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Is the "nuclear winter" real?

The discussion on the so-called "nuclear winter" is continued here, with further contributions to come in future issues of Nature.

THE article by Covey, Schneider and Thompson[1] breaks new ground in the atmospheric modelling of the possible effects of nuclear war, but despite that article and that of Turco *et al.*[2] two crucial questions remain: Will there really be a major cooling of the continental land masses (down to some −40°C)? And would such a cooling effect be maintained for months or seasons rather than days or weeks? Here I highlight outstanding uncertainties that need investigation.

Covey *et al.* start their model calculations by assuming a particulate layer in place in the atmosphere as a result of conflagrations of cities and forests following a nuclear exchange. This layer of smoke and soot is assumed to be more or less uniformly distributed over altitudes of 1 to 10 km; thick enough (optical depth = 3.0) to cut off the (shortwave) solar radiation from the Earth's surface but optically thin in the infrared (IR) (so that the surface can cool by radiating longwave radiation into space). In other words, they accept the physical model of Turco *et al.* and, not surprisingly, get a similar answer.

I have the following points to make about the certainty of these effects.

(1) The temperature change of the land surface (assuming small heat capacity) depends on a temporary imbalance between two very small fluxes: the inflow of solar radiation and the outflow of IR radiation, as well as the inflow and outflow of other energy fluxes. One cannot be sure even about the sign of the temperature change until all energy fluxes have been fully specified. Turco *et al.* and Covey *et al.* consider only a severe reduction of visible solar radiation, and explicitly assume that the particle layer would be optically thin in the IR, would not affect IR transmission so would not create a "greenhouse" effect.

(2) But the size and sign of the temperature change depend crucially on the ratio of the optical thicknesses (in the visible and the IR), and thus not only on the total amount but also on the size distribution of the particulates, especially on their detailed optical properties. The particle size distribution would be modified by agglomeration which is most important initially, when the smoke, soot and ash clouds are dense. For the same initial mass, the coalescence of smaller into larger particles will increase optical depth in the IR and decrease it in the visible.

(3) The conflagration would probably generate a variety of complex gaseous combustion products with absorption bands throughout the IR region.

(4) Water droplet clouds (located below the hypothetical particle layer) would trap and re-emit IR radiation emanating from the land surface below.

(5) About the generation of water vapour there can be no doubt, although the phenomenon was not considered by Turco *et al.*

The combustion of dry mass must generate a corresponding mass of water vapour, since (CH_2) is oxidized to form H_2O. A total dry mass of 2.2×10^{13} kg (see ref. 3) must lead to $\sim 2.5 \times 10^{13}$ kg of water vapour. The amount of water vapourized by the nuclear explosion itself is small: the energy of a 1 Mtonne explosion ($\sim 4 \times 10^{15}$ J), if converted at the rate of 1 per cent, would lead to 1.6×10^7 kg of H_2O. Quite important, however, is the conversion of the energy released in the combustion: (2.2×10^{13} kg of dry mass) · (14×10^6 J kg^{-1}) $\approx 3 \times 10^{20}$ J. A 25 per cent conversion would generate another 2.5×10^{13} kg of H_2O.

If the fire spread over an area of $\sim 10^6$ km^2, (ref. 3), it would produce from 2.5 to 5 g cm^{-2} of water vapour (2.5 to 5 cm at STP), adding substantially to the normal water content of the atmosphere of about 2.5 g cm^{-2}. Such a large release of water vapour is possible, depending on the state of the forest, soil moisture, existence of streams and lakes, etc. In forest fires steam is produced copiously, as well as clouds, making it difficult to spot them from IR detectors on weather satellites[4,5]. Eventually the water vapour will spread over a larger area, making it less effective as an IR absorber.

(6) Another neglected heat source, warming the Earth's surface, is the combustion energy of the very materials that contribute to the smoke and soot. The oxidation of wood releases 14×10^6 J kg^{-1}, and 1 kg m^{-2} daily corresponds to nearly 200 W m^{-2} — the average amount of solar energy at a cloudless low-latitude location. A smouldering combustion of only 1 ounce of material per square foot per day would generate about 50 W m^{-2}, many times the minimum solar energy (8 Wm^{-2}) calculated by Turco *et al.* for their baseline case. This would be sufficient to keep the surface temperature from falling too low.

Thus surface temperatures are unlikely to fall very low. They could even increase if particle size distribution, water clouds and combustion gases are such as to throttle the loss of heat radiation from the surface. Most probably, temperatures will decrease by a few degrees (rather than tens of degrees).

I now turn to a discussion of the lifetime of particulates in the atmosphere.

(i) The one-dimensional model of Turco *et al.* cannot capture mesoscale effects in the atmosphere. Nor, unfortunately, can the global three-dimensional models of Covey *et al.*; their resolution is too coarse. Yet mesoscale effects are likely to determine the residence time of the smoke and soot particles. Experience with mesoscale models[6] argues strongly against the existence of a stable layer in the atmosphere where the solar energy is absorbed. On the contrary, one would expect violent convective activity even if the layer were initially uniform, leading to cumulus-type formation, thunderstorms, rain squalls and accelerated cleansing of the atmosphere.

(ii) Further convective activity (plus rain showers and atmospheric cleansing) comes from the strong temperature gradient at the ocean–land boundary. Again, the three-dimensional model cannot capture these mesoscale effects, although the induced monsoonal circulation is yet another factor which limits large temperature excursions on the continents.

(iii) With the residence time limited by mesoscale effects, it is proper to ask if there is enough time to disperse the particulates uniformly through the global atmosphere, or at least the Northern Hemisphere, as explicitly assumed by Turco *et al.* and Covey *et al.* The latter suggest that the radiative heating of the particles may affect the atmospheric circulation so as to speed up their dispersion. This may well be the case; although in the absence of a fully interactive, self-consistent calculation, one cannot be sure how important the effect is.

Perhaps reasonably uniform dispersion can be achieved before rain-out cleanses the atmosphere. More probably, one will see patchy clouds which thin out rapidly — hardly a cataclysmic nuclear winter.

S. Fred Singer

1. Covey, C., Schneider, S.H. & Thompson, S.L. *Nature* **308**, 21-25 (1984).
2. Turco, R.P., Toon, O.B., Ackerman, T., Pollack, J.B. & Sagan, C. *Science* **222**, 1283-1292 (19837.
3. Crutzen, P.J. & Birks, J.W. *Ambio* **11**, 115-125 (1982).
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5. Matson, M., Schneider, S.R., Aldridge, B. & Satchwell, B. *Fire Detection using the NOAA-series Satellites* NOAA/NESDIS Tech Rep. April 1984.
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COVEY AND CO-WORKERS REPLY — Dr Singer's comments on the plausibility of "nuclear winter" deserve serious consideration, perhaps in more detail than limited space allows.

We emphasize again that the work reported in our article[1] was designed to examine how a three-dimensional climate model would respond to a hypothetical war-generated smoke cloud similar to that

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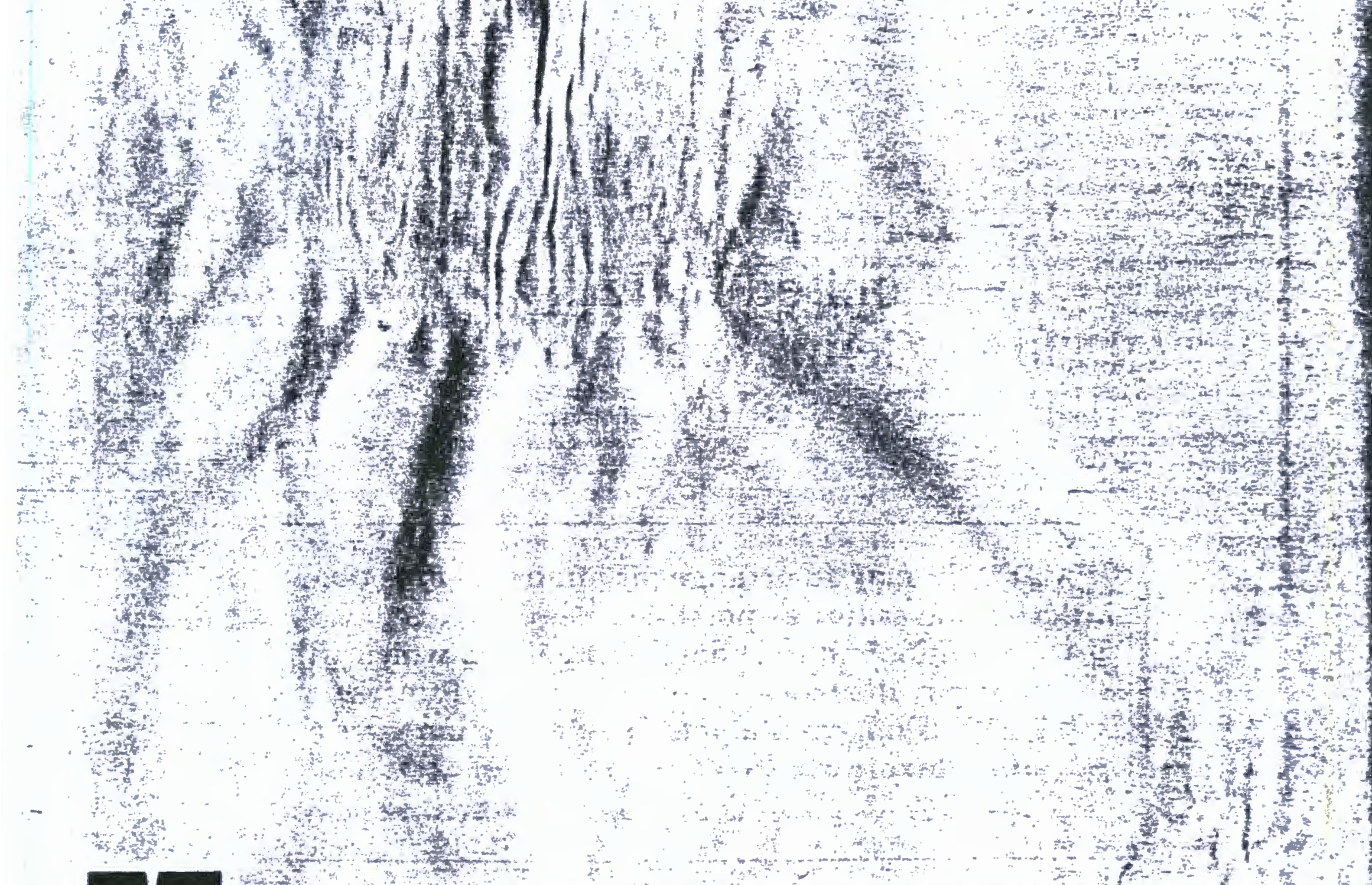
A well-publicized study predicts that even a limited nuclear war plunge much of the earth into darkness and freezing, threatening mankind. Many are taking the prediction as fact, but uncertainties



Modern intellectual history is replete with examples of the use of incomplete, inconclusive science for political ends. Rachel Carson's *Silent Spring*, published in 1962, scared a generation into believing that herbicides and pesticides were causing wholesale poisoning of the environment and that stringent government regulation was the only solution. Her disciple Barry Commoner translated environmental concern into ideological terms, asserting that the underlying source of pollution is capitalism itself, as if socialist farmers don't need fertilizer and weed killer to increase crop yields, or socialist factories don't emit smoke.

The doomsaying Stanford ecologist Paul Ehrlich and the Club of Rome, an informal group of thinkers concerned with global economic problems, published studies claiming that severe government intervention—perhaps even totalitarian methods of population control—were necessary to prevent "the population bomb" from destroying civilization. It is now nearly a generation later, and the apocalyptic predictions are nearly forgotten.

In a similar vein, Samuel Epstein in *The Politics of Cancer* (1978) summarized the misinformation propagated by a small group in the National Cancer Institute, claiming that industrial chemicals were generating an epidemic of cancer in the United States, and again (surprise) the solution was to be yet more government regulation. Only recently Edith Efron exposed the falsity of this claim in her brilliant book *The Apocalyptics: Cancer and the Big Lie* (1984).

The latest and most pervasive episode of the political misuse of science is the prediction of global climatic catastrophe from nuclear war, even if a small portion of the nuclear weapons in the world are ever exploded. The apocalyptic idea is that nuclear explosions and the fires they would ignite would send dust, smoke, and soot high into the atmosphere, where they would block the sun's heat and light from reaching the earth's surface, thus plunging the world into darkness and subfreezing temperatures: crops would fail, creatures would die, humankind itself might perish. Propagators of this idea are using it to promote various political causes, including "the nuclear freeze," unilateral disarmament, and proposals for immediate, drastic bilateral weapons reductions to a level below which catastrophe is felt to be unlikely.

