman, "Why Is No One Afraid of the Dark?," The Guardian, March 1, 1984.

130. "Atom War Report for Pope," The Daily Telegraph, February 11, 1984, p. 8.

131. "Cold, Dark World Would Starve After Nuclear War, Scientists Say," Toronto Star, November 1, 1983.

132. United Nations, "Resolution on Nuclear Winter," introduced by India, Mexico, Pakistan, Sweden, Uruguay and Yugoslavia, #A/C.1/39/L. 22.

133. United Nations, "Studies on Climatic Effects of Nuclear War Including the Possibility of Nuclear Winter," introduced by Belgium, Canada, the Federal Republic of Germany and Japan, #A/C.1/39/L. 69/REV. 1.

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