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Report to the Congress

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NUCLEAR WINTER

Uncertainties Surround the Long-Term Effects of Nuclear War

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Comptroller General
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To the President of the Senate and the
Speaker of the House of Representatives

This report examines scientific and policy implications of nuclear winter. It is based on extensive review of relevant literature and detailed discussions with a wide range of scientists, researchers, and policy analysts within and outside of government. It provides an overview of what is known about nuclear winter and of ongoing research addressing areas of scientific uncertainty. It also outlines potential implications for defense strategy, arms control, and foreign policy-making and points out the absence of a consensus on the need for policy changes at this time. We undertook this review because the nuclear winter issue deals with a controversial subject that lends itself to polarized views and misunderstandings.

Copies of this report are being sent to appropriate House and Senate Committees; the Secretaries of Defense, Energy, and State; the Administrators of the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration; the Office of Science and Technology Policy; and other interested parties.

Charles A. Bowsher
Comptroller General
of the United States

Executive Summary

"Nuclear winter"—a term used to describe potential long-term climatic and environmental effects of nuclear war—has been the subject of recent controversy. Scientists are researching the possibility that surface temperatures could be dramatically reduced by large quantities of sun-blocking smoke and dust particles injected high into the atmosphere, which could affect the survivors of a nuclear war. According to the theory, distant countries not directly involved could also be affected.

The controversy surrounding nuclear winter has polarized views about its scientific basis and potential policy implications. This report provides the Congress and others with (1) an overview of the science of nuclear winter, (2) pertinent information for considering policy implications, and (3) the status of U.S. research.

Background

Before 1982, studies on the effects of nuclear war focused mainly on immediate blast damage, radioactive fallout, and potential harm to the ozone layer which shields the earth from harmful ultraviolet rays. Two recognized reference works on the effects of nuclear war were issued by the National Academy of Sciences in 1975, and by the Office of Technology Assessment in 1979. Neither dealt substantively with long-term environmental effects.

In 1982 research began to suggest that soot, smoke, and dust injected into the atmosphere could produce global environmental and climatic disturbances. Nuclear winter was the term chosen by one research group to portray those effects.

The National Academy of Sciences, in December 1984, completed a Department of Defense (DOD) funded study assessing the nuclear winter theory. Stressing the many uncertainties in the theory's assumptions, this report found the theory plausible and recommended further research to reduce the uncertainties. Although the Academy could not confidently quantify potential long-term consequences, it did assert that nuclear war analyses should consider nuclear winter implications.

U.S. research is now trying to reduce these uncertainties. Approximately $3.5 million was devoted to nuclear winter studies in fiscal year 1985, principally through the Departments of Defense and Energy and the National Science Foundation. Fiscal year 1986 funding will be $5.5 million, and the research will be guided by an interagency plan developed at the request of the President's Science Advisor.

Results in Brief

GAO extensively reviewed pertinent research studies and scientific literature and discussed the range of nuclear winter issues with prominent scientists, researchers, and policy analysts in and out of government. (See appendixes I and II.) Overall, the consensus was that significant uncertainties and unknowns require further research.

Given these uncertainties, the administration believes policy changes based on the theory would be premature at this time. (See pp. 26-28.) Some scientists and policy analysts believe that the theory supports changes to some existing policies, but precisely what should be done and when remains unclear. (See pp. 29-35.)

The administration's interagency program for studying the scientific uncertainties is now underway. (See pp. 36-37.) The potentially far-reaching implications of the nuclear winter phenomenon suggest the need for continued congressional oversight to assure adequate attention is given to these implications.

GAO's Analysis

Current research has identified nuclear winter as a plausible theory with numerous uncertainties in critical areas such as war scenarios, fire research, and climate modeling. Some of these uncertainties will remain unresolved; some can be reduced by further research.

War Scenarios

War scenarios, important in calculating the potential effects, will remain uncertain due to the uncertainty of critical warfighting variables such as the targets, warheads, number/yield of weapons, and whether the weapons would be detonated on, above, or beneath the ground. The season of the year and weather conditions before, during, and after the detonations are also important considerations. (See pp. 16 and 17.)

Fire Research

Nuclear winter presupposes the injection of fire-produced smoke and soot into the atmosphere. Present research gives us limited knowledge of the fire effects of nuclear war. Significant components of fire research include combustibility of target areas, how much smoke is produced, how high it is injected into the atmosphere, and how much sunlight is absorbed by smoke particles. (See pp. 17-21.)

Computer Modeling

Scientists use computer simulations to project nuclear winter based on assumptions about war fighting variables and the amount of smoke and soot particles thrust into the atmosphere. Computer models have limited accuracy in representing physical laws of nature and the atmospheric disturbances integral to war. Specific modeling limitations include adequately representing small-scale weather variations, effect of moisture on smoke particles, smoke cloud movement, smoke particle chemical compositions and size changes, and analogues to validate projected results. Current research seeks to improve climate models and simulations of atmospheric conditions and responses. (See pp. 21-23.)

Interagency Research Plan

The administration's new interagency research program, begun in fiscal year 1986, ties together ongoing nuclear winter research efforts at various government laboratories and provides fiscal year 1986 funding that represents a $2 million increase over fiscal year 1985. However, some scientists believe the current funding level is insufficient to achieve timely research objectives. Future funding and research beyond fiscal year 1986 are contemplated but thus far have not been spelled out in the formal interagency plan. Some scientists are concerned that the interagency coordinating mechanisms will not be able to control funding effectively to assure that participating agencies perform priority research. (See pp. 36-40.)

Policy Implications

The administration is cautious about changing defense policy based on the nuclear winter theory; others, primarily outside of government, see policy implications in deterrence, nuclear arsenals, warfighting capabilities, targeting and strategy, and crisis management and control efforts. Some see nuclear winter deterring nuclear war; others speculate about a race to seek weapons or strategy to avoid nuclear winter consequences. Some urge massive cuts in nuclear arsenals to avoid triggering a nuclear winter, while others note possible destabilizing effects of such cuts. Nuclear winter may also underline the need to enhance crisis management measures. (See pp. 29-35.) Because there is no consensus, further analysis of policy implications should be fostered.

Agency Comments

GAO received formal comments on a draft of its report from the Office of Science and Technology Policy (OSTP). (See Appendix VI.) OSTP said that GAO, by discussing potential policy implications, was giving more validity to the nuclear winter theory than was warranted and suggested the tenor of the report be changed. GAO does not agree. GAO believes that its report recognizes the scientific uncertainties associated with nuclear winter and GAO does not advocate a particular policy position or change.

Contents

Abbreviations

C^3I	Command, Control, Communications, and Intelligence
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
FEMA	Federal Emergency Management Agency
GAO	General Accounting Office
IRP	Interagency Research Program
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCPO	National Climate Program Office
NOAA	National Oceanic and Atmospheric Administration
NPT	Non-Proliferation Treaty
NSC	National Security Council
NSF	National Science Foundation
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy

Introduction

Until recently, scientific research had not comprehensively addressed the potential long-term climatic and environmental damage of a nuclear conflict. History contains examples of fire induced smoke clouds such as from World War II bombings, including the limited nuclear war on Japan, and large scale fires of more recent origin. Due to the limited nature of these occurrences and the lack of previous appreciation for the potential effects, there is incomplete recorded measurement data from those events applicable to assessing and predicting environmental consequences. Now, however, scientific research suggests that a nuclear conflict could inject enough smoke and dust particles into the atmosphere to block out sunlight and cause severe drops in surface temperatures over a significant period of time. This, in turn, could adversely affect plants, animals, and humans. The term "nuclear winter" has been coined to describe these effects.[1] The implications of the theory are global in nature; preliminary research suggests that noninvolved nations, as well as those directly involved, could be vulnerable to the climatic and environmental effects.

The nuclear winter issue has sparked much congressional interest not only in the science associated with the theory but also in its relevant national security implications. Several congressional committees have held hearings on the issue, and the Congress has legislatively mandated administration reports on the subject. Also, the administration has funded some nuclear winter research since fiscal year 1983 and has recently begun an interagency research program chaired by the President's Office of Science and Technology Policy (OSTP). To date, because of the preliminary nature of scientific research, the administration has not acknowledged any ramifications of the nuclear winter theory that would change defense policy or programs. Although varying views exist, there is no consensus for action at this time.