Of course, there must be a buzzword for the publicity campaign and a "prophet of doom" for TV appearances. The buzzword is *nuclear winter*, and the leading prophet is Cornell University astronomer Carl Sagan. Sagan is the star of a media campaign that opened with his article "The Nuclear Winter," published in the Sunday newspaper-supplement magazine *Parade* on October 30, 1983. The article appeared on the eve of a two-day conference in Washington, D.C.—the Conference on the Long-Term Worldwide Biological Consequences of Nuclear War, in which celebrity-scientists Sagan

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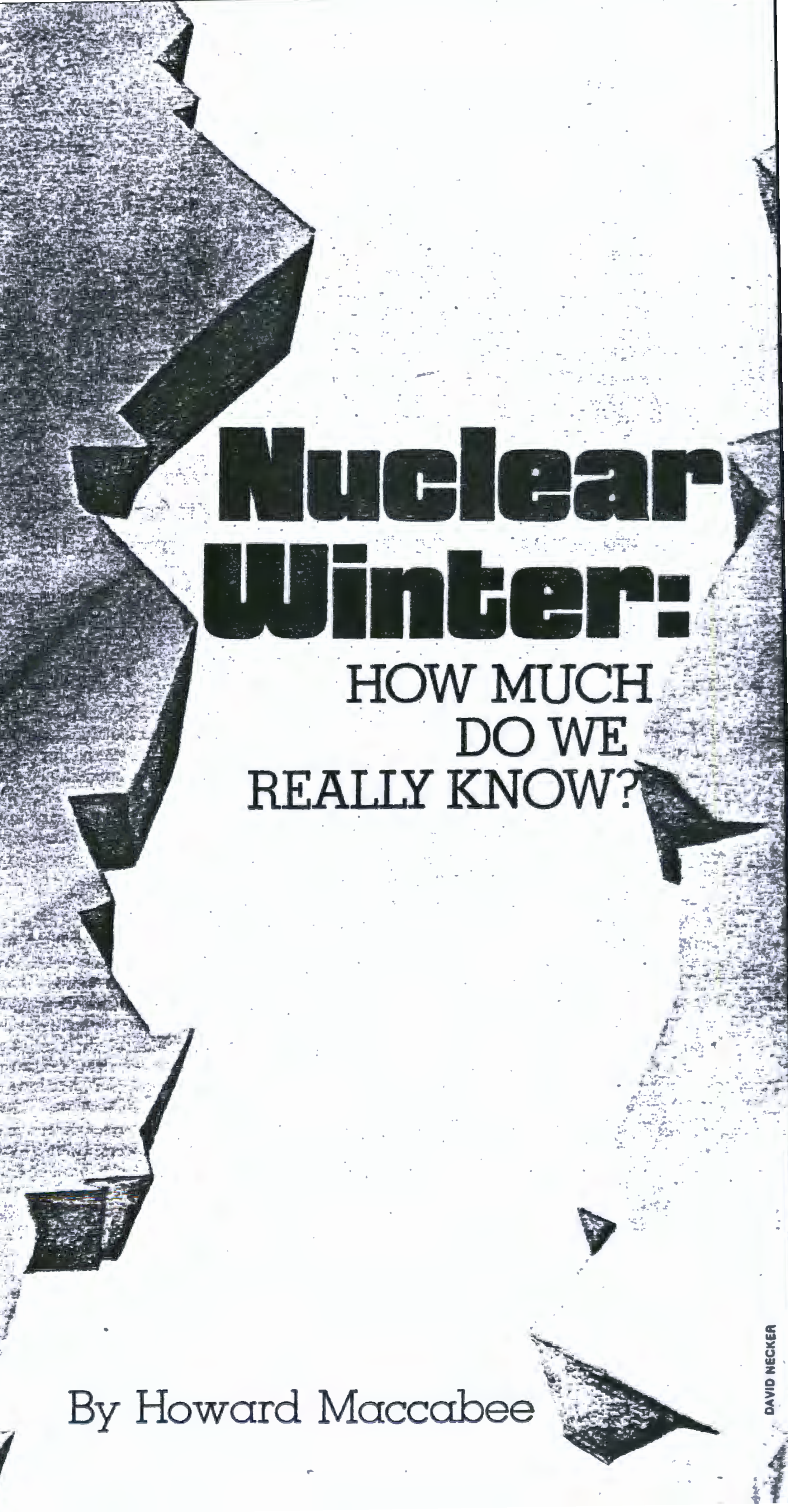
Nuclear Winter:

HOW MUCH DO WE REALLY KNOW?

By Howard Maccabee



DAVID NECKER

and Ehrlich were chief participants.

The well-orchestrated publicity campaign actually began in April 1983, when the conference organizers hired the public-relations agency Porter & Novelli Associates to publicize the issue and the impending conference. In an interview in *Science Writers*, a publication of the National Association of Science Writers, Porter & Novelli chairman Jack Porter unabashedly laid out the nuclear winterists' publicity strategy, reporting that the campaign ended up costing $100,000. Detailing the nuclear-winter PR tactics—including, for instance, efforts to arrange coverage by such major media as the *Phil Donahue Show* and *Parade* magazine—Porter recalled how the bombing of the Marine quarters and especially the US invasion of Grenada, though initially perceived as publicity "competition" (because both events occurred shortly before the conference was held), actually helped "heighten the dramatic perception" of the nuclear-winter idea: reporters returning from Grenada "quickly ran out of news," because of the restrictions on covering the invasion, Porter surmised, "and they had to come back and write about something else. Our story formed a kind of logical focus."

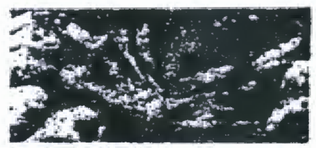
The first article in a scientific journal to spell out the gloomful hypothesis was "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions," by Richard Turco, Brian Toon, Thomas Ackerman, James Pollack, and Sagan, published in the December 23, 1983, issue of *Science.* (This article is often called TTAPS, referring to the first letter of each author's name.) This sequence of events—a publicity campaign paid for and launched *before* the publication and circulation of a scientific study—is very unusual. In fact, most scientists agree that this type of arrangement is destructive of the goals of honest inquiry and more consistent with attempts at stock-market manipulation or disguised political purposes.

Following the December 1983 *Science* article, additional doomful publications appeared, including "The Climatic Effects of Nuclear War," again by the TTAPS authors (*Scientific American*, August 1984). Transcripts of the proceedings of the Conference on the Long-Term World-Wide Biological Consequences of Nuclear War came out in a book, *The Cold and the Dark* (1984), by Paul Ehrlich, Sagan, Donald Kennedy, and W. O. Roberts.

Also following the publication of TTAPS, other studies of one aspect or another of the nuclear-winter hypothesis have been done, and still others are planned. For example, the National Research Council—principal research arm of the renowned National Academy of Sciences—performed a study of the hypothesis, the results of which were issued in December 1984. Moreover, the issue immediately percolated into the mainstream media, with scores of newspaper reports, magazine articles, and TV-show segments bringing the gloomy news to the American public.

The beginning of the nuclear-winter idea is attributed to Dutch scientist Paul Crutzen, director of the Max Planck Institute for Chemistry in West Germany. He had been concerned about nuclear war depleting ozone in the stratosphere, the uppermost part of the atmosphere. In 1982, he and a colleague, American chemist John Birks, predicted that widespread nuclear explosions could ignite enough forest fires to produce a thick smoke layer that, for a period of months, would reduce the amount of sunlight reaching the earth's surface. Upon reading Birks and Crutzen's study, Richard Turco, a young atmosphere scientist with R&D Associates in Los Angeles, realized that the loss of heat from sunlight could cause a severe temperature drop. Turco is credited with coining the term *nuclear winter.* Turco joined with Sagan and three scientists from NASA's Ames Research Center in California—Toon, Ackerman, and Pollack—to devise the models, assumptions, and calculations for the study that bears the acronym TTAPS.

Ehrlich and some of his colleagues seem to have a "strange love" for apocalyptic predictions.



Soon after the TTAPS article was published in *Science*, Sagan extrapolated the policy implications of the nuclear-winter predictions in a paper in the influential quarterly *Foreign Affairs.* He advocated rapid decreases in worldwide nuclear armaments to a total of fewer than 1,000, a "threshold" below which Sagan believes that nuclear winter is very unlikely.

The nuclear-winter idea has predictably been taken up by various groups advocating unilateral nuclear disarmament, accommodation with the Soviet Union, and the nuclear-freeze movement. Civil defense, the favorite whipping boy of the antinuclear factions, comes in for the usual attack: Why bother with shelters when we'll all freeze or starve?

In reality, the implications of the nuclear-winter idea are the *opposite* of what Sagan and his followers claim. Nuclear winter *is* avoidable, even in case of major conflict using nuclear weapons. Because of the possibility of disastrous climatic effects from attacks on cities—which, when burning, produce more smoke and soot than other targets—US military planners will continue to shift their target priorities from population centers (cities) to militarily strategic sites, as Soviet planners are believed to have already done. This shift will result in greater need for civil defense, fallout shelters, food reserves, and medical preparations. A "freeze" on current weapons, even if it were mutually verifiable, would be the worst possible response to the possibility of a nuclear winter, because older-generation weapons now present in the Soviet arsenal are the riskiest for causing severe atmospheric effects.

Indeed, fear of a nuclear winter is more likely to encourage further efforts toward nuclear-weapon modernization than toward general nuclear disarmament. That "conventional" nuclear weapons might cause climatic catastrophe even reinforces arguments for the "neutron bomb," which produces mostly temporary radiation instead of blast and fire. Furthermore, the possibility of a nuclear winter may make more urgent the need for active defense measures such as High Frontier and the Strategic Defense Initiative ("Star Wars"), the proposals for space-based defensive systems against nuclear attack. Even if they are not 100 percent effective, these could drastically reduce population destruction and climatic effects.

These implications may seem paradoxical, but think again—paradox abounds in the Nuclear Age. That a Strategic Arms Limitation Talk (SALT I) could *intensify* the arms race by causing multiple-warhead missiles (MIRVs) to be added to arsenals is a paradox. That the tragic attacks on Hiroshima and Nagasaki, with the resulting fear of nuclear weapons, may have prevented further nuclear war for 40 years is a paradox. There are more to come.

In order to understand the TTAPS study's nuclear-winter predictions, you must know something about its assumptions and method of calculation. Turco and company started with a series of "nuclear exchange" scenarios, in which they assume that a certain number of nuclear warheads explode with a given total explosive yield, measured in megatons (millions of tons

Two Ways to Destroy a Target

In a nuclear war, combatants will detonate their bombs on enemy targets in two different fashions: surface bursts and air bursts. In a surface burst (left), the weapons explodes on or near the surface of an enemy target, usually a "hardened" (that is, well-defended) military installation such as a missile silo. In an air burst (right), the bomb explodes in the air above the target—usually an industrial urban area (and, therefore, a population center)—creating a powerful downward blast over a large area. By comparison, a surface burst destroys a much smaller area than an air burst from a similar-size bomb. Though a surface burst injects much more dirt and dust into the atmosphere than an air burst, it creates much less fire (and, hence, smoke and soot) than an air burst.

of TNT equivalent, abbreviated "MT").

In some scenarios, a higher percentage of the explosions occur in surface bursts—in which weapons explode on or near the ground—on military targets (for example, missile silos and submarine or bomber bases); this has been called a "counterforce" strike. Other scenarios, known as "countervalue," assume a higher proportion of air-burst explosions, over cities.

Surface bursts form craters, generating a lot of fine-grained dust from explosive breakup, vaporization, and recondensation of the surface materials. Air bursts, on the other hand, make little dust but can cause instantaneous widespread fires: thermal radiation from the weapon's fireball ignites combustible materials, such as wood houses, dead trees, brush, and building roofs and contents.

To provide an example of what they perceive as a likely nuclear exchange and its climatic effects, the TTAPS authors used a "baseline scenario" assuming a total explosive yield of 5,000 MT from 10,400 explosions of various sizes. A majority of the explosive yield would be used in surface-burst attacks on military targets with one-fifth directed in "countervalue" attacks on urban or industrial areas. In another scenario, for example, TTAPS assumed that 100 megatons of explosives are distributed in 1,000 explosions, *all* in countervalue air bursts over cities, with no counterforce surface bursts on military targets.

Using published data from nuclear tests, TTAPS then calculated the amount of dust generated by surface bursts and assumed a distribution of dust-particle sizes to determine the amount of dust that is spread high into the stratosphere—smaller particles are carried higher and stay up longer. They calculated the amount of smoke nuclear explosions cause by multiplying (1) the area presumed ignited by thermal radiation from air bursts by (2) the amount of flammable material present per unit area, times (3) a factor for how much of this material is burned, times (4) a factor for the proportion that is emitted as smoke. They then extrapolated from previous fire events how high the smoke might rise in the atmosphere. They assumed that 5 percent of the urban fires become firestorms with smoke plumes as high as 19 kilometers (about 60,000 feet). Smoke and soot are highly critical elements of the nuclear-winter hypothesis (and therefore, too, the amount of smoke-producing burning that a nuclear conflict would ignite), because the black, carbon content of smoke and soot is highly absorbent of sunlight. Ordinary dust, on the other hand, tends more to scatter light than to absorb it.

ILLUSTRATIONS•LAURA MAIN & BRUCE JONES

Next TTAPS calculated the distribution of dust and smoke over time and their spatial distribution (how much of what size particles, at what altitude, in what area). This is an extremely difficult problem, involving assumptions of how a war might be fought—including targeting patterns and the timing of attacks and counterattacks—meteorologic conditions, characteristics of dust and smoke clouds, rates of mixing of particles in the atmosphere, rates of removal of particles from the atmosphere by "washout" from natural processes (such as rain), etc.

The TTAPS authors side-stepped the enormous complexity of this problem by assuming that the spatial distribution would be completely uniform over the Northern Hemisphere and, with regard to time, by assuming that the uniform universal "cloud" appears instantly at the beginning of a nuclear conflict.

Determining the cloud's absorption of the sun's rays involves assumptions about the optical properties of the cloud's smoke and dust particles. It also requires a model to calculate how much light and heat is transmitted to the earth's surface. TTAPS chose a "one-dimensional" model of light and heat transmission, which assumes that altitude is the primary (and only) variable that affects the radiation of light and convection of heat. Programmed with this model, computers can predict how temperatures at land surfaces will change over time after detonation of nuclear weapons.

For their 5,000-MT, baseline scenario, TTAPS predicted that the Northern Hemisphere average temperature would drop to -23 degrees Centigrade (-9 degrees Fahrenheit) after three weeks and only rise above freezing (32 degrees F) after three months. The prediction from the 100-MT scenario, in which only cities are attacked, is only slightly less severe, with two months of subfreezing temperatures. This seems surprising by comparison to the 5,000-MT, baseline scenario—which has 50 times the explosive yield—until one realizes that Turco et al. assumed the number of air-burst explosions over cities to differ by only a factor of two (1,000 in the 100-MT scenario versus approximately 2,000 in the baseline version). Moreover, TTAPS unaccountably assumed a doubling of the combustible material in the 100-MT (versus 5,000-MT) scenario, and they also increased the smoke-emission assumption for this case. The crux is that the explanation for the short-term temperature drop is dominated by the smoke from the burning of *cities*, with a much smaller effect from the long-term circulation of fine dust in the stratosphere, as produced by the surface explosions inherent in attacks on military targets.