Background and Perspective on the Environmental and Climatic Effects of Nuclear War

In 1975, the National Academy of Sciences issued a report, "Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations," which estimated the global radioactive fallout, ozone depletion and climatic effects from a nuclear exchange and the resulting effect on ecosystems, aquatic life, and people. The climatic effects were theorized to arise from dust placed in the stratosphere by near-surface nuclear blasts. These effects were concluded to be relatively small compared to current

[1] The term has come into common usage as a shorthand method of referring to potential long-term climatic and environmental consequences of nuclear war. We use the term in that sense also, without intent to endorse any specific set or duration of effects.

estimates. As the first attempt to quantify all the known or conjectured long-term effects of nuclear war, the report concluded that the most significant and the only potentially long-term catastrophic global scale effects were those resulting from the ozone depletion, which would allow more unfiltered ultraviolet rays to reach the earth's surface. Debate continues today on the importance of ozone depletion, and many uncertainties still exist as to the potential effects of radioactive fallout.

In 1979, the Office of Technology Assessment issued a report, "The Effects of Nuclear War," which focused mainly on the immediate consequences. The long-term effects discussed in the report centered on those generated from exposure to high levels of radioactive fallout, namely, cancer and genetic diseases. The report did note, however, that a large nuclear war could possibly produce irreversible adverse effects on the environment and ecological system. Since many scientific processes involved were still not well understood, the report stated that it was not possible to estimate the probability or the probable magnitude of such damage.

In the 1980's, some scientists introduced a new variable into the study of nuclear war effects—smoke and its long-term climatic and environmental damage which goes beyond any previously recognized dimensions.

Evolution of New Emphasis on the Long-Term Environmental and Climatic Effects of Nuclear War

In 1980, AMBIO, the environmental journal of the Royal Swedish Academy of Sciences, commissioned a series of studies on nuclear war. One such study published in June 1982, "The Atmosphere After a Nuclear War: Twilight at Noon," attempted to quantify for the first time the possible impact of smoke from burning forests and cities. According to its authors, Paul Crutzen of the Max Plank Institute for Chemistry in West Germany and John Birks from the University of Colorado, fires pushing smoke into the atmosphere could cause serious long-term effects. Crutzen and Birks speculated that the amount of smoke likely to be generated by such fires would be sufficient to reduce the incoming solar energy at the earth's surface for periods of several weeks or longer. They conjectured that smoke combined with dust raised from near-surface explosions would form a dark cloud at least over large areas of the northern hemisphere[2] and reduce the influx of light below

[2]Nuclear winter studies are generally predicated on a nuclear conflict occurring in the northern hemisphere.

the level required for photosynthesis. This study by Crutzen and Birks brought new attention to the potential long-term effects of nuclear war.

Public awareness of the nuclear winter issue came most prominently from the highly publicized work of five scientists who, in conjunction with their own analysis and modeling efforts, were able to build on the findings of Crutzen and Birks and more quantitatively describe the global climatic effect of a nuclear conflict. In late 1983, they published what is now referred to as the TTAPS[3] study, which used the phrase "nuclear winter" to describe the hypothesized severe and long-term effects involving continental-scale subfreezing temperatures.

TTAPS addressed numerous global effects, including radioactive fallout, ozone depletion, and production of toxic chemicals and gases from combustion. The study's major contribution, however, has been described as systematically analyzing the sequence of events; i.e., war scenario, fire ignition, smoke production, atmospheric injection, and finally the absorption of sunlight in the upper atmosphere and the resultant cooling of the earth. The study used a computer-driven, globally averaged mathematical climate model to postulate the effects. This model incorporated several war scenarios and contained numerous assumptions about critical variables, such as how cities burn, how much smoke is produced, where it goes in the atmosphere, and the optical properties of the smoke particles. Based on one of these war scenarios, TTAPS calculated that nuclear smoke clouds generated by a relatively low level of explosions (e.g., 100 megatons) could cool the earth's surface by 36° to 72° Fahrenheit and that temperatures might not recover for several months. The authors speculated that the smoke could spread from the explosion area to the attacking nation, even without a retaliatory nuclear strike, and could cover the southern hemisphere (as well as northern), even if that portion of the globe were spared the direct effects of the nuclear exchange. TTAPS further speculated that human and other species survivors of a nuclear blast would be seriously threatened by long-term exposure to cold, dark, and radioactivity.

These dramatic and controversial predictions received world-wide media attention. Some scientists, including those in the Department of Defense (DOD), stated that the effects of smoke from a nuclear explosion had gone virtually unnoticed within the scientific community. Others

[3]TTAPS is derived from the authors' last names: R. Turco from R&D Associates; O. Toon, T. Ackerman, and J. Pollack from NASA AMES; and C. Sagan from Cornell University. TTAPS author Richard Turco is recognized as having coined the term nuclear winter.

were critical of the TTAPS predictions, calling them premature because of the limitations they found in the assumptions and computer climate model used in the study.

TTAPS was widely distributed and since the magnitude of the predicted effects was so great and the potential implications so serious, other scientists began to vigorously and critically examine the issues raised. They were generally critical in three major areas. First, TTAPS was criticized for using a globally averaged climate model that analyzed atmospheric effects only as a function of latitude. Second, the authors applied either an all-land or an all-ocean planet to their computer model which neglected the important element of heat transported from oceans to land. Third, TTAPS was criticized for using annually averaged temperatures, thereby ignoring the potential effects of the various seasons. Another criticism was that the study did not address the possible effects of a disturbed atmosphere on the movement and removal of smoke. Some important smaller scale effects were ignored, such as fire plumes which can create thunderstorm-like clouds that could "wash-out" some of the initial smoke before it could go very high or spread very far into the atmosphere. Scientists, including the TTAPS authors, indicated that the major criticisms can be addressed somewhat by using more sophisticated computer models, whereas the other criticisms reflect limitations inherent in computer modeling. Some commentators believe that the assumptions used in computer modeling need to be derived from more realistic research than the current level of scientific knowledge allows.

The TTAPS authors acknowledged that their estimates of the physical and chemical effects of nuclear war were necessarily uncertain and recognized the weaknesses in their initial study. They also saw the need for additional research to definitively reduce the uncertainties. Notwithstanding these weaknesses, TTAPS was successful in focusing attention on a potentially important phenomenon and giving added support for studying the nuclear winter theory. Several major national and international studies to assess the overall nuclear winter problem have since begun, or have been completed.

National Academy of Sciences Study Supports Possibility of Long-Term Effects

One of the more authoritative assessments of the possible atmospheric effects of nuclear war was published in December 1984 by the National Academy of Sciences (NAS). Requested and funded by DOD in early 1983, the NAS assessment essentially echoed the preliminary TTAPS results and stated that long-term climatic effects with severe implications were plausible. Based on the study assumptions, which included a 6,500 megaton nuclear conflict, the report showed that during the summer months land surface temperatures could be reduced from 50° to 77° Fahrenheit in the northern hemisphere for a period of several weeks. Serious biological and agricultural problems could result due to the abrupt and long lasting atmospheric change. The NAS report also speculated that nations far removed from the target areas, including the attacking nation, could be vulnerable.

NAS scientists stated that because of uncertainties in the assumptions used, as well as limitations in computer climate models, they could not subscribe with confidence to any specific quantitative conclusions drawn from their calculations. Essentially, they believed that the estimates of the potential consequences have utility only as an indicator of the seriousness of what might occur. NAS nevertheless stressed that the potential long-term consequences of a major nuclear exchange had worldwide implications which should be included in any analysis of the consequences of nuclear war. NAS also believed that a major effort to narrow the scientific uncertainties was needed.

U.S. And International Research Efforts Focus on Nuclear Winter Uncertainties

Government, private, and university research centers continue to study the many uncertainties associated with the nuclear winter theory. To coordinate some of this research, the administration has established the Interagency Research Program (IRP), which incorporates current efforts at the Defense Nuclear Agency (DNA), the Los Alamos and Lawrence Livermore National Laboratories of the Department of Energy (DOE), and the National Center for Atmospheric Research (NCAR) of the National Science Foundation (NSF). Nuclear winter research at these locations and research subcontracted by these locations to other laboratories and universities totaled about $3.5 million for fiscal year 1985 and will increase to approximately $5.5 million under the IRP in fiscal year 1986. The IRP hopes to coordinate these and other nuclear winter research efforts to ensure that the major uncertainties are adequately and fully addressed.

The international scientific community is also studying the nuclear winter issue. The Royal Society of Canada published a Canadian appraisal of nuclear winter and its associated effects in January 1985.[4] The report, based on the analysis of numerous consultants mainly from

[4]"Nuclear Winter and Associated Effects: A Canadian Appraisal of the Environmental Impact of Nuclear War," The Royal Society of Canada, January 31, 1985.

the United States and Canada, concluded that nuclear winter is a credible and formidable threat which could last for several months and cause severe damage or destruction to crops and vegetation. It recommended that the Canadian government immediately consider the military, strategic, and social consequences of such a major climatic effect, notwithstanding the many scientific uncertainties in the theory.

Scientists from other countries, such as Australia and West Germany, continue to conduct research into the nuclear winter theory. In addition, a committee (Scientific Committee on Problems of the Environment—SCOPE) of the International Council of Scientific Unions, in September 1985, completed a 3-year study focusing on nuclear winter. Scientists from numerous countries, including the United States and U.S.S.R., worked on the study. They researched the physical and atmospheric consequences of nuclear war as well as the biological, agricultural, and human implications. SCOPE concluded that indirect effects (the latter implications) of a large scale nuclear war could be potentially more consequential globally than the direct effects. The report recommended continued research on the entire range of implications with close interaction between biologists and physical scientists.

Soviet Union involvement in nuclear winter research has not, according to many U.S. scientists, contributed substantially to reducing theory uncertainties, primarily because of weaknesses in modeling capabilities. Also, Soviet scientists have been unwilling or unable to make fire and smoke research data available. DOD and many other scientists and analysts believe the Soviets have used the issue mainly for propaganda purposes in the media and at international forums. We did not see information which would permit any firm conclusion on how the Soviet Union perceives nuclear winter uncertainties.

Objective, Scope, and Methodology

The objective of this report is to provide the Congress and others with an overview of what is known about nuclear winter, its potential implications for defense strategy, arms control, and foreign policy-making and the status of U.S. efforts to further study the issue. Specifically, our report

- highlights the nature and status of research on the long-term effects of nuclear war;
- describes the uncertainties that presently exist with nuclear winter research;

- discusses varying views on potential defense policy implications based on the theory; and
- examines how the IRP will manage, coordinate, and fund the necessary research.

We undertook this review because the nuclear winter issue deals with a controversial subject that lends itself to polarized views and misunderstandings. We sought to learn from those in the research community what the range of present scientific uncertainty is, what approaches are being taken to reduce the uncertainty, how long this might take, and what their views were on how much the uncertainty may be reduced. We also sought to determine the range of current thinking regarding the potential implications of the nuclear winter theory on national security.

Review of subject matter, rather than agency activity, was the main focus of our work. Issues identified in our report were drawn from reviewing scientific and other literature on the subject and from detailed discussions with scientists, researchers, and policy analysts knowledgeable of the subject both within and outside of government.

Within the government we contacted numerous officials within the Executive Office of the President; the Departments of Defense, Energy, and State; the National Oceanic and Atmospheric Administration of the Department of Commerce; the National Aeronautics and Space Administration; the National Science Foundation; and the National Academy of Sciences. In addition, we attended various seminars and symposia on nuclear winter and related issues where differing and opposing views were debated. Appendixes I and II, respectively, identify some of the relevant literature reviewed and persons contacted.

Because this report examines the facts of a technical issue and its possible policy implications, and does not review or evaluate executive agency activities, a draft was sent for formal review and comments only to OSTP, the coordinator for U.S. nuclear winter research. We did, however, solicit informal reviews and comments and discuss the general observations presented in the report with other administration officials and scientists and selected scientists outside the government.

Experts Recognize Significant Uncertainties in the Theory of Nuclear Winter

The term nuclear winter has recently gained common usage, yet some have viewed it to be an unfortunate label in that current scientific research cannot definitively confirm or refute the extreme effects predicted by the theory. The most common point of agreement is the new recognition that a nuclear war is apt to result in adverse climatic, environmental, or biological impact, but of uncertain scale and duration. Scientists in DOD, government laboratories, and private and university research centers all recognize that significant uncertainties and unknowns exist with the theory. Despite differing views, they agree that these uncertainties need to be studied.

Nuclear winter uncertainties can be placed in three categories: war scenarios, fire and atmospheric research, and computer atmospheric modeling. While some of the uncertainties cannot be resolved or known absent a nuclear conflict, knowledge of others can be refined and the unknowns of some others, at best, can only be reduced. Some scientists believe it may be 5 years or longer before the uncertainties will be reduced to the point where more widely accepted projections could be made on the climatic and environmental consequences of nuclear war. Other scientists believe significant incremental increases in knowledge could occur over shorter timeframes.

War Scenario Variables Can Only Be Assumed

Highly classified plans provide the details for waging a nuclear war, but the actual course of events and the prevailing conditions are impossible to know in advance.

Given the highly classified nature of war plans, scientists must base their research to some extent on speculation or unclassified informed opinion about the likely targets of nuclear weapons. They cannot know in advance, for example, the number and yield of weapons which would actually be used, the distributions of targets against which those weapons would be directed, or the number of weapons which would actually reach their targets and detonate successfully. In addition, an adversary's response during a nuclear conflict will not be known in advance.

Another variable is whether the bombs will explode in the air or upon impact. This is an important variable since each type of blast would inject different quantities of dust into the atmosphere and block out the sun to varying degrees. NAS scientists note that the climatic and environmental effects depicted in their 1984 report could be several times larger if a combatant decided to rely more on groundbursts in a war because they would likely inject the most dust into the atmosphere. Fire and resulting smoke and soot generation are also affected by altitude of detonation, but to a much smaller degree than dust.

The time (season) of the year also matters greatly, according to nuclear winter theory. A smoke cloud from a nuclear exchange in July could severely affect crops and plant life if the resulting temperature decrease is significant. Yet, the same exchange in January could have little or no effect in the northern hemisphere, depending on its duration and spread, if it occurs where temperatures are normally cold at that time of year. Finally, weather conditions existing in a target area could mitigate long-term effects. For example, moisture tends to "wash-out" smoke and dust particles before they can get very high into the atmosphere.

Given the intrinsically uncertain nature of these variables, scientists must make critical assumptions for their nuclear winter simulations and cannot therefore offer definitive predictions. Some scientists claim that a small number of high yield weapons, specifically targeted, can produce severe climatic and environmental results. This claim has fostered an apparent misconception that going beyond a specific "threshold" would trigger a nuclear winter. Scientific research cannot now prove this with any accuracy. Most scientists note that too many independent variables (e.g., combustible target, groundburst, clear weather, etc.) would have to occur in a precise fashion before a small number of nuclear weapons could create long-term climatic and environmental effects. They indicate that if a threshold does exist it is more likely to be in terms of the amount of smoke, soot, and dust particles injected into the atmosphere rather than in the number of weapons or the megatonnage used.

Fire Research Is Crucial in Determining Nuclear Winter Probabilities and Consequences

A large and significant uncertainty in nuclear winter research concerns fire characteristics. Scientists are focusing on a number of important variables ranging from how much material will burn under a prescribed exchange to the effect of fire-produced toxic chemicals and gases on the surviving environment. They note that the knowledge gained by studying fire characteristics can help computer modelers who need the data to more accurately simulate climatic conditions in a perturbed environment. The following are the more significant components of fire research.

Fire Source	• Combustibility of targets • How much will burn; for how long?
Smoke Production	• How much smoke is produced? • What are the smoke characteristics? • What is the smoke particle size and shape? • What is the smoke chemical composition?
Plume Characteristics	• How high will it go? • How much will survive the first few hours?

Studying fire uncertainties is a detailed and lengthy exercise involving several scientific disciplines which are inter-related and dependent on each other. Research is progressing in each of the areas discussed below and is beginning to provide computer modelers with valuable data from which they can better simulate atmospheric conditions. Scientists must rely on laboratory experiments, prescribed and/or actual forest fires, and accidental industrial burns to test their calculations. In each case, results must be analyzed and then scaled up to meet the assumed proportions created by a nuclear exchange. The "built-in" unknown of a nuclear weapon produced large-scale fire will always exist, and scientists can only work towards achieving reliable probabilities of fire and smoke production based on some assumed range of variables.

Targets—The Source of Fire

Fire source uncertainties relate to the issue of targets which would remain uncertain until an actual conflict. Scientists assert that the severity of nuclear winter is sensitive to the quantity of urban/industrial combustible material which eventually burns. They state that cities are much more combustible than nonurban areas, have higher fuel densities, and would therefore produce larger amounts of smoke and soot. Other targets may be situated near industrial sites with large quantities of petroleum products—a major source of oily, sooty smoke particles. Scientists, however, can only postulate about the types of potential targets using categories such as urban cities, rural areas, or wildlands to calculate combustibility. Scientists note that developing better data on the detailed fire characteristics of potential areas would provide valuable information on how much of an area will burn under a given scenario, how intensely, and for how long. It would also provide valuable information on how fires ignite, how many would start in a given area, and how far they would eventually spread.

Smoke—The Critical Input

Another element of uncertainty is smoke production per fraction of material that burns. To date, little scientific research has been done in the area of smoke production and spreading. The amount of smoke produced depends on the quantities, types, and distribution of combustible materials in target zones. Some materials tend to produce relatively little smoke, especially wood that is prevalent in residential construction. However, other materials such as oil, tar, asphalt, rubber, plastics and synthetics, which are increasingly common in modern commercial construction, tend to produce thick black smoke.