Nuclear Winter and Nuclear Weather

According to the nuclear-winter hypothesis, a doomful light- and heat-blocking cloud of smoke, soot, and dust from nuclear explosions would form in the stratosphere, that portion of the atmosphere that begins at about 50,000 feet up. Weather activity such as rain and snow—which washes particulate out of the sky—normally occurs only in the troposphere (the lower portion of the atmosphere). By contrast, the stratosphere is stable: weather activity ordinarily does not occur there, so particulate like smoke and soot may remain suspended there for a long time. But studies indicate that storms would likely occur in the stratosphere following a nuclear war, stimulated by condensation of the debris cast up there.

In critically analyzing the TTAPS study's method and assumptions, it should first be acknowledged that the study is a brilliant tour-de-force, opening up whole new areas of scientific speculation and contention. The TTAPS authors bridged previously uncrossed gaps between nuclear-weapons physics, pyrology, aerosol dynamics, optical physics, thermal transport phenomena, meteorology, computer modeling of climate, etc., as well as nuclear strategy. They have been "thinking about the unthinkable" in ways that had escaped the late futurologist Herman Kahn and nuclear physicist and renowned weapons expert Edward Teller.

The climate effect of nuclear war *is* an important, perhaps a vital, question for all of us who live with this Sword of Damocles overhead. Nevertheless, when apocalyptic claims are being made that affect the psychological security of millions of people, when policy recommendations are made that can affect the freedom and physical security of hundreds of millions, the ideas, assumptions, and calculations must come under heavy scrutiny. It is in this spirit that I will consider the weaknesses of the nuclear winter prediction.

First, the TTAPS team's assumption that all explosion products—dust, smoke, soot, and other particulate—are spread uniformly and simultaneously over the surface of the hemisphere is physically impossible and not even a good approximation of any realistic situation. The TTAPS authors assumed, by analogy with known atmospheric effects of volcanic eruptions and cooling effects of dust storms on Mars, that both dust and smoke would be spatially well-mixed.

But in reality, the rapidity and uniformity of mixing depends on the distribution of particle sizes. And one would expect "nuclear" dust and smoke to have a distribution different from what is known from previous non-nuclear explosions.

The TTAPS researchers used this model ostensibly because it fit into their "computer code" and is simple enough to make calculations convenient. But the value of their results suffers thereby, for this model is equivalent to a *worst-case* assumption.

Intuitively, we know that any "break in the clouds" will allow much more sunlight at the earth's surface. Indeed, it can be proven rigorously that *any* nonuniformity in the spatial distribution (that is, patchiness in the smoke cloud) will allow more solar energy transmitted. We also know that nuclear explosion patterns and smoke plumes will be intrinsically nonuniform; thus, surface temperature drops and the darkness of the nuclear cloud's overcast will be less than the TTAPS model predicted.

Furthermore, the TTAPS team's assumption of simultaneity—that all dust and smoke would be injected into the atmosphere at once—is also a worst case. Explosions and subsequent spreading of smoke from a massive nuclear exchange are more likely to occur spasmodically and unevenly over a period of days to weeks. Hence the sharp maximum temperature drop that the TTAPS researchers calculated actually would be "smeared" over time, resulting in smaller net maximum temperature changes than the researchers predicted.

Without explicit justification, the TTAPS authors assumed that a firestorm (a devastating type of urban conflagration with especially powerful updrafts) would be a factor in 5 percent of cities burned and that smoke and soot from these firestorms would rise into the stratosphere (up to 19 kilometers, or about 60,000 feet) and stay there a long time, causing great cooling effects. In fact, most experts believe that firestorms, as distinguished from mass fires, are unlikely from nuclear explosions, because the special circumstances needed to generate a firestorm—a highly concentrated fuel supply and weather conditions allowing the fire to consume all available oxygen—would not be present and because the powerful blast wave that follows the thermal flash would blow out many nascent fires. There were massive fires at Hiroshima and Nagasaki in the blown-down rubble of buildings, but *no* firestorms. Furthermore, smoke plumes from the firestorms created by deliberate incendiary bombing in Dresden and Hamburg, Germany, in World War II did not exceed 10 kilometers in height. The injection of smoke into the stratosphere (that is, above 15 kilometers, or 50,000 feet) seems highly unlikely.

Forest-fire expert Craig Chandler believes that the TTAPS researchers exaggerated their estimates of smoke from wildfires by a factor of two or more, because (1) for much of the year Northern Hemisphere forests are almost immune to ignition and (2) immediately upon a thermal-radiation pulse, forests emit steam, which helps shield them from catching on fire.

The possibility of a nuclear winter makes the MAD doctrine look more insane than ever.

The TTAPS team's estimate probably additionally exaggerated by a factor of 10 the amount of smoke produced by a nuclear conflict, according to some nuclear-weapons-effects experts (such as Cresson Kearny from Oak Ridge National Laboratory) and the Defense Nuclear Agency. In itself, this lower level of smoke production would reduce the climatic effect from catastrophic to noticeable but not severe, because as optical density (smoke) declines, the penetration of light and thermal radiation increases very rapidly (exponentially).

Even if the TTAPS baseline calculation of smoke production were correct, it is of the same magnitude as current annual global smoke emission, which does not have catastrophic effects. The TTAPS team's claim, without evidence, that "nuclear smoke" is *100 times* more effective in disturbing the atmosphere is not convincing.

Once dust and smoke particles are in the troposphere (the portion of the atmosphere below the stratosphere), they may be removed by coalescence (sticking together to form heavier particles that fall out faster), by rainfall, and by all other natural processes that currently scavenge out of the sky particles from fires, dust storms, smoke stacks, etc. The TTAPS researchers, however, underestimated these processes and consequently exaggerated the nuclear cloud's capacity to block sunlight (opacity).

Furthermore, in the presence of cooling, dust and smoke particles themselves act as condensation centers for the formation of raindrops and snowflakes, causing precipitation that washes out much of the remaining particles, which would further decrease the nuclear-winter effects. Studies performed at the Lawrence Livermore Laboratory in California, a major center for weapons research, suggest that this process would very effectively remove smoke from even the stratosphere, which is above the atmospheric level at which the normal "scavenging" of weather activity occurs. Physicist Joyce Penner, head of Livermore's nuclear-smoke research, simulated on a computer the exploding of a one-megaton bomb. The simulation showed that though smoke rose into the stratosphere, half rapidly fell back into the troposphere (where normal weather activity would wash it out quickly). Penner estimated that the half remaining in the stratosphere had almost three times the condensation needed to make rain. So even stratospheric smoke would be washed back to earth by storms of its own creation.

In fact, the TTAPS study did not take into account many of the moderating effects of water in atmospheric dynamics and radiative effects. The researchers appear to have ignored not only the generation of large amounts of water through combustion from the postulated fires, but also the much-larger mass of water that is naturally present in the atmosphere. Through continuous evaporation and precipitation, this water completely recycles itself in about one week. In their baseline case, the TTAPS researchers calculate the emission of 225 million tons of smoke, but this is about *10,000 times less* than the mass of atmospheric water. Thus, according to nuclear physicist Edward Teller, the TTAPS assumption that dust and smoke particles would remain in the troposphere for weeks to months is highly suspect.

In their projections of atmospheric cooling, Turco and team also neglected the critical impact of the oceans, which cover most of Earth's surface. The sea would powerfully mitigate cooling from a nuclear cloud, because it has an immense capacity to hold heat and, at the surface, transfers heat to the atmosphere very well. Thus, no matter what the initial cooling over land surfaces, the ocean temperature will not change signifi-

The Nuclear Winter Hypothesis

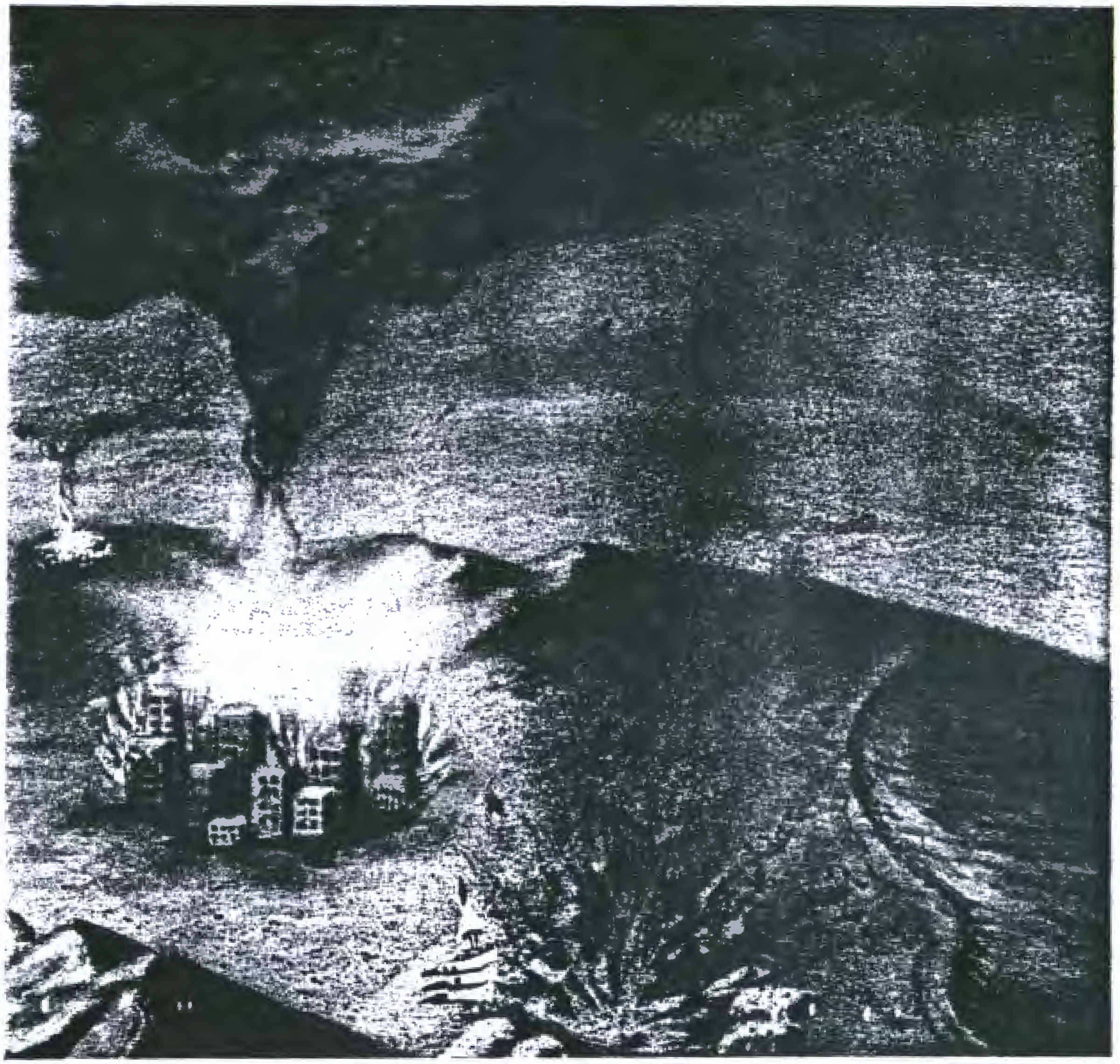
The authors of the TTAPS study considered many different scenarios of nuclear war that might create a nuclear winter. Their baseline scenario is depicted below.

Altogether, combatants detonate nuclear weapons with a total explosive yield of 5,000 megatons, in 10,400 simultaneous explosions. Of the total yield, 57 percent is in surface bursts, with 20 percent of the yield hitting urban or industrial targets (population centers, that is).

Of the urban fires ignited, 5 percent become firestorms, sending smoke and soot into the stratosphere.

Instantaneously, the 10,400 explosions inject smoke, soot, and dust into the stratosphere, creating a uniformly dense cloud that blocks much of the sun's heat and light from the Northern Hemisphere.

Within three weeks, temperatures in the Northern Hemisphere drop to subfreezing levels and do not rise above freezing for three months.



cantly, and it will act as a massive heat source to warm the atmosphere, rapidly increasing the temperature at the coastlines and eventually the interior temperatures, as well. Moreover, temperature differences at the shore would likely cause massive storms, which would accelerate the moderating and scavenging processes.

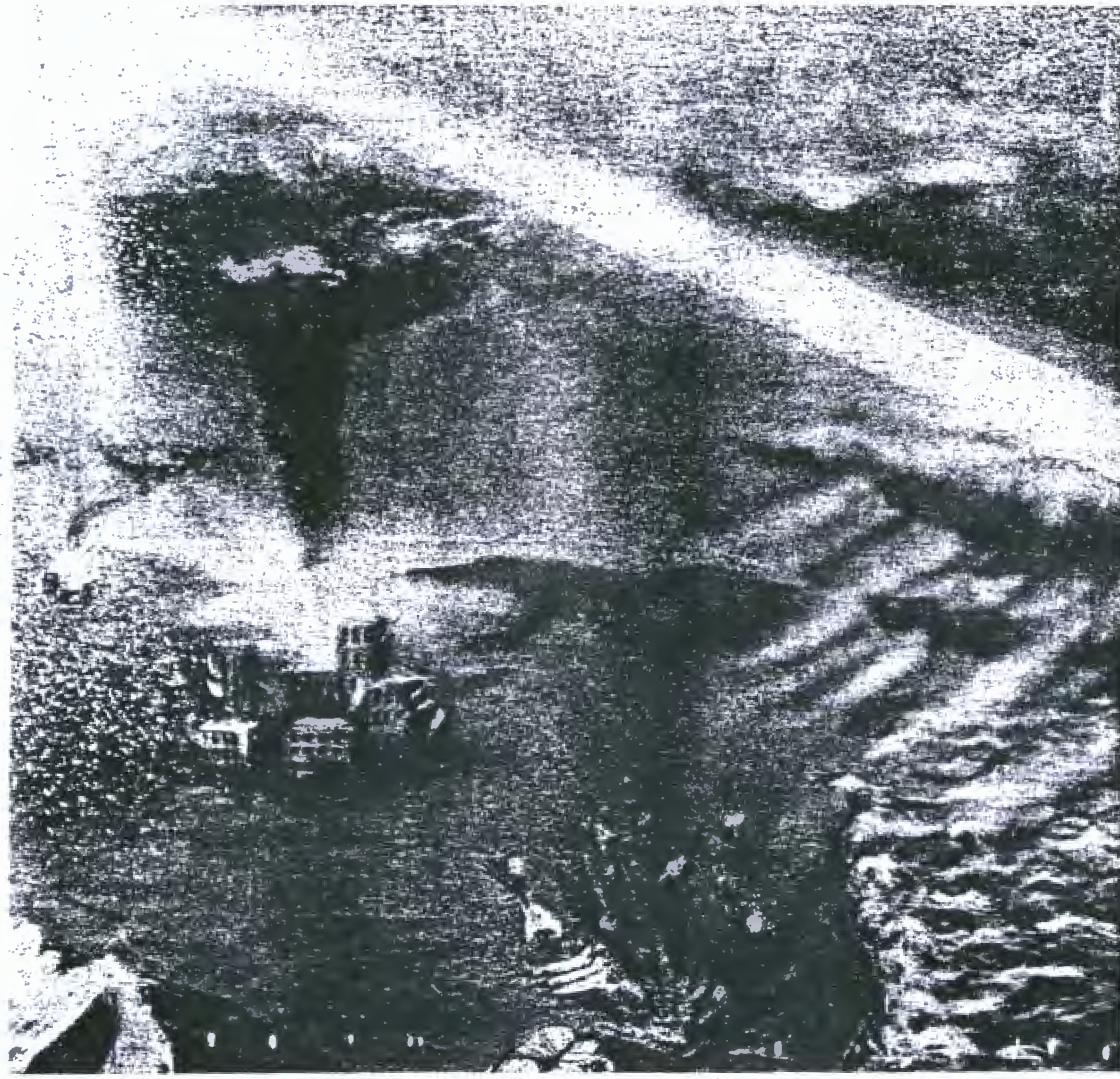
If a nuclear conflict produced 10 times less smoke than TTAPS predicted, and if other moderating processes (rain, for example) were to reduce by three times the average cloud opacities that TTAPS predicted, climatic effects would hardly be noticeable, except in the local areas of the explosions. The biological consequences of a nuclear cloud, too, would be negligible compared to the effects of the blast, fire, radiation, and fallout. As John Maddox stated eloquently in an editorial in the British science journal *Nature*, the nuclear winter hypothesis is not yet established, and "talk of some of the consequences of nuclear warfare had better be postponed until the underlying assumptions are better understood."