Scientists also need to better understand smoke particle size and shape. Some particles absorb light whereas others scatter light, depending on their composition. According to scientists, if smoke particles only scatter sunlight, the resulting temperature decrease at the earth's surface would not be as severe. Also, they state that smaller smoke particles tend to absorb sunlight more efficiently, resulting in larger temperature reductions. However, scientists need to study further the composition of smoke particles produced by different fuels in large-scale fires. Until then, accurate predictions of how much sunlight will be absorbed and how far temperatures will drop will be difficult to make. How far the predictions can be refined is questionable. Further progress may have to rely on laboratory and small scale fire research requiring considerable extrapolation to simulate the magnitude of fires that would be produced in a nuclear exchange.

Scientists are also studying how high the smoke will go into the atmosphere, how long it will last, and how far it will travel. Smoke injected very high into the atmosphere would accentuate nuclear winter effects for two reasons: (1) high altitude smoke is more effective in cooling the surface than low altitude smoke and (2) high altitude smoke has a much longer lifetime since it would be less affected by the water vapor in the atmosphere. Many scientists also note that if smoke enters the stratosphere (i.e., 6 miles above the earth's surface), the cloud would remain for a much longer time because there would be no moisture condensation to remove it quickly. Since weather (i.e., rain, snow) removes smoke particles from the atmosphere under normal conditions, scientists theorize that smoke in the stratosphere could extend nuclear winter effects by up to several months.

Some researchers have speculated that even if smoke does not enter the stratosphere, nuclear winter effects could be long-term. This belief is based on conjecture because it is uncertain what happens to smoke particles in the early stages of a nuclear fire. For example, scientists are studying smoke particles as they go through a fire plume to see if they "scavenge," e.g., coagulate or wash-out. The removal of particles, or scavenging, can separate a continuous smoke cloud into patchy clouds which allows a certain amount of sunlight to pass through, thus lessening the degree to which surface temperatures would drop. It also increases the potential for varying effects over the impacted area. Coagulating particles come together and form larger smoke particles. These larger particles would be less effective in blocking solar energy from the surface. Smoke particles could also be washed out by existing moisture or rain during or immediately after a nuclear conflict. Some scientists believe that the initial wash-out could be so great that no long-term smoke cloud would form. Others say that the fires would be very intense and would quickly push the smoke beyond where coagulation or wash-out normally occurs. These assertions are subject to further research, and scientists concur it is an area that is critical in assessing the probability and severity of nuclear winter.

The distance a smoke cloud will travel is important because of its global implications. TTAPS was the first to speculate that winds could move a nuclear smoke cloud across the northern hemisphere, eventually encompassing the entire globe after a major nuclear exchange. The probability of this occurring is presently very uncertain, particularly since the movement of smoke from the northern to the southern hemisphere would require changes to normal atmospheric circulation patterns. History, however, has shown that smoke clouds can travel great distances. For example, in 1950, a fire in Alberta, Canada, produced a smoke pall which spread over portions of Canada, the eastern United States, and western Europe. This cloud lasted for several days and is said to have caused measurable decreases in observed temperatures as compared to those expected. Although this example shows that extended movement of smoke clouds is possible, the probability that a smoke cloud would encompass the globe or even the northern hemisphere after a nuclear exchange remains scientifically uncertain. Even if it could, the degree of uniformity (or patchiness) is also uncertain.

Dust, Toxic Gases, and Chemicals

In addition to the above fire uncertainties, the effects from dust and toxic gases and chemicals are questionable. Scientists claim that dust lofted into the atmosphere would not necessarily make acute climatic and environmental effects more severe but could make them last longer. They theorize that tiny submicron particles, or dust, produced by near-surface explosions could be injected into the stratosphere where they would remain for many months, depending on the number and individual yields of weapons used in surface bursts. Since these variables are currently uncertain and must be assumed for scientific analysis, the effects of dust from a nuclear exchange cannot be predicted. As for toxic gases and chemicals, scientists do not know how much would be produced in a nuclear exchange or what effect they would have on the surviving environment. They do believe, though, that burning synthetic and plastic material would produce a certain level of toxic substances. However, their effect and duration are unknown and require further study.

Ability to Model Atmospheric Effects Is Limited

Studying detailed, complex physical phenomena such as nuclear winter requires sophisticated mathematical models. These models, run in high capacity computers, are deterministic by nature; that is, once the input variables are selected the results are uniquely determined. However, the computer atmospheric models currently used in nuclear winter research are limited in their ability to accurately represent the physical laws of nature and are very much dependent on other research efforts to provide needed data.

Impediments to Computer Modeling

In studying nuclear winter scientists must assume many distinct input variables (i.e. number of weapons used, targets hit, amount of smoke injected into the atmosphere, height of injection, etc.). Computer simulations to date have produced varying results and effects which are limited by the reliability of the input data and constrained by the capabilities of computer software to model dynamic changes in atmospheric conditions and realistically project how long potential effects would last. Until scientists receive more accurate data to apply to their computer climate models and improve their software to simulate atmospheric responses more accurately, modeling results will only show a plausible range of nuclear winter effects under strictly prescribed conditions.

A large impediment to accurately modeling nuclear winter effects is the lack of an analogue from which to compare results. Some scientists in the past have used thunderstorms, volcanic eruptions, day/night and winter/summer changes, large scale forest or urban fires, and even Martian dust storms to help validate their computer atmospheric simulations. However, a nuclear exchange could bring about unprecedented climatic disturbances and there is no analogue which is well suited to test the validity of modeling results. As such, scientific findings will, to some degree, always remain uncertain.

Types of Computer Atmospheric Models Used

The computer atmospheric models used in investigating the nuclear winter theory fall into three categories: (1) local cloud or "plume-scale" models, (2) regional weather or "mesoscale" models, and (3) global climate/weather models.

Plume-scale models are used to simulate the dynamics of smoke plumes created by single large fires. The most sophisticated of these models can simulate, in three dimensions, fire plumes including movement of smoke particles, thunderstorms, water condensation, rain, and scavenging. The plume-scale models are used to estimate how high smoke would be injected into the atmosphere and the fraction of smoke particles removed by early scavenging. Regional weather, or "mesoscale" models, are used to simulate the details of weather (e.g., fronts) on a few-day time scale. Their resolution, i.e., definition or clarity, is greater than those of global models, but they only cover a limited region, e.g., the eastern half of the United States. They are used to examine the effects of small-scale weather systems on smoke scavenging and movement. Global climate models, some of which predict large-scale weather as a by-product, are used to make predictions on time scales longer than a few days.

Scientists continue to improve all three categories of atmospheric computer climate models so they can more accurately predict the effect of smoke and dust on atmospheric conditions.

Nuclear winter studies are now primarily performed by global models which are three-dimensional (depth, width, and height) as opposed to the globally averaged TTAPS model which focused only on height to simulate atmospheric conditions over the entire earth. A three-dimensional model simulates the earth's surface in a series of finite grid boxes, each about the size of the state of Colorado. To calculate potential climatic effects, scientists average all the weather conditions occurring in a given area (e.g., within the state of Colorado) into one grid box. The process must be repeated for each grid box until the entire globe (or area under study) is represented. Averaging weather conditions to represent larger areas is an improvement over using local conditions simulated by one-dimensional models. However, this is still a critical modeling limitation because local weather conditions (e.g., rain, humidity, wind, etc.) within the grid area would have a direct effect on fires created by nuclear explosions and on the local scavenging of smoke.

Plume-scale and mesoscale models provide much detail about local and regional conditions. Global climate models provide good, larger scale simulations. Scientists are working on integrating the various modeling scales so that several scales of atmospheric conditions can be simulated simultaneously. The technology of this time consuming and costly task is not very far advanced, especially for mesoscale modeling. However, nuclear winter research could benefit from the results.

Attempts to Expand Modeling Capabilities

Scientists are beginning to factor the movement of smoke in their models and are conducting various experiments to remove it under realistic conditions. However, advances are made slowly and are constrained by the lack of input data on fire characteristics and smoke production.

Models have been limited in their abilities to move the smoke cloud over a period of time in a perturbed environment. This capability is important to discern the potential for nuclear winter effects being widespread (up to global) in nature. In addition, scientists have stated that further study is needed to reliably model how long a smoke cloud would last if the particles were injected into the stratosphere where there is no moisture condensation to rapidly remove them. Scientists are now expanding the number of vertical layers in their three-dimensional models so they can better understand the vertical movement of atmospheric smoke. Minimal results have been produced to date and many uncertainties regarding the characteristics of smoke particles in the stratosphere remain.

Biological and Agricultural Effects: The Bottom Line of Uncertainty

Beyond the unknowns of how a nuclear war will be conducted and the physical science uncertainties associated with fire research and climate modeling is the question of the potential effects a nuclear exchange would have on the biological and agricultural environments. Many scientists believe the real long-term consequences of any nuclear crisis would be the potential disruption of ecosystems upon which man is dependent.

Ecosystems consist of the community of plants, animals, and microorganisms that exist in an area (e.g. field, valley, lake, state, continent, etc.) and the physical environment of that community. They depend on the light energy of the sun, which is converted through photosynthesis in green plants into chemical energy that is used by all organisms. The disruption of photosynthesis, scientists conclude, by the reduction of sunlight or temperature drops could have consequences that ultimately cascade through the food chain. Compounding these effects is that after a nuclear war the available supplies of food could be destroyed or contaminated, located in inaccessible areas, or rapidly depleted. In addition, natural ecosystems may not be able to recover in a perturbed environment to resupply the food chain. This presents some important questions which scientists believe need to be addressed. They include:

- What is the effect of sustained low light on plant physiology?
- What would plant stress response be to an unnatural sudden or slow temperature decrease?
- How long would ecosystems, or parts thereof, take to recover?

Research on the potential biological and agricultural implications that could arise from a nuclear winter scenario has been very limited to date. Some scientists and others stated that it is premature to devote significant attention to biological consequences because the assumptions about the environmental and climatic conditions would have to be estimated so broadly as to render the results highly uncertain. But others say that the biological sensitivities to nuclear war are critical to post-war recovery. They believe the potential range of effects warrants studying this issue now in parallel with the physical science research. Also, a view has been expressed that contributions from the biological sciences community can help physical scientists identify or modify priorities in their own research, and that some effort to this end is warranted.

Nuclear Winter Raises Policy Concerns, but Responses Needed Are Unclear

Publicity surrounding the nuclear winter issue has given rise to speculation and concern over its policy implications. Views on implications range from rhetorical questioning of what nuclear winter adds to the already recognized horrors of nuclear war to views that massive reductions in nuclear arsenals are needed to avoid triggering a nuclear winter should nuclear weapons ever be used. The administration's response to date has essentially been to take a wait-and-see attitude from a policy standpoint, particularly in light of the recognized scientific uncertainties. Others, however, believe that the theory supports changes to some existing policies. But precisely what should be done and when remains unclear. Continued debate and discussion on potential policy implications are needed and should be fostered as a basis for informed decision-making.

This chapter does not advocate a particular policy position or change but provides information for considering the broad policy implications of the nuclear winter issue as scientific research continues.

Administration Officials Are Aware of Nuclear Winter but Cautious About Its Implications

To date, the primary focus of the administration's reaction to nuclear winter has been to identify and develop a plan for researching the physical scientific uncertainties of the issue. The numerous officials we contacted within DOD and the military services were very much aware of the nuclear winter issue but they neither planned nor contemplated any actions based on the theory. An official of the Plans and Policy staff under the Joint Chiefs of Staff told us that no new policy guidance had been issued or planned based on the nuclear winter issue. For purposes of assessing the consequences of using nuclear weapons in target planning, this official told us that only damage associated with the immediate blast is presently considered.

Overall, statements by DOD and other administration officials indicated a view that it may be some time before policy implications can be seriously considered. In commenting on a draft of this report, the acting director of the President's Office of Science and Technology Policy (OSTP) said that the position of the IRP's Coordinating Committee is that the basic science research must be addressed before the policy issues. Earlier, another OSTP official had told us that nuclear winter policy assessments are 4 to 5 years away.

Informal comments by some individuals indicated skepticism that the nuclear winter issue could add much to the already known devastating effects of nuclear war. Defense officials preferred to take a wait and see attitude, deferring to the Office of the Assistant to the Secretary of Defense for Atomic Energy or the Defense Nuclear Agency (DNA), which have key roles in responding to the nuclear winter issue.

Preliminary assessments of policy implications have been produced for DOD—one under a DNA contract and another by the Air University Center for Aerospace Doctrine, Research, and Education. Both, for purpose of study, were predicated on the assumption that nuclear winter is a possible outcome of nuclear conflict. Neither study is recognized by DOD as a definitive assessment of nuclear winter policy implications nor are they considered as providing a basis for action at this time.

Congress Requires Administration to Report on Potential Nuclear Winter Policy Implications

The administration's formal position on nuclear winter policy implications is most clearly stated in a legislatively mandated March 1985 report to the Congress by the Secretary of Defense on "The Potential Effects Of Nuclear War On The Climate." Views expressed in that report indicate a cautious approach toward acknowledging policy implications much less considering any changes at this time. Dissatisfied with the report, Congress has required DOD to reassess potential nuclear winter policy implications and provide a new report by March 1, 1986.

The Original Congressional Mandate

In enacting legislation in 1984, the Secretary of Defense was tasked to give a report to the Congress no later than March 1, 1985 providing:

- A detailed review and assessment of the current scientific studies and findings on the atmospheric, climatic, environmental, and biological consequences of nuclear explosions and nuclear exchanges.
- A thorough evaluation of the implications that such studies and findings have on (1) the nuclear weapons policy of the United States, especially with regard to strategy, targeting, planning, command, control, procurement, and deployment; (2) the nuclear arms control policy of the United States; and (3) the civil defense policy of the United States.
- A discussion of the manner in which the results of such evaluation of policy implications will be incorporated into the nuclear weapons, arms control, and civil defense policies of the United States.
- An analysis of the extent to which current scientific findings on the consequences of nuclear explosions are being studied, disseminated, and used in the Soviet Union.

DOD's Response

DOD's report, after synopsizing nuclear winter's scientific aspects, concluded that (1) the present uncertainties concerning the effects of nuclear war on the atmosphere preclude considering policy changes at this time and (2) present policies appear adequate. The report avoids the use of the term nuclear winter in favor of such terms as the potential effects of nuclear war on the climate or atmosphere. We use the term nuclear winter in paraphrasing DOD's position solely as a shorthand reference to the theory, and not to infer DOD's endorsement of the theory.

DOD concluded that nuclear winter only strengthens the basic imperative of U.S. national security policy—to prevent nuclear war through a strong deterrence capability.[1] The report cited ongoing U.S. initiatives or policies as being appropriate responses based on what is now known about the nuclear winter theory. They include:

- Strategic modernization efforts which include retiring older weapon systems that might create a greater risk of climatic effects than their replacements. Modernization is also aimed at improving the survivability and effectiveness of warfighting capabilities including command and control features, thereby enhancing deterrence.
- Efforts to negotiate reductions in nuclear arsenals.
- Strategic Defense Initiative research into ways of destroying incoming nuclear weapons before they reach their targets.
- Flexible targeting options to control the escalation of conflict in the event nuclear weapons are used.

The DOD report recognized that new initiatives for mitigating nuclear winter effects might be possible but took the position that improved scientific understanding is needed before specific initiatives can be developed. Civil defense was similarly regarded. The report cited the Federal Emergency Management Agency's (FEMA) position that, until scientific knowledge regarding climatic effects of nuclear conflicts is more fully developed, it would not be practical or cost-effective to develop civil defense policies or to change existing policies.

The DOD report assessed Soviet activities on climatic effects. It cited limitations in the Soviet research, primarily involving computer modeling capabilities and the tendency towards exaggerating conclusions for

[1]This refers to preventing war by showing that U.S. defense capabilities can respond to any level of attack by inflicting unacceptable damage to an aggressor and denying their attainment of war objectives.

propaganda purposes. The report said there is no indication that the nuclear winter issue has affected Soviet policies, strategy, or force structure.

An Extended Congressional Mandate

Dissatisfied with DOD's attempt to address potential nuclear winter policy issues, the Congress amended DOD's fiscal year 1986 funding authorization to have them again prepare a report on nuclear winter by March 1, 1986. The report is to follow the format prescribed for the 1985 report, focusing on nuclear winter findings and potential policy implications.

In addition to the congressionally mandated report, the Foreign Relations Authorization Act for fiscal years 1986 and 1987 includes a "sense of the Congress" provision indicating "that the President should propose to the Government of the Soviet Union during any arms control talks held with such Government that—

> "(1) the United States and the Soviet Union should jointly study the atmospheric, climatic, environmental, and biological consequences of nuclear explosions, sometimes known as 'nuclear winter,' and the impact that nuclear winter would have on the national security of both nations;
>
> "(2) such a joint study should include the sharing and exchange of information and findings on the nuclear winter phenomena and make recommendations on possible joint research projects that would benefit both nations; and
>
> "(3) at an appropriate time the other nuclear weapon states (the United Kingdom, France, and the People's Republic of China) should be involved in the study."