We do know, however, that nature has already "performed" an experiment that tends to refute the TTAPS predictions. In 1815, the largest and deadliest volcanic eruption in recorded history occurred with the explosion of Mount Tambora on the Indonesian island Sumbawa. Writing in *Science* magazine last year, NASA scientist R. B. Stothers calculated that this explosion injected approximately 200 million tons of particles into the stratosphere, on the same order predicted by the TTAPS baseline scenario. "Mean temperature in the Northern Hemisphere apparently dropped by 0.4 to 0.7 degree in 1816," Stothers further reported. There were remarkable meteorological phenomena, Stothers noted, but no long-lasting widespread winterlike effects or biological disasters.

In order to disarm critics who believe that their baseline case is not the only way a nuclear war might be fought, the TTAPS authors performed similar calculations on at least 18 different nuclear-exchange scenarios, with the "smallest" being the previously mentioned 100-megaton, air-burst attack on cities only. The researchers varied their assumptions of total explosive yield, warhead sizes, and percentage of yield hitting on cities, rural areas, etc. They concluded that many different scenarios above the 100-MT "threshold" would cause nuclear winter. Thus Paul

Why Nuclear Winter Is Unlikely

Even if the TTAPS baseline scenario reasonably represents how a nuclear war might be fought, its assumptions about environmental and physical effects are highly doubtful.



Particulate injected into the stratosphere (half, perhaps), would rapidly fall back to earth from the force of gravity. The balance would condense enough to create storms there, removing much of the smoke, soot, and dust that TTAPS hypothesizes would remain in the stratosphere for months.

Acting as vast thermal reservoirs, the oceans would heat the atmosphere, coasts, and, eventually, the continental interiors. Moreover, the meeting of ocean-warmed air and cooler air over the continents would cause storms at the coastlines, and these would further remove smoke, soot, and dust from the skies.

The nuclear cloud that TTAPS assumes would be uniformly dense would actually be patchy, with holes here and there allowing more sunlight and heat to reach the earth's surface than TTAPS estimates.

Ehrlich states that "the [TTAPS] predictions of climatic changes are quite *robust.*"

If this is true, why must Ehrlich and company use the worst-case scenario for their projections of biological effects (a 10,000-megaton exchange in which the properties of the cloud's particles "are assigned adverse but not implausible values and in which 30 percent of the soot is carried by firestorms to stratospheric altitudes")? Ehrlich and some of his colleagues seem to have a "strange love" for apocalyptic predictions.

In fact, even if one could accept the TTAPS researchers' methods, their nuclear-winter predictions are *not* robust. All of the cases they postulate to cause climatic changes involve substantial burning of cities, which contributes the bulk of smoke. At one place in their study, the TTAPS authors implicitly admit this. Yet Sagan and Ehrlich have not mentioned this assumption in their public presentations on the issue.

The National Research Council's December 1984 study of the nuclear-winter hypothesis—which TTAPS researcher Richard Turco says "legitimizes" the hypothesis—similarly overemphasizes attacks on cities in its nuclear-exchange scenario. The study assumed a 6,500-megaton war with the largest NATO and Warsaw Pact cities among the targets. The NRC calculations concluded that within only days following such a war a nuclear cloud could block 99 percent of the sun's light from reaching the Northern Hemisphere.

If urban areas—population centers, that is—are *not* deliberately attacked, nuclear winter is unlikely. If they are deliberately avoided, climatic catastrophe is probably impossible.

The suggestion that cities will *not* be burned in a nuclear war may seem surprising to anyone who saw the ABC television movie *The Day After* or the film *Last Epidemic*, presented by a group calling itself "Physicians for Social Responsibility." In the standard PSR presentation of a nuclear-war scenario, every major American population center is the direct target of massive air-burst attacks. These scenarios violate everything that is publicly known about Soviet targeting policy and are most probably contradictory to current US target priorities, as well.

Common sense dictates that in case of nuclear conflict, the first-priority targets must be the enemy's nuclear-weapons-launching facilities, including missile silos, submarine bases, and bomber bases. Of second priority would be command, control, and communications facilities, and third would be other military installations and non-nuclear forces. Fourth, perhaps, would be industrial targets that would provide an enemy military support in case of a long war. Populations per se should be *last* on the list—unless the goal is pure revenge or the civilian and military leadership have jointly gone insane with a desire for mass-murder.

But there is more than common sense behind this assessment. Soviet military leaders have stated openly and repeatedly that their objective is not to turn the large economic and industrial regions into a heap of ruins but to destroy strategic combat means and paralyze military production. In other words, their basic strategy is one of *counterforce*—targeting enemy facilities of strategic military value—not *countervalue* (attacks on population and nonmilitary production facilities).

Much of the confusion and misunderstanding about this issue has been caused by widespread publicity for the idea of "mutual assured destruction" (MAD), a doctrine usually attributed to former Defense Secretary Robert McNamara. In case of massive attack on the United States and its allies, the doctrine asserted, enough nuclear weapons would be left—and *would be used*—to assure destruction of all major cities in the attacking country.

Even if this doctrine were ever desirable because of technological limitations that prevented weapons from accurately hitting only military targets, or for establishing mutual deterrence through a "balance of terror," subsequent technical developments have made weapons much more accurate for counterforce targeting—and the side-effects of even a pure counterforce attack are quite terrible enough to assure deterrence with current arsenals. President Reagan recently issued a directive on counterforce targeting—population centers per se are not to be attacked deliberately—and many experts now believe that US targeting strategy is now as "humane" as that of the USSR.

Nevertheless, many military-industrial targets are in or near cities, and even a "pure" counterforce attack would cause terrible collateral damage to civilian populations, especially if explosions are inaccurate or if especially powerful bombs are exploded in air bursts. Currently both the US and Soviet arsenals are being rapidly modernized, and the USSR—like the United States—is believed to be decreasing the explosive power of warheads as targeting becomes more accurate.

If the nuclear-winter prediction is scientifically valid at all, the maximum risk of its occurrence was probably in the late '50s and early '60s, during the era of multimegaton warheads, inaccurate missiles, and the MAD doctrine. The more recent increases in the number of tactical weapons and the advent of smaller but more accurate delivery systems (MIRVs and Cruise missiles) may have increased the total number of weapons but probably did not increase the risk of burning cities. In these days of "nuclear freeze" propaganda, few people realize that the total explosive yield of the US weapon stockpile is now only approximately a quarter of what it was two decades ago.

To sum up the discussion to this point: the TTAPS researchers' model calculations and assumptions are equivalent to a worst case. Although plausible as an extreme limit under certain nuclear-exchange scenarios, a worldwide, catastrophic nuclear winter is an unlikely outcome. Furthermore, the nuclear-winter hypothesis is much less plausible under scenarios that involve less city-burning than the TTAPS team generally assumed. And since common sense, current strategy, and technical trends all make countervalue (city-directed) attacks less likely, climatic disaster is rather improbable.

Despite the widely acknowledged uncertainties about the nuclear-winter hypothesis, many who ought to know better are presenting the prediction as all but certain.

Yet despite the widely acknowledged uncertainties about the nuclear-winter hypothesis, many who ought to know better are presenting the prediction as all but certain. At the October-November 1983 nuclear-winter conference in Washington, for instance, conference spokesman Paul Ehrlich uttered a string of doomful pronouncements, as if only minor details remained to be worked out. "If there is a full-scale nuclear war," Ehrlich said, "odds are you can kiss the Northern Hemisphere good-bye." And: "There is simply no question of what the long-term effects of any size nuclear war are going to be: Catastrophic. So there is no need to hang tough, wait for more research, see what happens."

Carl Sagan, too, has promoted the hypothesis as if it is all but fact. In a *Parade* magazine article that appeared nearly one year after his original "Nuclear Winter" article of October 1983, for example, Sagan viewed the nuclear-winter hypothesis as sufficiently confirmed to render any civil defense "a dismal and largely untenable prospect." And when the National Research Council issued its nuclear-winter study in December 1984, Sagan quickly seized its findings as an endorsement of the TTAPS conclusions. Physicist Jonathan Katz, a member of the NRC study panel, corrected Sagan, noting in a letter to the *New York Times* that the NRC study "emphasized the very large uncertainties plaguing all calculations of this phenomenon." Katz concluded: "This difficult problem needs further research. It does not need partisans claiming that it is settled."

Unless it is proven impossible, the very idea of a nuclear winter makes it necessary to do more accurate calculations based on better models, with more realistic assumptions, more likely scenarios, and improved data about the emission of smoke, its properties of light absorption, etc. Various governmental bodies have now commissioned a number of studies to address what the December 1984 National Research Council study called "enormous uncertainties" still surrounding the nuclear-winter hypothesis. Among those performing or commissioning studies are the National Oceanic and Atmospheric Administration, the Defense Nuclear Agency, the Department of Energy, the National Aeronautics and Space Administration, and the Environmental Protection Agency.

If the plausibility of the nuclear-winter hypothesis is to be accurately determined, such studies must, for example, develop a realistic model of how dust and smoke would spread throughout the atmosphere both longitudinally and latitudinally. Just as essential are models for the distribution of smoke and dust over time, assuming more realistically than the TTAPS study does that all nuclear attacks would not occur simultaneously but spasmodically.

How water contributes to the scavenging of smoke particles and how the oceans mitigate temperature changes also are important to investigate. Moreover, all data from previous atmospheric weapons tests and from World II firebombing should be released, so that this information can be reviewed to refine our knowledge of how dust, smoke, and soot are injected into the atmosphere.

A nuclear winter, if it occurred, would be felt far from the site of attack and thus redound to the detriment of the attacker. It could affect every nation in the Northern Hemisphere (effects in the Southern Hemisphere are expected to be much less). Thus, data and calculations on the nuclear-winter hypothesis should be shared with the USSR and all nuclear-armed nations, as it would be in all of our interests to prevent such an occurrence. This is one hypothesis that no one wants to test with a full-scale experiment.

If more-refined calculations still suggest the possibility of a nuclear winter, but with uncertainty due to lack of sufficient data about dust or smoke injection from actual tests, we might consider a minimal atmospheric test series, especially near a forest or simulated city, done in cooperation with the USSR, with other nations as observers. This sounds outrageous only until one realizes that "the fate of the earth" could hang in the balance. It would be an absurd irony if the atmospheric test ban treaty (signed by the United States, the USSR, and other nations in 1962) has "backfired" on the world, leading to the buildup of potentially suicidal nuclear stockpiles because atmospheric effects of nuclear war are not understood. (Obviously, any such tests should be done with every effort to avoid sending radioactive fallout toward downwind populations.)

A "freeze" on present nuclear stockpiles and weapons development, however, would be an especially *absurd* response to the fear of nuclear winter: it would keep in place the very weapons that are alleged to be capable of causing global catastrophe—very powerful weapons that are less accurate than weapons now being developed. A much more logical response would be to negotiate a "build-down" (for example, eliminating two old weapons for each new one produced), or mutual "deep cuts" (for example, each side eliminating 20 or 30 percent of the total megatonnage of their arsenals). Most vital is to eliminate the weapons with explosive yields greater than one megaton, which produce the most collateral and environmental damage, the largest area of fire in air bursts, and the largest amount of stratospheric dust from surface bursts. These have largely been removed from the US stockpile but are still somewhat prevalent in the USSR arsenal. If the nuclear-winter hypothesis has any validity, it is in our interest (and the Soviets' as well) to do away with these weapons. And, of course, there are moral and environmental reasons for doing away with these weapons, as well.

Strategic-arms *reduction* and modernization are also desirable on these grounds. But a "freeze now" could make it more likely that we will all freeze later in a nuclear winter.

As I noted earlier, calculations of the likelihood of nuclear winter strongly depend on assumptions that 100–1,000 cities will burn. So if the nuclear-winter prediction has any validity, it would imply that *urban areas should be removed from target priority lists* on practical grounds of self-interest, as well as on moral grounds. In his 1962 book *Thinking About the Unthinkable*, Herman Kahn anticipated this strategy when he detailed a "counterforce plus avoidance" targeting policy: only militarily strategic sites should be attacked, with deliberate efforts to spare people and civilian property. Indeed, the possibility of a nuclear winter makes the MAD doctrine look more insane than ever and is another argument for counterforce instead of countervalue military strategy.