Policy Issues Frequently Linked With Nuclear Winter

To highlight the range of views on potential policy implications, we have summarized them in terms of the following questions:

- How could nuclear winter affect deterrence?
- How could nuclear winter affect nuclear arsenals and prospects for arms reductions and nonproliferation?
- How could nuclear winter affect warfighting capabilities, targeting, and strategy?
- How could nuclear winter affect crisis stability and control efforts?
- How could nuclear winter affect U.S. civil defense?

How Nuclear Winter Could Affect Deterrence

The goal of U.S. nuclear strategy is to prevent nuclear war by maintaining deterrence. One perspective on the nuclear winter issue is that the possibility it could occur should in itself act to deter a nuclear attack especially if scientific research adds support to the theory that adverse climatic and environmental consequences might rebound to an attacking nation even absent a retaliatory strike. Others express concern that if nuclear winter effects are eventually discounted or reduced significantly, nuclear war could be perceived as less disastrous than previously thought and thus possibly more thinkable. This view seems to ignore the horrible effects of nuclear war which are already recognized. Another perspective regarding the goal of deterrence states that a greater risk of conventional warfare is possible if the nuclear winter theory becomes so well accepted that using nuclear weapons is viewed as an unacceptable option. Proponents of this view would thus see a need to strengthen conventional weapons capabilities.

How Nuclear Winter Could Affect Nuclear Arsenals and Prospects for Arms Reductions and Nonproliferation

Because of concern over nuclear winter, some views at one end of the scale have argued for massive reductions in nuclear weapons, while at the other end, some have expressed the potential need for a new round of weapons development. Some cite reduction in U.S. stockpiles of older weapon systems and the trend toward lower yield, more highly accurate nuclear weapons as being steps in the right direction based on current scientific knowledge. Others see potential impacts on arms reductions negotiations and nonproliferation efforts.

One position which has received much attention calls for massive reductions in nuclear arsenals based on the simplified and popularized premise that nuclear conflict involving a yield of as few as 100 megatons (out of an estimated inventory of 50,000 weapons with a total yield of 15,000 megatons between the United States and U.S.S.R.) could create a nuclear winter. Most scientists we contacted, irrespective of their predispositions toward the nuclear winter theory, pointed out that a threshold for triggering a nuclear winter is not nearly so straightforward and question the scientific validity of the premise. They viewed nuclear winter as predicated on fires injecting millions of tons of smoke and soot particles high into the atmosphere, which would block out the sun and depress surface temperatures for a long period of time. In their view this is heavily influenced by the types of combustibles involved and other fire related variables (see chapter 2) and not just by number and yield. Significant uncertainties in this area prevent definitive predictions of a threshold. Also, several views have been voiced regarding major reductions in the nuclear weapons arsenals of the United States and U.S.S.R. designed to avoid a nuclear winter. These include the views that

- it would be difficult to verify exactly what level of reductions had been made;
- it might be perceived that nuclear war would be safer to wage given reduced arsenals, or the prospects of waging a conventional war might be more likely; and
- other nations might choose to strive for superpower status by attaining or increasing nuclear capabilities, thus creating greater world instability.

The view has also been advanced by some that the nuclear winter issue could fuel rather than quell an arms race; that is, it could trigger weapons development to find ways to fight a nuclear conflict and minimize the risks of environmental and climatic damage. Some speculation has already focused on the potential need for developing lower yield, highly accurate, earth penetrating nuclear weapons that could be used to reduce the risk of fire and the injection of smoke and soot particles into the atmosphere. A related speculation, already noted in another context, is that nuclear winter could add greater urgency to the need for developing more sophisticated conventional weapons. These two alternatives raise the question as to whether and how well such weapons could meet requirements of U.S. defense plans.

DOD's March 1985 report to the Congress cited the President's Strategic Defense Initiative as a step in the right direction to avoid the potential for a nuclear winter. Others have speculated that the Soviet Union's reaction would be to build up its nuclear arsenal to increase its chances of penetrating such a system.

Another issue involves the question of how nuclear winter might affect the use of tactical nuclear weapons. One side of the issue is that tactical nuclear weapons have the potential for avoiding or reducing nuclear winter because their deployment could be controlled to eliminate the likelihood of the effects occurring. This could be done by modifying target selection and warfighting objectives. Another side of the issue is the speculation that a tactical nuclear weapon exchange, once initiated, would quickly escalate and be difficult to control.

To date, there is little to indicate that the nuclear winter issue played a role in fostering resumption of negotiations on arms reductions between the United States and U.S.S.R. To the extent it becomes a focus of negotiations, two views show how those negotiations could be influenced. One speculates that nuclear winter might negate traditional concerns over strategic superiority if it becomes widely accepted that current nuclear arsenals are more than sufficient to cause severe climatic and environmental consequences. A second view speculates that what now constitutes strategic advantage could change if the potential impact of nuclear winter is seen as so severe as to require a shift to low yield, highly accurate nuclear weapons. Another important element frequently cited is the degree of acceptance by the superpowers of the nuclear winter theory. Without mutual agreement, actions by one side to reduce the risk of nuclear winter could be destabilizing by providing a distorted perception of strength or weakness.

The United States and over 125 other member states (including the U.S.S.R.) are party to a 15-year old Treaty On the Non-Proliferation Of Nuclear Weapons (NPT). The NPT includes among its major provisions an obligation to pursue negotiations in good faith on effective measures leading to cessation of the nuclear arms race and nuclear disarmament. The provision was meant to provide an incentive for nonnuclear nations to commit themselves not to seek, acquire, or manufacture nuclear explosives. It is unclear at this time whether or to what extent the nuclear winter issue will add to any existing concerns or actions by other nations regarding what many see as limited progress towards arms reductions and disarmament. Nor is it clear what, if any, influence they might seek to assert on arms negotiations if it becomes clear these and other nations would no longer be unaffected bystanders to a nuclear conflict between the United States and the Soviet Union.

How Nuclear Winter Could Affect Warfighting Capabilities, Targeting, and Strategy

In the past people have questioned what effect a protracted nuclear conflict would have on warfighting capabilities. The nuclear winter issue adds another dimension to this question and a corollary one of whether command, control, communication, and intelligence (commonly referred to as C^3I) functions would be effective in a perturbed environment. DNA officials told us there is ongoing classified research on the effects of nuclear war on, for example, weapon systems and communications satellites, regardless of nuclear winter.[2]

[2]We have issued a number of classified reports on the survivability and endurance of strategic C^3 systems in a nuclear warfighting environment though not from the standpoint of nuclear winter effects.

One issue that has stirred considerable discussion involves potential targets in a nuclear conflict, particularly whether, and to what extent, likely targets include or are located in close proximity to urban/industrial areas (cities). DOD's official response to questions on this subject is to the effect that the United States does not target cities. This response does not indicate what their beliefs are regarding the Soviet Union's targeting plans. Also not addressed by this response is to what extent specified targets and objectives in urban/industrial areas would be struck, directly or indirectly, even if cities are not targeted. This is important because of the potential for urban targets to generate and inject greater amounts of smoke and soot particles into the atmosphere. An apparently serious proposal that has been advanced in some of the literature on the subject calls for a U.S./U.S.S.R. bilateral agreement on non-targeting of cities. However, some have questioned the effectiveness of such an agreement since the commitment to its terms could not be verified.

In terms of the strategy used to initiate a nuclear conflict, some policy analysts have speculated how one side might use nuclear winter for strategic advantage. That is, if a threshold or some degree of specificity and certainty were known for triggering a nuclear winter, an aggressor might see an advantage to limiting a nuclear attack marginally below the threshold, gambling that the risk of exceeding the threshold would prevent the attacked nation from retaliating. This assumes the other nations involved shared a common understanding and belief in what level of exchange would trigger a nuclear winter. Also, if scientific theory indicated that adverse environmental and climatic effects were deemed likely to affect another country more quickly or severely, that too might cause one side to see strategic advantage. However, as previously noted, the establishment of a scientifically valid threshold is very uncertain. Likewise, the spread and severity of potential climatic and environmental effects are not yet well understood. Thus, it is unclear at this time what range of actions might be desirable or necessary regarding warfighting capabilities, targeting, or nuclear war strategy.

How Nuclear Winter Could Affect Crisis Management and Control Efforts

Crisis management and control efforts are seen by many as safeguards to prevent nuclear war. The potential implications of nuclear winter could provide an incentive to improve these safeguards to make crisis management more efficient and survivable. Such improvements would also reduce both the potential for nuclear weapons use and the possible threat of nuclear winter's adverse environmental and climatic consequences.

During the last 25 years, the United States and U.S.S.R. have concluded some important agreements to facilitate communication between the superpowers to reduce the likelihood of nuclear war. These have included the Hotline Agreement of 1963, the Hotline Modernization Agreement of 1971, the Accidental Measures Agreement of 1971, and the Prevention of Nuclear War Agreement of 1973. In 1983, the administration endorsed four DOD initiatives to improve crisis management. They were to (1) upgrade the hotline for greater speed and for facsimile transmissions, (2) establish a joint military communications link between the Pentagon and Soviet Defense Ministry, (3) improve communications between the government capitals and their respective embassies, and (4) facilitate discussions to resolve terrorist nuclear acts or other unauthorized use of nuclear weapons. The administration has achieved agreement with the Soviet Union on only the first and last initiatives.

The Congress, in enacting the Foreign Relations Authorization Act for fiscal years 1986 and 1987 (the same act which encourages the United States to propose cooperative measures to study the nuclear winter issue with the Soviets) also mandated a detailed executive branch study and evaluation of the U.S. crisis management system, including consideration of the additional steps needed to enhance crisis stability and crisis control capabilities, such as:

- Establishing redundant, survivable direct communication lines between and among all nuclear-armed states.
- Concluding an agreement to create "non-target" sanctuaries for certain direct communication lines to enhance their survivability.
- Creating procedures for communicating, and possibly cooperating, with the Soviet Union and other nuclear weapon states in the event of nuclear attacks by third parties.
- Installing coded security locks over nuclear weapons aboard U.S. ballistic missile submarines which could be activated or deactivated at various levels of alert, and encouraging the Soviet Union to do the same.
- Establishing training programs for National Command Authority officials to familiarize them with alert procedures, communications capabilities, nuclear weapons release authority procedures, and the crisis control and stability implications thereof.
- Relocating a National Command Authority official outside Washington, D.C., to a secure location with access to the strategic command and control system.

Though not directly addressed by DOD's initial report to the Congress on nuclear winter, efforts to upgrade or enhance crisis management and control measures could be viewed as steps in the right direction to mitigate the implications of the nuclear winter theory given the current level of knowledge and the inherent policy uncertainties that go with it.

How Nuclear Winter Could Affect U.S. Civil Defense

FEMA officials indicated they have monitored the nuclear winter issue from a scientific and policy perspective from its inception. Their position, as previously noted, is that scientific knowledge regarding the climatic effects of nuclear explosions has not been developed enough to warrant development of new policies or to change existing policies regarding civil defense. We did not examine U.S. civil defense planning or the adequacy of FEMA's resources to accomplish its mission. We did note, however, a range of views on the potential effect of nuclear winter on civil defense efforts that may provide some perspective for examining future civil defense needs.

One view often publicly expressed is that the United States does not adequately protect against even the immediate effects of nuclear attack. Therefore, it would be unrealistic to think that civil defense programs could be implemented to protect against nuclear winter effects. Another view is that if nuclear winter consequences reach the magnitude suggested by some scientific studies, then it could render useless any attempted civil defense measures. Others say that to the extent scientific research shows reduced levels of effect or a variety of effects and/or severity over space and time, then an argument for contingency planning addressing such factors as food and water, fuel supplies, and delivery systems becomes more convincing.

Conclusions

To date, because of the uncertainty of existing scientific research, the administration has not translated nuclear winter concerns into policy changes. The foregoing discussion of some of the policy implications concerning nuclear winter indicates the difficulties likely to be encountered in trying to sort out the implications and required responses. Our treatment of these concerns is not meant to be either exhaustive or definitive. However, they do provide a frame of reference for the Congress and others to evaluate the DOD report on the implications of nuclear winter for policy and defense programs due in March 1986.

Interagency Research Program Now Coordinates U.S. Response: Some Concerns Remain

In 1983-1984, the nuclear winter phenomenon was being researched by DNA, DOE's Los Alamos and Lawrence Livermore National Laboratories, and NSF's National Center for Atmospheric Research. A DOD funded study by the National Academy of Sciences was also in progress. The need for an additional, high level effort to address the nuclear winter issue was evidenced by a February 1984 request by the President's Science Advisor that an interagency plan be developed for studying nuclear winter's scientific uncertainties. The interagency effort to prepare such a plan was led by the National Climate Program Office of the National Oceanic and Atmospheric Administration (NOAA).[1]

The plan was approved by OSTP in February 1985 and was implemented as the IRP on October 1, 1985. The study plan identified research priorities and recommended various funding levels. DOD, DOE, and NSF are funding the research from their own budgets. The program will be coordinated by an interagency committee[2] to ensure that effective use is made of research monies.

According to OSTP officials, the IRP adequately provides for the research needed to refine the probability of incurring long-term climatic and environmental consequences through nuclear warfare. Some scientists, however, question the adequacy of funding and the administration's long-term commitment to studying the issue.

IRP: Framework for Studying Nuclear Winter Uncertainties

The IRP identifies priorities, such as

- addressing major uncertainties in fire and smoke characteristics,
- improving computer climate modeling of the atmospheric effects of nuclear war, and
- providing a plausible set of atmospheric effects for assessing consequences.

It gives highest priority to a number of carefully planned laboratory and field fire experiments and modeling studies to better describe the

[1] The drafting committee for an interagency plan included representatives from federal departments and agencies, government laboratories, and academia. The reviewing committee consisted of representatives of the Departments of Agriculture, Defense, Energy, and State; Arms Control and Disarmament Agency; Environmental Protection Agency; FEMA; NASA; NOAA; and NSF. See appendixes III and IV, respectively, for a listing of the interagency members involved in drafting and reviewing the plan.

[2] See appendix V for the agencies represented on the interagency coordinating committee.

properties of smoke and soot particles injected into the atmosphere and subsequent cloud and chemical reactions.

DNA, DOE's Los Alamos and Lawrence Livermore laboratories, and NSF's National Center for Atmospheric Research will sponsor or conduct most of the research. Other government, university, and industry scientists will do research under contracts with these three agencies. Thus, the three principal agencies will handle the daily research activities while the interagency committee chaired by OSTP is responsible for coordinating the overall IRP. A subcommittee of the coordinating committee is tasked to recommend priorities based on blending the IRP and the principal agencies' proposed research.

The drafters of the IRP had recommended that a full-time program manager be designated as a way of fostering a balanced and cost-effective program. Some scientists are concerned that the interagency coordinating mechanisms will not be able to control funding effectively to assure that participating agencies perform priority research, and that the plan is unclear on whether funding will be provided beyond one program year.

IRP Funding

The IRP basically continues the nuclear winter research efforts that have been ongoing since about 1983 and funded by DOD, DOE, and NSF. The three agencies allocated $3.5 million for nuclear winter research in fiscal year 1985 by reprogramming funds from other activities within their agencies. The IRP officially began with fiscal year 1986 and an additional $2 million was reprogrammed by the agencies from their budgets for a total of $5.5 million. DOD and DOE each allocated $2.5 million and NSF $.5 million. The approved IRP does not specify the duration of nuclear winter research, or the level of future funding contemplated.

According to its chairman, the interagency drafting committee considered several funding options up to as much as $50 million in new funding over a 5-year period. For fiscal year 1986, the committee presented options ranging from no increase over the fiscal year 1985 level of $3.5 million up to $10.5 million more. The amount approved for fiscal year 1986 followed a lengthy review process involving OSTP, OMB, DOD, NSC, and others and resulted in $2 million being added to the 1985 funding level. The following table shows the fiscal year 1986 funding options presented in the draft study plan submitted by the interagency drafting committee to OSTP, and the actual budget adopted for fiscal year 1986.

Table 4.1: Funding Options and Approved Budget for Nuclear Winter Research

Dollars in thousands

Program components	Fiscal year 1986 options[a]			Approved fiscal year 1986 IRP budget[b]
Coordination	$0	$100	$350	
Meetings and review	0	100	100	
Target data base and policy studies	150	0	0	
Impact studies	50	200	500	
Fire Source				
Program preparation	0	0	100	
Theoretical studies	550	200	400	
Controlled experiments	300	500	700	
Field studies/rapid response	150	700	2500	
Historic analysis and background studies	450	200	750	
Data management	0	100	200	
Atmospheric chemistry and electricity	100	200	500	
Modeling				
Process and analogue	0	200	500	
Radiation	200	200	400	
Cloud and mesoscale	500	800	1600	
Global modeling	1050	500	1200	
Stratospheric dynamics	0	0	500	
Computer upgrading	0	0	200	
Funding				
New	$000	$4.000	$10.500	$2.000
Existing	3.500	3.500	3.500	3.500
Total Program	**$3.500**	**$7.500**	**$14.000**	**$5.500**

[a]Options delineated in a November 30, 1984, plan drafted by the interagency drafting committee and approved by an interagency review committee for submission to OSTP. The first column is the fiscal year 1985 funding level.

[b]The approved study plan did not delineate funding by program components.