At conferences on the nuclear-winter idea in late 1983, publicists of the idea proudly announced that this new argument would "put the final nail in the coffin" of civil defense. Paraphrasing Mark Twain, rumors of the death of civil defense are again highly exaggerated.

It may seem paradoxical, but if the chance of a nuclear winter is justified scientifically and accepted by the nuclear powers, long-term civil defense and medical preparations will be all the more desirable. If military planners appreciate that a city-burning strategy might cause mutual suicide from a nuclear winter, they will continue to shift toward a "counterforce plus avoidance" strategy. This would mean fewer fire-producing air bursts over cities and more fallout-producing ground bursts on military targets, with more people surviving attack but needing shelter from increased radioactive fallout, as well as food, water, medical attention, and supplies. Civil defense is still necessary for future scenarios of all-out nuclear war, as well as for all other possibilities (accidental detonation, limited war, terrorist explosion, attack by a smaller nation with a crazed dictator, etc.).

A portion of current expenditures on "defense" (offense, in reality) should be shifted into truly passive (that is, civil) defense. A shelter cannot directly kill a Russian or any other person, while both old and new weapons can. Lest the USSR misunderstand this action as a prelude to attack, we should invite the Soviets to join in an open race to protect both our populations instead of making them more vulnerable to mutual destruction. Even if strategic-arms-reduction talks are successful, there will be periods of danger during reduction when war may be more likely because of suspicions about mutuality, worries about inadequate verification, doubts about the adequacy of a remaining deterrent, etc. Adequate civil defense could help to bridge this credibility gap on the way to mutual assured survival.

Nuclear winter may be possible, but it is highly improbable. To the extent that it is possible, the risk can be reduced by shifting strategy from targeting attacks on cities to "counterforce plus avoidance" and by emphasizing civil defense and preparedness, along with bilateral strategic-arms reduction and modernization of weapons instead of a nuclear freeze.

Apocalyptic predictions of the end of humanity, however, in spreading the message that such measures are futile, can only worsen our present unenviable situation. Such predictions are, as usual, more useful for irresponsible propaganda than for the kind of careful thinking that is necessary to avoid nuclear disaster while preserving freedom from potential aggressors. ◼

Howard Maccabee is a physician whose specialty is radiation therapy for cancer patients. He also holds a Ph.D. from the University of California at Berkeley, earned jointly from the departments of nuclear engineering and medical physics, with dissertation research in radiation biophysics. From 1982 to 1984, he was president of Doctors for Disaster Preparedness.

K FYI, Edward

TK

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

July 26, 1984

Dear Edward:

John Maddox took me to lunch and made me aware of your interest in the "nuclear winter" business. He tells me that my letter which critiques the TTAPS and CST studies will appear in the same August issue as your paper.

I only became aware of Sagan's activities last winter and wrote articles/letters to the Wall Street Journal and Science, and later to Nature and Foreign Affairs.

Science has dragged its feet and seems to be unwilling to publish any critical letters on TTAPS. They have even claimed that my WSJ article may constitute prior publication!

Foreign Affairs seems to be unenthusiastic about publishing my reply to Sagan's recent article. I make the following new points:

1) A nuclear winter scenario would be worse for the USSR than for the US -- in a number of different ways;

2) A nuclear winter scenario would tend to further decouple the tactical use of nuclear weapons from a large-scale strategic nuclear war.

I would really be pleased to have your comments on any of these points -- even though I don't plan to do much more work on the nuclear winter phenomenon.

I'm consulting for Jay Keyworth here. I am mainly concerned with acid rain and with the problems of commercial nuclear power. I'll have to let him know about my space interests so that I can get involved with him in anti-satellite matters and SDI ("Star Wars").

Best wishes,

Fred

S. Fred Singer

P.S. Effective September 1, I will be at George Mason University (Fairfax, VA 22030), on leave from the University of Virginia.

Dr. Edward Teller
Lawrence Livermore Laboratory
University of California
P. O. Box 808
Livermore, California 94550

cc: Dr. G. A. Keyworth

For GAK

SFS/5/84
6/7/84

NUCLEAR WINTER AND NUCLEAR STRATEGY

S. Fred Singer

INTRODUCTION

"Apocalyptic predictions require, to be taken seriously, higher standards of evidence than do assertions on other matters where the stakes are not as great."[1]

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[1] Quoted from Carl Sagan, "Nuclear War and Climatic Catastrophe: Some Policy Implications" Foreign Affairs, Winter 1983/1984.

But conclusive and sure evidence is not available to make a judgment about the climatic aftereffects of a nuclear exchange. At best, a certain probability can be attached to the occurrence of a world-wide freeze as a result of smoke from fires started by nuclear explosions. There is disagreement both about the probability of a nuclear winter and about the threshold at which possible climatic effects would become of worldwide importance. (See Figure)

Nevertheless, since the probability is finite -- that is, greater than zero -- is important to consider the strategic implications of a nuclear winter scenario, particularly as it relates to the relative effects on the Soviet Union and the United States, as well as on the rest of the world including the southern hemisphere. The consequences to the various countries involved appear to be sufficiently different to affect nuclear strategy as well as their political actions. Before discussing these differential effects of a nuclear winter scenario, we will review, briefly, the uncertainties surrounding such a scenario.

THE NUCLEAR WINTER SCENARIO

It was recognized from the very beginning that nuclear weapons, in addition to being much more powerful, are qualitatively different from conventional explosive bombs which produce blast effects and heat. There is the emission of radioactivity in the form of direct radiation which has its effect immediately in the vicinity of the explosion. There was discovered the problem of "fallout", radioactivity which is conveyed by the wind and can affect quite distant points sometime after the explosion. In the early 1970's, it was discovered that nuclear detonations could produce effects on the upper atmosphere and lead to the partial destruction of ozone in the stratosphere. The implications are that enhanced ultraviolet radiation, now shielded by the ozone layer, would be able to penetrate towards the surface of the earth and cause biological damage to people, animals, and plants.

Nuclear explosions cause fires as the heat radiation from the fireball ignites combustible materials. Among the first studies that I know of is that by Prof. Robert Ayres.

During the years 1962-1965 at the Hudson Institute in New York State, he calculated the fires produced by a nuclear explosion and also pointed, quite correctly, to the fact that the smoke would absorb solar radiation and could thereby cause darkness and lower temperature at the surface of the earth. His three-volume study published in 1965, however, attracted little attention and the matter was forgotten until quite recently.

What stimulated renewed interest was the discovery that dust storms on the planet Mars produce lower surface temperatures; that dust emitted by volcanoes into the stratosphere leads to cooling at the earth's surface; and most particularly the hypothesis put forward by Prof. Louis Alvarez and his colleagues that the impact of a meteorite about sixty-five million years ago projected sufficient dust into the atmosphere to block out the sun and cause enough cooling to wipe out the basis for life support for the dinosaurs. In 1982, Paul Crutzen and J. Birks then pointed out that a full nuclear exchange could produce sufficient smoke and soot to cause an equivalent effect on the earth. This idea was developed in much greater detail by Prof. Carl Sagan and his colleagues Turco, Toon, Ackerman, and Pollack. Their paper published in Science magazine in December 1983, generally referred to as TTAPS, has stimulated much of the present discussion.[2]

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(2) R. P. Turco et al. "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions" Science 222, pp. 1283-1292, 1983.

The TTAPS paper has virtues and faults. It is the most detailed study currently available on the climatic aftereffects of a major nuclear exchange. It makes use of a large but incomplete data base and several physical-atmospheric models back-to-back, some well-tested, others inadequate. But because this study is detailed and well-documented, it is also easiest to criticize. A major critique must be that it does not indicate the wide range of uncertainty that exists in the outcome -- because of problems with the basic assumptions, the fundamental data, and the validity of the models.

This is not the place to have a scientific interchange; but the scientific journals will be full of discussions which will question, support, or amend various aspects of the nuclear winter hypothesis. This is as it should be. A large number of specialists in different areas will find fault with one aspect or another and will contribute their expertise through the process of criticism. Some of them, like myself, will simply point out aspects that have been overlooked and need to be fully considered; others will furnish detailed studies which will complement or supplant the TTAPS study in one area or another.

All of this scientific discussion will eventually focus down on two sets of issues. First: How serious is the nuclear winter effect in terms of temperature change, time duration, and geographic extent? Will there be sub-freezing temperatures covering all of the world [except the ocean and coastal regions] for many months or longer; or will there be a slight depression in temperature covering the inland continential regions; or could there even be a warming in some areas and a cooling in other areas as a consequence of the fact that the smoke clouds are not uniform.

Secondly, what is the threshold for climatic effects? This "threshold" cannot be a very precise number in terms of megatons or warheads exploded, but will depend on how they are exploded, at what altitude, at what locations, at what time of the year, against what targets, etc.

Most important: How serious are the ecological impacts on plants, animals, and especially on human beings in different parts of the world?

I fully expect that the threshold will turn out to be quite broad -- and this is of importance for strategic reasons. I also expect that there will not be any consensus soon on the climate effects themselves; rather people will assign widely differing probabilities to different scales of the effect. I further expect that with time, as we have more scientific discussions, the range of probabilities which, right now, might range from close to zero percent to nearly one hundred percent will narrow somewhat.

One thing is certain: The nuclear winter scenario will be a boon to atmospheric researchers everywhere -- in the United States, the USSR, and the rest of the world, as government support for atmospheric studies increases. Not only research on global climate change, but also more detailed studies of mesoscale meteorology, cloud physics, fire phenomena, will expand. We have some recent experience to fall back on. The controversy about the supersonic transport which swirled around the United States in 1970-71 led to an ambitious research program on the chemistry of the stratosphere, and particularly on what happens to ozone. In turn, this research program has given us a basis for gauging other important environmental consequences on the stratosphere quite un-related to supersonic transports.

NUCLEAR WINTER IMPLICATIONS

In spite of the uncertainty about the reality of the nuclear winter scenario -- its magnitude, time duration, geographic extent, and the threshold at which climatic phenomena would become important -- the probability of a nuclear winter effect must be factored into strategic thinking. My conclusion is that the nuclear winter scenario is bad news for the Soviet Union. Specifically, a Soviet attack is more likely to create a nuclear winter than a U.S. attack. Further, the Soviet population is likely to be harder hit by the effects of a nuclear winter than Americans.

The initial thinking has been fairly crude. It assumes or implies a well-defined threshold which is easily reached by even a minimal nuclear exchange scenario. It derives catastrophic consequences to all humanity.(1) This zero-order treatment of the problem leads to the seductive conclusion that nuclear war is unthinkable and will not happen because it would destroy also the nation who carries out a first-strike surprise attack. This doomsday scenario is attractive because no one really wants a nuclear war. The tendency, therefore, is not to delve further into either the assumptions that went into the construction of the nuclear winter scenario nor into the reasoning that led to this conclusion.

Unfortunately, it is necessary to be a little more precise. Specifically, since the climate effects cover a wide range of possibilities -- from slight warming all the way to deep freeze, with the probabilities for each scenario not known[3] -- we must pay attention to the differential effects. The effects on the US and USSR are not symmetric.

US-USSR Asymmetry

We want to sketch out here some physical facts and consequences that would affect the USA and USSR in a differential way.

1. The nuclear winter scenario wipes out any advantage the USSR might have because of their megaton weapons. On the contrary, megaton weapons are blunt instruments. They are only marginally more effective against military targets than precisely-aimed sub-megaton weapons held by the USA. But they create much greater environmental impacts. Specifically, weapons with explosive power in excess of one megaton would put particulate material into the stratosphere, thereby producing a longer-lasting climatic effect; they would have a greatly enhanced effect on stratospheric ozone, thereby causing longer-lasting biological problems for the world's population. Finally, they would start fires on a larger scale and over larger areas than an equal number of smaller weapons, thereby contributing more smoke and soot to set off a nuclear winter.

2. To the extent that targets in the USSR are more likely to be snow-covered than U.S. targets, explosions over the USSR

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(3) S. Fred Singer, "The Big Chill" Wall Street Journal, March 30, 1984

produce less of a nuclear winter effect. The reason is that snow is an effective reflector of the radiation from the fireball so that only a fraction of the energy is available to start conflagrations. Furthermore, the snow must be evaporated before burning starts.

According to the well-known reference The Effects of Nuclear Weapons by Glasstone and Dolan, a one-megaton burst will ignite a variety of materials out to a range of 5 miles (by supplying a heat pulse of 25 calories per square centimeter). With snow reflecting up to 90 percent of the energy, 250 cal/cm^2 must be supplied in order for 25 cal/cm^2 to be absorbed. But the snow must first be evaporated before any ignition can take place; hard-packed snow requires some 700 cal/cm^2 for every centimeter of thickness. Therefore, if the snow layer has a depth of only one inch (2.5 cm), the heat input required is $2.5 \times (700 + 25) \times 10$ or 18125 cal/cm^2. This energy is 725 times greater than the ignition energy required without snow, and would be obtained only within about 1000 ft of the explosion. If the burst occurs at a moderate altitude, there would be no ignition produced on the surface.

3. The Soviet Union has just about one-half the energy consumption of the United States (and even less on a per-capita basis). In general, less fuel storage means less smoke, and therefore a reduced nuclear winter effect if bombs explode over the USSR.

4. The nuclear winter scenario wipes out any Soviet advantage in civil defense. The Russians have invested heavily, we are told, in conventional civil defense which provides protection against blast effects and radioactive fallout. But it does not provide protection against the longer-lasting effects of a nuclear winter. To the extent that Soviet nuclear strategy is based on the belief that their civil defense system will save a large fraction of their population, this thinking now has to be revised or, at least, seriously re-examined.

5. The Soviets have had the traditional geographic advantage of a larger territory. The conventional aftereffects of a nuclear exchange, even radioactive fallout, would be less effective in a larger, more sparsely populated area; the nuclear winter effect, being global (or at least hemispheric), wipes out this geographic advantage.

6. On the contrary, a nuclear winter effect would be more severe in the Soviet Union because of their precarious agricultural base. Without large grain stores and without excess production, the Soviet Union is extremely sensitive to even minor climatic fluctuations. The poor performance of Soviet agriculture is regularly blamed on droughts and other climatic events which are not commonly considered as catastrophic. The United States, on the other hand, would have available not only a reserve base of production which would be effective if the climatic disturbance is not too severe, but also stored

grain. One of the important forms of storage is the beef cattle population which consumes something like 90% of all grain in the United States. In a major climatic disturbance, prices would rise to such an extent that it would become uneconomic to feed grain to cattle; it would be available for human use. The surviving U.S. population, therefore, would not starve but would consume less meat.

7. In the case of a nuclear winter, the climate effect on the Soviet Union is likely to be more severe. Most of the Soviet Union has a continental climate; the major cities are inland, far removed from the moderating influence of the ocean. The Soviet Union has its population much further north than the United States; Moscow is at about the latitude of Labrador. While the U.S. and USSR are likely to have adequate supplies of oil and gas, the distribution to population centers by pipelines is less developed in the USSR; therefore its surviving population would be harder hit by a deep freeze.

Enough has been said to indicate that, all other things being equal, the Soviet Union would be at a serious disadvantage with respect to the United States -- even if the nuclear winter effects are not as severe as indicated in the TTAPS scenario. Of course, much research needs to be done, and this is a fertile field for climate modellers, geographers, resource analysts, nuclear strategists, and foreign policy experts, not to mention military planners.

Tactical Weapons and Escalation

Turning from strategic nuclear exchanges to the tactical use of nuclear weapons, the accepted wisdom has it that nuclear war necessarily escalates and that therefore the use of nuclear weapons in Europe would lead to a Russian nuclear strike against the United States. But this wisdom needs to be re-examined, particularly in view of the probability that a major nuclear exchange will leave the Russians at a disadvantage, as discussed above.

It is likely that there is no automatic coupling between a defensive use of nuclear weapons in a tactical situation and an offensive first-strike with strategic nuclear missiles. The nuclear winter scenario decouples these two events even further.

Of particular interest is the not yet available "enhanced-radiation" weapon, which by its very design puts most of the energy into penetrating nuclear radiation rather than into the blast and heat effect. As a result, the ER-weapon will produce little radioactive fallout and significantly less fire, smoke, and climate effect. While 100 megatons of strategic nuclear weapons exploded at the right places and altitudes could trigger a nuclear winter according to TTAPS, 100 megatons of ER-weapon air bursts would produce little, if any, climate effect.

Imagine, therefore, the following scenario. The Soviet Union launches a massive attack against Western Europe using conventional weapons and especially their overwhelming superiority in tanks and artillery. The attack is quickly stopped by ER-weapons (if deployed) while the tanks are moving through Eastern Europe. Neither the Soviet Union nor NATO launch attacks on population centers. Would the Russians escalate nuclear warfare and launch an overwhelming missile attack against the United States?

Of course, much depends on the Russian perception of the reality of the nuclear winter scenario. High-ranking Soviet scientists who are well connected with the establishment, such as Yevgeniy Velikhov and Serguei Kapitsa, have participated with American scientists in endorsing the reality of the nuclear winter scenario. The Russian press and television have given much publicity to this scenario. We are told that the Soviet foreign minister and defense minister have been personally briefed. From all indications, the Soviet establishment has embraced the TTAPS scenario, particularly since it appears consistent with their general political aims of achieving a "nuclear freeze". Whether they will continue to embrace it once they become convinced that it leads to disadvantages for them, remains to be seen. Expert Soviet watchers will, no doubt, look for tell-tale signs in the right journals and in statements to the public as well as to international forums. Soviet scientists may yet disown the nuclear winter scenario which they have just embraced so fervently.

Third World Strategies

Even though we cannot know how Soviet leaders really feel, it is safe to assume that their leadership, like ours, will assign a certain probability to a nuclear winter scenario, and that these probabilities may grow and wane depending upon scientific and political fashions. But it would not be safe to discount the existence of such a scenario entirely.

Similar perceptions will probably circulate in the rest of the world, influenced largely by pronouncements from the major scientific centers, principally the United States. Once accepted, they will cause some re-thinking in the strategies of other nations, particularly the trigger-happy radical regimes.

One can imagine that in their fondest dreams Khomeini or Qaddafi would like to see the U.S. and the USSR finish each other off, together with all of Europe; in the conveniently-created power vacuum the radical Islamic nations could play an important role. There are scenarios extant in which such nations would try to provoke an all-out nuclear war between the superpowers. There are strategists in the U.S. who hope for a Soviet-Chinese knock-out. There must be strategists in China who fervently hope for a nuclear knock-out between the capitalists and Soviet neo-imperalists.

All of this thinking must now be rethought and revised. No longer can non-superpowers get off scot-free in a superpower confrontation. It should give the Third World a powerful incentive to do everything possible not to provoke the superpowers into a nuclear exchange.

As far as the populations of NATO and the East bloc are concerned, a nuclear winter scenario adds only marginally to the general horror of an all-out nuclear war. There is a well-known aria in "The Abduction from the Seraglio" when Osmin Pasha threatens Belmondo: first he'll behead him, then hang him, then burn him, then flail him. After being exposed to megaton blasts, incineration, radioactive fallout, etc., people may not care if the weather turns cold. But to the Third World, dependent on U.S. grain exports and other assistance, a nuclear winter scenario, even a minor one, may spell the difference between life and death.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

WASHINGTON POST
May 29, 1984

NEWS OF INTEREST

U.S. Begins Study of Possible Climatic Disaster in Nuclear War

By Philip J. Hilts
Washington Post Staff Writer

The Reagan administration is beginning a national research program to find out if a nuclear war would trigger the worldwide weather catastrophe called "nuclear winter."

After initial suspicion and debate in the administration about whether the nuclear winter discussion was merely a veiled attack on Reagan defense policy, the president's science adviser, George A. Keyworth II, approved the project as a nonpolitical scientific mission.

Several federal facilities are studying the problem, including a nine-person team at Lawrence Livermore National Laboratory and a group at the Defense Nuclear Agency. But the new program would cost several million dollars a year for the three prime years of study, and would include not only massive calculations on supercomputers but also some experiments in which city-sized fires would be set to measure their intensity and ability to throw soot into the upper atmosphere.

It is generally agreed by critics and proponents of the new calculations that, if they are found to be true, major shifts in nuclear defense policy could result.

Most frequently mentioned is the idea that, if both sides suffer climatic disaster after a first strike, then first strikes might be ruled out as too costly even to the aggressor.

"We wanted to take the lead on this issue," said Alan D. Hecht the head of the climate section at the National Oceanic and Atmospheric Administration who is leading the study project.

Although the issue has political overtones, Hecht said Keyworth told him to begin a scientific study because "this is a real question of science, one that won't go away, and we can't answer it until we get the data."

"The policy people want good information. They may use it or ignore it, but they need the information," Hecht said.

There has been fierce debate about the nuclear winter idea, including a closed-door argument in a congressional hearing between astronomer Carl Sagan, who helped make the nuclear winter calculations, and physicist Edward Teller, who said nuclear winter is "improbable" and "quite dubious."

The possibility of the nuclear winter catastrophe was first raised by a group of scientists who used mathematical models to test how nuclear bombs would affect the world's weather. Until the calculations were made, it was believed that a nuclear war would be destructive, but not a climatic disaster, and would cause great changes in life outside the areas hit by war.

The new calculations, however, made independently by several groups of scientists in the United States and the Soviet Union, suggest that it is possible that a war involving 1,000 to 6,000 nuclear weapons could trigger a climatic catastrophe from the dust and debris thrown into the atmosphere that would cut off sunlight. Temperatures could plunge 75 degrees or more, they figured, and sunlight could be blocked enough to kill most plants and the animals that depend on them.

Although the calculations are uncertain, the scientists said it is conceivable that not only war zones but the entire Earth would undergo such a catastrophe, and threaten the human species.

Whether nuclear bombs can trigger a nuclear winter depends chiefly on a few things about which little is known, such as how many fires are caused, how much soot and smoke they emit, whether firestorms are triggered and how high the plumes of smoke rise, since particles injected into the upper atmosphere stay there longer and block more sun.

The new study has been outlined by officials and scientists from defense and basic research institutions to assure its credibility. Hecht said the research program is nearly ready to go to Keyworth for approval, and he said money will be sought to fund the program from a supplemental appropriation to the 1985 budget or the 1986 budget.

Put in "nuclear Winter File" TC

LAWRENCE LIVERMORE LABORATORY

May 24, 1984

Dr. Allan D. Hecht
11400 Rockville Pike, Room 108
National Climate Program Office
Rockville, MD 20852

Dear Allan:

This is the paper on fires and smoke which I am taking to Moscow for discussion with Velikhov. We shortened and clarified somewhat the material you sent us.

Sincerely,

Mike

~~Michael M. May~~
Associate Director at Large

Enclosure

May 24, 1984

UNCERTAINTIES IN THE GENERATION AND EVOLUTION OF THE ATMOSPHERIC SMOKE BURDEN

[This paper is a preliminary draft based upon the input of a number of writers. The material was gathered together in the course of preparing a plan for the investigation of possible climatic effects of large scale fires which may be caused by a nuclear war.]

I. CRITICAL ISSUES OPEN TO EXPERIMENTAL RESOLUTION

A major issue concerning climatic effects of large scale fires is to understand better the emission from urban and forest fires and the interaction of the emissions with the atmosphere. The following are the main questions to be answered by laboratory and field experiments:

- o What are the amount, altitude of injection, and properties of smoke and gases generated in large scale urban and wild fires?

- o To what extent do fires generate clouds and precipitation and how do these remove or modify the emissions?

The answers will depend on the nature of the fuel source and scale and intensity of the fire. Hence several types of experiments must be planned to quantitatively understand the full range of source inputs.

Current views of the major elements of an experimental fire research program are discussed in the following. The ideas presented here may change after further review.

SOURCES

Main uncertainties related to the initial input of smoke in the atmosphere are shown in Table 1. The discussion that follows reviews these uncertainties and identifies measurements required to resolve them.

How much burns depends on the distribution of ignition points, the fire spread and the fraction of available fuel which actually burns. Parameters governing these processes are fuel type and distribution, the distribution of fire breaks and meteorological conditions.

TABLE I

FIRE COMPONENT	QUESTIONS ADDRESSED	MEASUREMENTS
Source Material	Amount of smoke and soot produced for a variety of fire sizes and fuels	o ignition point o fuel type and distribution o fire intensity o oxygen environment o ventilation o thermal environment
Properties of Smoke	Level of infrared and visible extinction Effects of aging	o composition of smoke o smoke optical properties o smoke mass and size distribution o scattering phase function o particle shape
Plume Dynamics	Height of plume Entrainment processes	o plume top and bottom o ambient humidity and winds o vertical stability o altitude of formation of water clouds o plume velocities
Smoke Transformations	Aerosol scavenging and rainout Cloud-induced coagulation Aging	o background and emission inventories o time-resolved aerosol properties o in-cloud aerosol characteristics

The fraction of burned material which is converted to particulate matter depends on the material burned, on the oxygen environment in which the principal combustion takes place, on the residence time of soot particles within the flame (burnout), and on the thermal environment in which soot formation takes place.

Substances which have significant oxygen in their composition (like wood, phytomass and some fabrics) burn somewhat cleaner, all other things being equal, than substances which are less well oxygenated. Some substances which are not well oxygenated nevertheless burn rather efficiently, and produce little smoke by virtue of the volatile and combustible nature of their pyrolytic emissions. By contrast, some materials (notably some plastics) give rise to copious soot emissions in burning. Thus the structure of the fuel molecules determines, in part, the emission of smoke. The smoke emission rate in a mixed fuel environment is, however, not known.

The effect of oxygen and thermal environment may be illustrated by enclosed fires. In this case, the ratio of available oxygen to that required for complete combustion can become quite small. There are two reasons for this. First, the oxygen must come through the available apertures (windows, doors, leaky seams) and may not be freely available. The consequent inefficient combustion causes the condensation of unburned hydrocarbons to form smoke. Second, additional smoke and soot generation is promoted by acceleration of pyrolysis and incomplete, oxygen-deficient combustion due to the elevated temperatures achievable within enclosures. It is not known whether similar conditions, causing increased smoke emissions, might occur in the centers of large mass fires.

On the other hand, burnout of volatiles and carbonaceous residue leading to a cleaner burning fire may take place, depending on the size of the burning area and on the intensity of the fires. For moderately low-intensity, individual fires, particle mass and character will be dominantly determined by material type and ventilation effects. For larger-area, more intense fires, continued combustion may extend up to a considerable height, allowing for a much more efficient burn.

Before the nuclear fires reach this large scale environment, however, significant amounts of smoke may be formed in the initial enclosed fires themselves. The issue should be pursued by experimentation.

There have been many observations of smoke generation from various fuels. Some of these measurements also included assessments of the effects of flaming versus smoldering conditions. Other experiments have addressed some of the effects of oxygen-deficient combustion environments. What remains in this important area are principally experimental and theoretical assessments of: smoke generation from mixed fuel fires; the relation of smoke emission from small scale tests to room-sized fires; oxygen availability, which depends in turn on oxygenation level of modern urban materials, confined fire effects, blast enhancement of open fires, effects of rubbleized fuels, and ventilation effects in large fires; thermal environment and burnout in large-scale intense fires.

OPTICAL AND OTHER PROPERTIES

Optical properties of the smoke particles are critical to calculations of the climatic changes following a nuclear exchange since they determine the amount of sunlight and infrared radiation absorbed by the particles. Measurements have been made of the properties of smoke particles created both in laboratory environments and in natural fires. For example, studies have been done of the optical absorption by smoke produced by laboratory burns of pine needles. Other workers have measured the particle sizes, and mass emission rates in a variety of small prescribed fires in Washington and Oregon. Although such studies have limited the uncertainty in the properties of smoke, a number of significant questions remain.

Optical properties of smoke are sensitive to the fuel composition, fire temperature, fire ventilation, and degree of coagulation in the plume. Measurements have not been made in urban fires, where many synthetics are present, or in very large forest fires. High smoke loadings in a large fire may lead to rapid coagulation and growth of large particles with little optical cross section. On the other hand, coagulation may not be significant, or it may lead to chain-shaped particles whose optical cross section will not decline with size as rapidly as it does for spherical shapes. The ratio of infrared to visible extinction is also in question. Calculations and some observations show that infrared extinction is lower than visible extinction. However, there are large differences between theoretical and observed properties of particles in plumes. Sufficient radiation measurements using modern instruments have not been made.