Program Funding Adopted Amidst Some Scientific Concerns

Experts generally agree with the basic research strategy and areas of needed research set forth in the IRP. However, some scientists have noted that because of funding constraints research efforts may be limited or may be stretched out, slowing progress in areas of atmospheric chemistry, stratospheric dynamics, and dust effects. Two other areas where some disagreement exists among experts are large scale fire research and biological implications.

Large scale fire research incorporates aerial observations of controlled and/or natural large fires, focusing on uncertainties in smoke production and transport. This information would give computer climate modelers important data to more accurately simulate climatic conditions in a perturbed environment. Such research, according to scientists, can cost from $400,000 to $1 million for each event depending on the fire size, observation time, and whether an aircraft needs to be instrumented. Since $3.5 million of the IRP is already committed to current research efforts, some scientists believe the remaining $2 million, after allowing for other research necessities, cannot support productive large scale fire research. A DNA official, however, stated that large scale fire experiments are planned under the IRP. Some scientists believe there is a need to first better understand small scale fire processes and develop a theoretical basis for scaling up. They say such experiments can be performed more economically in laboratories. Others suggest viewing fires under controlled conditions in Canada, which involves a much lower cost than actually creating the experiment. Still others question the relevance of studying forest fires since they would not provide relevant data for modeling city fires and plume dynamics.

Some scientists argue for concurrent biological research given the range of likely consequences in nuclear war. Others, including OSTP officials, think biological implications have secondary importance. Some preliminary work on biological implications has been done at the Lawrence Livermore Laboratory, but the subject is not currently included in the fiscal year 1986 IRP.

Future Funding Concerns

Many scientists think nuclear winter's complexity warrants coordinated long-term research. They note that commitment to projects is often driven by perceptions of available future funding. Without some evidence of commitment to a long-term effort, they voice some apprehension that the IRP might lose valuable expertise.

The IRP was completed late in the year in relation to administration and congressional action on the fiscal year 1986 budget. The three funding agencies have indicated an intent to sponsor research through fiscal year 1990, but the levels of proposed funding and continued coordination beyond fiscal year 1986 are not spelled out in the IRP. OSTP officials stated that intended future funding considerations by DOD, DOE, and NSF show the administration's seriousness toward nuclear winter research.

Management Concerns

Some scientists who drafted the original plan wanted a full-time program manager. They saw a program structured under a coordinating committee as less effective and apt to inhibit program efficiency because it (1) has neither formal power nor direct control over funding, (2) does not review or approve research proposals, and (3) can only advise but not direct or enforce actions. They also worried that because the coordinating committee does not have direct control over funding, the research program may not have the built-in flexibility to move funds to projects which are determined to be higher priority after funding decisions have been made. On the other hand, coordination chaired through a White House office is often seen as fostering high level interest and politically empowering it.

Conclusions

The administration has taken the important step of initiating a plan for researching the scientific uncertainties of nuclear winter. Current funding is being provided through reprogramming actions by three operating agencies. Future funding is anticipated, but its scope and duration have not yet been determined.

Agency Comments and Our Evaluation

We requested formal comments on a draft of this report from the Office of Science and Technology Policy, which chairs the IRP's Coordinating Committee. OSTP's official comments noted that the report provides a reasonably balanced view on the issues. However, OSTP did express concern over our treatment of policy issues and the funding of nuclear winter research.

OSTP expressed the view that the report, in its discussion of policy issues, was giving more validity to the nuclear winter theory than was warranted and suggested the tenor of the report be changed. We believe the report recognizes the scientific uncertainties associated with nuclear winter. The report does not advocate a particular policy position or change, and our intent is to provide information for considering the broad policy implications as scientific research continues.

OSTP also took the position that a portion of the report dealing with various funding options should be deleted since no funding options were contained in the final Interagency Research Report and initial funding options proposed by the National Climate Program Office (which chaired the drafting committee effort) were not considered by the drafting committee. We recognize that the final plan did not contain any funding options, but they were included in a report issued by the drafting committee to OSTP. Our report has been revised to more clearly reflect this. Our treatment of this subject is intended to indicate the range of thinking about nuclear winter research components and funding that accompanied development and final adoption of the interagency research plan and not to express disagreement with funding levels provided.

OSTP also objected to our including any information on the funding options because OSTP says that it was provided to us with a nondisclosure proviso. During our fieldwork, OSTP never asked us to withhold this information; in fact, this issue was first raised when we briefed OSTP officials on our draft report. Since many individuals in and out of government participated in drafting and reviewing the plan, the plan's research needs and potential funding were widely known. We see no reason for not including the funding options, as presented, in our report.

We also solicited informal reviews and comments from other administration officials and scientists and selected scientists outside the government. Changes based on these reviews have been incorporated to enhance clarity or improve accuracy. Those commenting informally generally considered the report to be balanced and expressed no opposition to the treatment of issues. The Defense Nuclear Agency, which provided a written response, said the report was technically correct.

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National Oceanic and Atmospheric Administration

National Science Foundation

Office of Science and Technology Policy[1]

National Security Council (ex officio member)

Office of Management and Budget (ex officio member)

[1]Chairs the committee

Comments From the Office of Science and Technology Policy

THE WHITE HOUSE

WASHINGTON

February 12, 1986

Dear Mr. Conahan:

Thank you for the opportunity to review and comment on your proposed report, Nuclear Winter: A Plausible Theory With Many Uncertainties in Science and Policy.

In general, the report provides the relevant history and a reasonably balanced view on the issues. As chairman of the Coordinating Committee of the Interagency Research Program, I am far less sure of what the results of a nuclear war would be on the climate than is portrayed in the report. The desire to answer policy issues without first understanding the basic science associated with the climate tends to give more validity to the nuclear winter theory than is warranted. Consequently, I recommend that you recast the tenor of the report in the light of the many uncertainties that exist. As to administrative comments on the report, I recommend the following changes:

Page prior to page 1, titled "Abbreviations", add: NCPO, National Climate Program Office.

Now on p. 12, line 25.

Page 7, line 7 after (NSF), add: and NOAA.

Now on p. 26, line 30.

Page 24, line 10, change the sentence beginning with "An official" to read: The position of the Coordinating Committee for the Interagency Research Program is that the basic science research must be addressed before the policy issues.

Now on page 45.

Page 47, add: reference to our report, titled Interagency Research Report for Assessing Climatic Effects of Nuclear War, dated February 5, 1985, copy attached.

2

Now on page 37.

There is an issue of substance on page 41 that has to be corrected. The second paragraph of the section titled, Various funding options considered, should be deleted. There are no funding options contained in the final Interagency Research Report referenced in my comments above. The first draft of our report, which contained funding options, was provided to your staffers with a non-disclosure proviso that is similar to the one attached to your own draft report. During the initial staffing process, those options, which were only recommendations provided by NCPO, dropped out and were not considered by the interagency drafting committee. Consequently, that paragraph should be deleted and the title of that section be changed to something appropriate, such as, Interagency Research Program Funding.

Thank you again for the opportunity to review your draft report. I hope you find my comments helpful and agree with me on the necessity of maintaining the propriety of the Governmental report review process. Thank you for your consideration.

Sincerely,

John P. McTague
Acting Science Advisor to the President

Mr. Frank C. Conahan
Director
National Security and
International Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Glossary

Analogue	something that is similar to another, providing a basis for comparison.
Coagulation	a scavenging process that removes smoke particles by combining or aggregating smoke and soot particles to form large particles. See "scavenging" below.
Combustibility	ability to catch fire and burn, inflammability.
Dust	airborne soil and rock particles created by nuclear explosions near the ground. Dust is created by actual blasts, not by fires.
Megaton	one million tons; a 1-megaton bomb is equivalent in energy release to 1 million tons of TNT.
Mesoscale	intermediate modeling scale (10-100 kilometers) used to define the area between local and global scales.
Modeling	using computer hardware and software to perform mathematical calculations which simulate atmospheric conditions and responses.
Optical Properties	refers to the degree to which smoke particles absorb sunlight.
Ozone Layer	a gaseous layer formed in the stratosphere which acts as a shield against penetration of ultraviolet light from the sun.
Plume	an elongated, usually open and mobile column or band of smoke shooting upwards from an intense fire.
Scavenging	the removal of gases or particles from the atmosphere.
Smoke	all airborne particles resulting from combustion.

Soot	the carbon-containing (i.e., black) component of smoke.
Stratosphere	upper portion of the atmosphere normally between 6 and 15 miles above the earth's surface.
Toxic Substances	any of various poisonous substances produced by fires; potentially harmful or fatal to humans and other organisms.
Wash-Out	a scavenging process which removes smoke and soot particles from the atmosphere by water condensation; used interchangeably with rain-out.
Yield	the amount of energy expended by a nuclear explosion, usually expressed in kilotons or megatons of TNT.

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