In order to resolve these questions, the composition of the smoke and the smoke optical constants need to be determined for fires of a variety of sizes, intensities and fuel compositions. Direct data on the particle scattering phase function, on the infrared and visible optical depth of the cloud, and on the solar heating rates should help calibrate our ability to calculate radiative parameters in a dense smoke cloud of the type which may be globally distributed following a large nuclear exchange.

The smoke mass and size distribution must be determined to resolve the significance of coagulation to the smoke particle size in the plume, and to better relate the submicron smoke mass to the mass of material burned. In this regard, it should be noted that recent smoke particle size distribution measurements have shown that the super-micrometer particle mass in the size range from 1 - 50 micrometer can be comparable to the submicrometer mass.

Because many particle characteristics depend strongly upon the fuel source and fire environment, studies of forest fires may not resolve questions on optical properties or smoke emission rates from urban fires. It will be necessary to extrapolate laboratory data and data from small burns of urban materials. A well-planned series of scaling experiments might aid this extrapolation.

PLUMES

Dynamics of plume rise and turbulent entrainment are important to the quenching of combustion, condensation of unburned pyrolysis products on smoke particles and also to the specification of the environment in which coagulation growth of mature smoke particles occurs. Dynamics and entrainment, along with atmospheric stratification, moisture profile and fire intensity and extent serve to define the plume stabilization height thereby giving the smoke injection altitude.

Numerous tested models are available for plume rise from sources like smoke stacks or volcanoes. However, these studies are not easily extended to model urban or wild fires because of the unprecedented size of the fires. In particular the effects of vertical atmospheric stability, entrainment of ambient air near the combustion zone and by the rising plume, condensation of entrained water vapor and release of latent heat, radiative heat loss from the flame, heat transfer from the smoke to the gas, and the effects of vertical shear in the ambient wind all pose complexities which tax even the most sophisticated model. The result of all these uncertainties is that some scientists believe that the smoke from large fires will be predominantly restricted to the boundary layer where it will be removed by precipitation in a few days whereas others believe that some smoke will rise into the stratosphere where it may remain for several years.

In order to help resolve these questions it is useful to measure the top and bottom smoke altitude, as well as the downwind dynamics for a variety of fires. The dependence of these quantities on areal extent and fire intensity, ambient humidity and ambient wind field must be determined. The degree of air entrainment and the heat radiated by the fire must be measured, since they are not easily calculated from first principles. It is also necessary to measure the altitude of formation of water clouds in these plumes, to relate the horizontal location of the water cloud to that of the plume and to relate the region of precipitation to the region in which the plume is located.

Analysis of past experiments should help to understand the entrainment process. Some of these experiments are large-scale convection experiments in which Doppler radars were used to map the three-dimensional kinematics of isolated convective clouds. Smaller scale, but more intensely buoyant experiments have been performed using oil burners distributed over a large square grid exceeding ten thousand square meters in area.

The reduction and analysis of experimental data in these experiments was not comprehensive. These or similar data must be more fully analyzed to acquire an adequate model of turbulent entrainment for both intense and weakly buoyant phases of plume rise. Fires of opportunity like large scale urban, grass or forest fires, if they could be studied adequately on short notice, would provide additional understanding of entrainment processes.

Another issue involving plume dynamics is whether the solar heating in dense plumes is sufficient to induce mesoscale convection. For example, the plume may be buoyant even far downwind from the fire, because of solar heating. This may cause plumes to continue to rise as they are advected downwind, long after they should have reached their stabilization height.

Another possibility is that inhomogeneities in the plumes may lead to the development of small scale convective cells. Potentially these cells could mix the materials downward, or induce precipitation which might lead to smoke removal.

The downwind dynamics are only likely to be observed for very large fires. However, large forest fires have shown some evidence of temperature changes occurring beneath dense smoke clouds. There is a need to evaluate past accounts of climate effects associated with large wild fires of this and the preceding century, including the Siberian peat fires early in this century.

Except for the effects of fire intensity due to heavy fuel loadings, the dynamics of plumes should depend primarily upon properties which are relatively independent of the fuel source. To that extent, measurements made in large forest fires are likely to be relevant to plume dynamics for large urban fires, and they should provide the best verification test for models of plume dynamics.

SMOKE TRANSFORMATIONS

A complicated uncertainty which needs to be better understood is the interaction between precipitation and smoke, since the residence time of the smoke in the atmosphere and hence the longevity of its climatic effects may be controlled by precipitation. Smoke will often interact with fire capping clouds in which the ratio of cloud mass to smoke mass is about ten thousand to one. In these cases, clouds control the initial injection properties of the smoke and its eventual removal.

This interaction has two parts. First the removal of smoke by precipitation may be size selective as well as sensitive to the chemistry of the smoke particles. Second the smoke may modify clouds either directly by changing the ambient concentrations of cloud nuclei and the clouds' optical properties, or indirectly by modifying atmospheric temperatures and wind fields which control the formation of clouds.

In order to better understand these problems, several different levels of experiment are needed. Some work has already been done to measure the particulate sizes before and after smoke passes through a cloud, but more work is needed. Simultaneous measurements are needed of cloud drop distributions to determine whether the smoke has modified the cloud microphysics itself. The optical properties of smoke-containing clouds also should be measured since theoretical calculations predict that a water cloud containing even small amounts of soot can efficiently absorb sunlight.

Finally, sooty smoke may not be removed efficiently until photochemical reactions in the atmosphere deposit soluble materials such as sulfate on the soot surfaces. To test this point, the number of cloud condensation nuclei in fresh smoke clouds must be measured. Since soot is not pure carbon, and since winds may lift much organic and soil material from the surface, there could be abundant condensation nuclei in the fire plumes, as is observed commonly in prescribed and wild fires. The nucleation capabilities of fresh smoke and soot must be contrasted with that of aged smoke and soot to determine if background photochemical processes do make the smoke and soot more susceptible to removal by rainfall.

In addition to determining the particulate properties in fire plumes, the particulate loading in the background atmosphere must be characterized for two reasons. First, we do not know the amount of smoke and soot in the ambient atmosphere, either in that 50% of the Earth's atmosphere over the tropics where burning seems to be concentrated, or in the Arctic where observed smoke and soot content is unexpectedly large. Soot may already play a larger role in the earth's heat budget than we expect. Better defining this role might allow experimental insight into the interactions of soot with the climate.

Second, the concentration of soot in the tropics results from the mingling of the emissions from many different fires as well as from interactions with precipitation processes. Understanding how the current processes control the amount of soot can provide the basis for understanding how the processes might function to control the amount of soot after a nuclear exchange.

In order to gain this understanding it is necessary to get better estimates of the number of fires burning in the tropics. This might be done from analysis of satellite data currently being gathered. The amount of soot and smoke generated by these fires, the altitude of injection of this smoke and the amount of smoke and soot typically present must all be measured.

Most of the processes having to do with the interaction between smoke and clouds should not depend strongly upon whether the smoke is generated by an urban fire or by wild fires. Exceptions may be particle size and the abundance of cloud nuclei. Data from laboratory and small urban fires will need to be used to extend atmospheric measurements in wild fires to the urban mass fire case.

The state of our understanding of the source term uncertainties is summarized in Table 2.

TABLE 2

Process	Ability to Predict occurence	Range of Effect on Physical Quantity			
		Emission rate	Composition (optical properties)	Mode radius of size distribution	Amount of fuel burned
Mixed fuels effects	Small uncertainty	Factor of 10	Factor of 10 in elemental carbon content	Factor of 20	
Oxygen availability, burnout, and thermal environment	Unknown, depends on flow field prediction near fire	Factor of 100	Factor of 2 in single scattering albedo		
Coagulation and condensation in plume	Factor of 2 uncertainty in large scale flow field			Factor of 20	
Interaction with H_2O	Unknown for sooty smokes		Factor of 2 in single scattering albedo	Factor of 2 in mode radius in a few minutes	
Firebrand production and spread	Depends on prediction of flow field near fire				Factor of 10

II. SMOKE AND FIRE EXPERIMENTS

Because so many different kinds of measurements are required, field experiments must be carefully planned to maximize information content. Since the problem itself can only be treated by extrapolation or modeling, the field experiments must be planned by both experimentalists and modelers.

The goals of an experimental plan designed to address the issues discussed above are summarized in Table 3.

TABLE 3

1. Quantify and characterize the properties of the particulate and gaseous emissions from fires. To be credible some of these fires must approach the scales and intensities of the postulated nuclear fires.

2. Determine how the gas and particulate properties depend on fire and fuel characteristics. Quantitative scaling rules must be developed to relate variables to these characteristics.

3. Determine how meteorological parameters effect flammability, fire spread, fire intensity, particle properties and plume heights.

4. Quantify the interactions between fires, smoke, clouds and precipitation. These interactions will be on two time scales: prompt effects of plume-induced capping clouds and the delayed effects of entrainment of ageing smoke into ambient cloud systems.

5. Determine the ambient smoke levels in a region with many natural sources such as the tropics and determine the number of active sources. The goal is to determine if we can correctly calculate the regional smoke concentration through our understanding of cloud-smoke interactions and our observations of the emissions and burden inventories.

6. Experimentally determine the dynamics of a variety of buoyant plumes in order to both test and constrain plume models.

7. Measure the radiative properties of dense smoke plumes for direct comparison with calculated characteristics based on particle measurements.

To understand properly the scaling relationships needed for nuclear scenario assessments, a range of fires of varying intensity and size must be studied for both principal fuel bases, urban and wildland. Unfortunately, there are intrinsic differences between urban and non-urban fires. For one thing, because of lower relative accessibility and value, wildfires are naturally more prone to develop into large, intense fires than are urban fires. For another, urban fuel bases are different from natural fuel bases, both in fuel density and in fuel type.

These differences suggest different approaches to non-urban and urban fire experiments. In the non-urban case, it should be possible to focus on the several large set fires each year and use aircraft to assess smoke quantity and character at altitude. In this way, an integrated result in which the effects of mixed fuels, oxygen deficiency, burnout, coagulation and possibly rainout are integral parts of the observation is obtained.

The lack of a similar opportunity to observe large scale, intense urban fires suggests a different approach for this environment. Instead of an experimental focus on the few largest urban fires, it would be more appropriate to develop a more finely resolved set of scaling experiments, allowing the development of confidence in the extrapolation from small scale to large scale urban fire effects.

These separate approaches are complementary. Phenomenology acquired from the smaller scale urban-focused experiments should be applicable to non-urban fire phenomenology. Similarly, much of the wildland large fire effects should be interpretable for the large scale urban fire environment.

NON-URBAN FIRES

Proper source function characterizations require a range of fire size intensities and fuel types be available to study. A variety of planned fires will be identified through contacts with the U.S. forest service, and with foresters in other countries. For example, the Canadian forest service burns large areas each year and very large fires are set in many tropical countries. Efforts will be made to have these groups, or others, start moderate size mass fires as well as smaller fires in a variety of fuel sources. Although the initial experiments may be conducted in line fires, it is hoped that an opportunity will develop to study a mass fire.

Location, size and the experimental focus of these wildland fires all argue that the principal measurements should be made from airborne platforms. The observations which should be made are included in Table 4. They are directed at defining the relationship between observed fuel, fire size and intensity and the following features:

o Plume Dynamics

-- measured by nearby and more remote observations of vertical and horizontal dynamics, the plume temperature structure, ambient temperature and moisture structure, plume morphology and entrainment measurements.

o Smoke Quantity and Character

-- measured by gas and particulate inventories using gas chromatography and a variety of passive and active particle sampling techniques.

o Smoke Optical Properties

-- determined from transmissivity measurements of filter samples, passive solar and infrared photometry and measurements of individual smoke particle scattering phase functions.

o Capping Cloud Characteristics and Effects

-- determined from measurements of cloud droplet size and concentrations, vertical variation of cloud interstitial aerosol and observations of cloud electric fields and particle and droplet charges.

Finally, a set of smoke and soot measurements in the tropical atmosphere remote from fire plumes should be made. These measurements could be related to satellite observations of the number and extent of fires throughout the tropics during the several weeks preceding the experiment. The point would be to determine the effects of multiple fires in producing a uniform smoke pall and the scavenging effect of the precipitation.

URBAN FIRE EXPERIMENTS

Both laboratory and larger scale controlled experiments for a variety of structures and urban conditions could be planned to determine quantity and character of emissions from homogeneous and mixed fuel fires. Passive particle sizing and counting equipment, thermal precipitators and filter sampling for electron-microscopy could be used in controlled experiments to provide smoke inventories and properties from which to infer the effects of mixed fuels.

It is of interest to understand whether the initial stages of confined fires might produce significantly more smoke before they break through the structure and become open fires. Data may already exist to estimate this effect. If not, laboratory experiments could investigate this effect, using instrumentation similar to the mixed fuel instrumentation.

Here, the oxygen level and the fire environment for a homogeneous fuel could be controlled. If these experiments suggest a significant effect, then larger more complex experiments could be explored.

The primary issue with respect to urban fires, however, is whether large scale, intense fires are more or less efficient and therefore produce more or less smoke for the same mass of fuel consumed than do smaller, quieter fires.

To study this question, a series of indoor, controlled experiments of varying scales might be planned, to see whether soot and aerosol emission factors can be empirically scaled to larger-size fires. The effects of nearby heat sources (i.e., other burning structures) should be investigated, as well as oxygen availability effects and burnout. To integrate these effects into a coherent picture of a mass urban fire, models of soot and smoke formation and near-fire dynamics must be developed. These models could be validated by various scales of controlled experiments.

Once there is confidence in the predictability of emissions from larger scale fires, a set of structure fires should be planned. These would allow at least one check on the validity of the scaling experiments described above. However, to relate the emissions from a single structure fire to those expected in a large mass fire would require a model that could predict the oxygen and thermal environment near the smoke formation region. The development of this model must be linked to the smaller scale experiments planned above in order to be credible.

TABLE 4

SAMPLE OF PARAMETERS TO BE MEASURED FROM INSTRUMENTED AIRCRAFT

PARAMETER	INSTRUMENT
1. Local dynamics (vertical updraft in plume, induced winds)	meteorology boom on aircraft Doppler radar Doppler lidar
2. Air temperature Plume temperature	aircraft thermistors
3. Plume top, bottom and downwind extent Morphology	fast response particle size detector, lidar, or condensation nucleus counter; cinematography
4. Degree of plume mixing with ambient air	passive tracer
5. Fire intensity	ground based temperature measurements; airborne spectral scanner
6. Radiative flux	flux meter
7. Fire area	spectral scanner
8. Particle mass loading	filters, fast response integrating nephelometer, microbalance impactors
9. Smoke composition	filter collection impactor collections
10. Smoke particle size Morphology	particle sizing instruments multi-wavelength lidar laser imaging probe
11. Smoke optical properties Scattering phase function	filter collections with laboratory analysis; scatterometer
12. Smoke visible & infrared optical depth	sun photometer infrared photometer
13. Atmospheric heating rates in smoke cloud	net flux measurements at several altitudes
14. Presence of H_2O cloud & characteristics	cloud particle size spectrometers
15. Cloud removal efficiency for smoke	particle size detector
16. Gaseous emissions	gas chromatography, special sensors

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Patree Sweeney

DATED: October 1985

SUBJECT:

Tells Dr. Keyworth "Quit stuffing Nuclear Winter under the rug."

RECEIVED: October 15, 1985

ACTION BY: Executive Director/dlw

ACTION COPY TO: Roesch

INFORMATION COPIES TO:

Lynch

SUSPENSE DATE: November 4, 1985

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ______________________.

( ) No action necessary.

( ) Other

File Nucl. Winter

STP FORM 9

Presidential Science Advisor
Dr. George A Keyworth
Director
OSTP
Old Executive Office Building
Washington, DC 20500

Dear Mr. Keywarth:

Please quit stuffing Nuclear Winter under the rug. Just like in the movie "War Games" you can't win a nuclear war!

Sincerely,

Patrice Sweeney

P. Sweeney
115 1/2 Broce Drive
Blacksburg, VA 24060

ROANOKE, VA 240 34
PM
8 OCT
1985

Dr. George A Keyworth
Director
OSTP
Old Executive Office Building
WASH, DC 20500

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Lee M. Thomas United States Environmental Protection Agency	**DATED:** July 26, 1985
SUBJECT: Possible cooperative nuclear winter research with the USSR.	
RECEIVED: July 29, 1985	**ACTION BY:** Executive Director/lsj
ACTION COPY TO: Roesch	
INFORMATION COPIES TO: Lynch	
SUSPENSE DATE: August 19, 1985	

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

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( ) Action transferred to ________________.

( ) No action necessary.

( ) Other

Filed Nucl. Winter

OSTP FORM 9

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUL 26 1985

THE ADMINISTRATOR

Dr. G.A. Keyworth
Science Advisor to the President
The White House
Washington, D.C.

Dear Dr. Keyworth:

This letter is occasioned by the outline of the Interagency Research Program on nuclear winter provided in your letter to me of June 10. You should be aware of an indirect role which I may be called upon to play with regard to cooperative nuclear winter research with the USSR.

As you may know, I serve as U.S. co-chairman of the US-USSR Joint Committee on Cooperation in the Field of Environmental Protection. The ninth Joint Committee meeting (JCM) is scheduled to take place in Moscow November 12-21 of this year. This will be the first session of the environmental Joint Committee since December 1979. Our agreement to participate follows the President's statement of June 27, 1984, concerning US-Soviet exchanges.

An important component of our USSR program is the joint working group on "Influence of Environmental Changes on Climate." Dr. Alan Hecht, director of NOAA's National Climate Program Office, co-chairs this working group on the U.S. side, with support from Dr. Eugene Bierly of NSF. As your June 10 letter points out, both Drs. Hecht and Bierly participate in the Interagency Research Program on nuclear winter. Dr. Hecht plans to attend the November JCM.

Discussions with various Soviet contacts in recent months lead us to believe that they plan to present us in November with a proposal for joint nuclear winter research. This proposal may focus on purely technical aspects which have already been discussed in the context of the working group on climate effects: model refinements, physical properties of dust and smoke, and other components of the basic atmospheric response to a nuclear exchange.

At the same time, we have reason to believe that my Soviet counterpart as co-chairman of the Joint Committee, Academician Yuriy Izrael, may also press for joint study of secondary and tertiary effects (e.g., disruption of food chains and ecosystemic responses). This latter type of proposal would represent a significant expansion of cooperation, inasmuch as it would extend well beyond the bound of the existing climate effects working group, into areas largely uncharted by the scientific community.

EPA has no regulatory or research interest in the nuclear winter problem. However, inasmuch as I may be leading a U.S. delegation to Moscow at an important time in US-Soviet relations, I want to be sure that our response to any Soviet initiative in this very sensitive area is fully coordinated with the Interagency Research Program and the NSC Ad Hoc Policy Group on Nuclear Winter. EPA Associate Administrator Fitzhugh Green and his staff in our Office of International Activities are fully acquainted with this situation and are ready to work with your staff and the other agencies involved.

Please let us know how we can support the Administration's nuclear winter effort in the context of the US-USSR Environmental Agreement.

Sincerely,

Lee M. Thomas

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: R. H. Canaday	DATED: July 9, 1985
SUBJECT: DOD March 1985 report, "The Potential Effects of Nuclear War on the Climate."	
RECEIVED: July 17, 1985	ACTION BY: Executive Director/lsj
ACTION COPY TO: Roesch	
INFORMATION COPIES TO: Lynch	
SUSPENSE DATE: August 7, 1985	

REMARKS: FOR APPROPRIATE ACTION

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If written correspondence was sent, please attach a copy.

( ) Written correspondence.

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( ) No action necessary.

( ) Other

File Nuclear Winter

OSTP FORM 9

74 Placid Place
Rochester, NY 14617
9 July 1985

To: Dr. George Keyworth II
Presidential Science Advisor
Washington, DC 20506

From: R.H. Canaday

Subject: DOD March 1985 report, "The Potential Effects of Nuclear War on the Climate"

The subject report discusses, among other things, what is called the TTAPS report.

The TTAPS material predicts climatic effects caused by 'blocking' of the sun's radiation by dust and soot particles thrown into the atmosphere by nuclear weapons.

Radiation from the sun may be scattered (without attenuation) or absorbed by dust and soot. The part which is absorbed will raise the temperature of the particles until each reaches a temperature at which it reradiates or transfers to air molecules all the energy it absorbs, not only from the sun, but from other particles, the air, and the earth. It is true enough that the radiation from the sun will not reach the earth, but the earth's temperature depends upon the energy arriving and leaving, not the wavelength of the energy.

The earth, instead of radiating into the cold of starlit space, would be enclosed in a warm shell of particulates which must be in energy balance with sun, earth, and space. Even if the TTAPS authors had a desire to include this Venus-like effect, it would be difficult to do with their one-dimensionsl model of the atmosphere and their non-rotating earth.

Neither in the TTAPS material nor that from DOD do I find any mention of the effect of the temperature of the particulates. (except that the DOD IRP will include research on 'radiative and circulation feedbacks', pp 7-8)

Could you tell me why it was decided, in the DOD critique, to omit any consideration of the effect of atmospheric heating due to the absorption of energy from the sun by the particulate layer?

If this effect alone creates an uncertainty (using the TTAPS assumptions of particulate size, quantity etc.) as to whether the result would be 'nuclear summer' or 'nuclear winter' the general public would quickly conclude that it is a little early to go into shock over print-outs from the TTAPS model.

Provided that the message is short and non-technical, even the media would be able to understand that a model which cannot reliably predict whether the earth would be warmed or cooled is not worth the attention and concern it has already been accorded.

Yours truly,

R.H. Canaday

R.H. Canaday

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM		DATED:
	Rich - Office of the Director National Science Foundation	July 15, 1985

SUBJECT:

Letter thanking Dr. Keyworth for his support of "Rich's" appointment.

RECEIVED:	ACTION BY:
July 18, 1985	Executive Director/lsj

ACTION COPY TO:

NAN

INFORMATION COPIES TO:

Lynch

SUSPENSE DATE:

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ____________________.

( ) No action necessary.

( ) Other

File NSF

OSTP FORM 9

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE DIRECTOR

7/15/85

Dear Jay –

I just want to thank you personally for your support of my appointment. I will try to justify the confidence you have shown in me. Needless to say, please call me at any time you think I can be of help or assistance.

Regards,

Rich

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM:	DATED:
William J. Dircks U.S. Nuclear Regulatory Commission	July 1, 1985

SUBJECT:

Thanking Dr. Keyworth for his letter of June 10, 1985, which explains the Administration's research program on the "Nuclear winter" issue.

RECEIVED:	ACTION BY:
July 3, 1985	Executive Director/lsj

ACTION COPY TO:

NAN g

INFORMATION COPIES TO:

Lynch
Roesch

SUSPENSE DATE:

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ______________________.

( ) No action necessary.

( ) Other

Filed Nucl. Winter

OSTP FORM 9

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 01 1985

Dr. G. A. Keyworth, Science Advisor
to the President
The White House
Washington, DC 20506

Dear Dr. Keyworth:

Thank you for your letter to Chairman Palladino dated June 10, 1985, which explains the Administration's research program on the "nuclear winter" issue. Although the NRC has no direct expertise regarding the atmospheric effects of nuclear war, we are pleased that you are keeping us informed. If anything does develop in which our technical resources would be helpful, we will be glad to participate. Please address any such requests for assistance to Mr. Robert B. Minogue, Director, Office of Nuclear Regulatory Research.

Sincerely,

William J. Dircks
Executive Director
for Operations

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Barbara Faughnan Space Studies Institute	DATED: June 28, 1985
SUBJECT: Letter thanking Dr. Keyworth for giving the keynote address.	
RECEIVED: July 3, 1985	ACTION BY: Executive Director/lsj
ACTION COPY TO: NAN g	
INFORMATION COPIES TO: Lynch Abell add Murray P 5-7	
SUSPENSE DATE:	

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ______________________.

( ) No action necessary.

( ) Other

Filed 'F' Folder

OSTP FORM 9

Space Studies Institute
285 Rosedale Road
P.O. Box 82
Princeton, New Jersey 08540
Telephone: (609) 921-0377

Gerard K. O'Neill
President

June 28, 1985

Dr. George A. Keyworth, II
The White House
1600 Pennsylvania Avenue
Washington, DC 20500

Dear Dr. Keyworth:

On behalf of all of us connected with the Space Manufacturing Conference I would like to thank you for giving us the keynote address. We all agreed that your presence added so much to the professional atmosphere of the Conference. Please excuse the delay in writing you, but we have been busy preparing for the publication of the Proceedings. Your talk will be included and we will send you a copy as soon as they are available - probably early September.

Thank you again for coming.

Sincerely yours,

Barbara Faughnan
Conference Coordinator

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: David A. Freiwald
MRJ

DATED: May 22, 1985

SUBJECT:

Encl: Items regarding the Nuclear Winter issue.

RECEIVED: May 24, 1985

ACTION BY: Executive Director/lsi

ACTION COPY TO: Roesch

INFORMATION COPIES TO:

Lynch

SUSPENSE DATE: June 14, 1985

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ______________________.

( ) No action necessary.

( ) Other

Filed Nuclear Winter

OSTP FORM 9

FOR OFFICIAL USE ONLY

MRJ, INC. ● 10455 WHITE GRANITE DR. ● SUITE 200 ● OAKTON, VIRGINIA 22124

22 May 1985

Dr. George A. Keyworth, Chairman
Coordinating Committee
Interagency Research Program
c/o OSTP
White House - OEOB
Washington, DC 20500

Re: Nuclear Winter Studies

Dear Dr. Keyworth:

I have learned from the NSF that your committee will be having a look at the Nuclear Winter issue. Here are some items that you may feel free to share with the members of the committee if/as you wish:

1. The subject is indeed an important contemporary issue.

2. The subject also needs to be placed in perspective with other contemporary threats.

3. A 'Spectrum of Potential Conflict' is shown in Figure 1 attached. Note that though nuclear warfare has the highest risk (as recognized by the DoD), it also has the lowest probability.

4. Another 'Threat Matrix' is shown in Figure 2 attached.

5. Thus, between the illustrations there are about 7 dimensions to the total threat/conflict matrix:

- o Type
- o Risk (impact)
- o Probability
- o Geographic Extent
- o Duration of Impact
- o National (U.S.) Status when event occurs
- o Type of Weapon(s)

6. Note that the Soviets have done little over the past 40 years in going into some country in order to simply destroy something. What they have done is to take actions to capture or control assets of value to them, such as military-strategic realestate or minerals. For this, the use of nuclear weapons would (has been) avoided. Even extended use of conventional munitions

FOR OFFICIAL USE ONLY (NRO)

is avoided if at all possible. Think BW/CW, and think advanced conventional munitions like long-range low-CEP cruise missiles with conventional (HE) warheads.

7. We now have cruise missiles with a range of 1500 n.m. and a CEP of 60 feet (see: Nat. Defense, Jul/Aug 84). Allow for the possibility that the Soviets have, or soon will have, similar capabilities. Allow for the Possibility that such missiles can carry conventional (HE) or BW/CW warheads as well as nuclear warheads, and that the Soviets are working on such systems (see: Aerospace American, Feb 85).

8. Thus, needs for the "nuclear shotgun" became less as the "cruise missile rifle" becomes more accurate, since these new, fast and accurate delivery systems enable an enemy to go after people, and ships in the harbor or aircraft on the tarmac, while leaving valuable assets like the docks or runway in tact. This changing scene could result in an increase in the probabilities in the center portion of Figure 1.

9. What happens if terrorists also start using CW? (The chemical compositions are in unclassified publications.)

10. It is not clear that just looking at the nuclear winter issue alone is fair to the public; it relates to only a narrow slice (and lowest probability) of the total threat scene, which is changing away from nuclear anyway.

11. What is needed is a good study that looks at the various threats, does a comparative analysis, and puts them in perspective in terms of probabilities of occurance.

Sincerely,

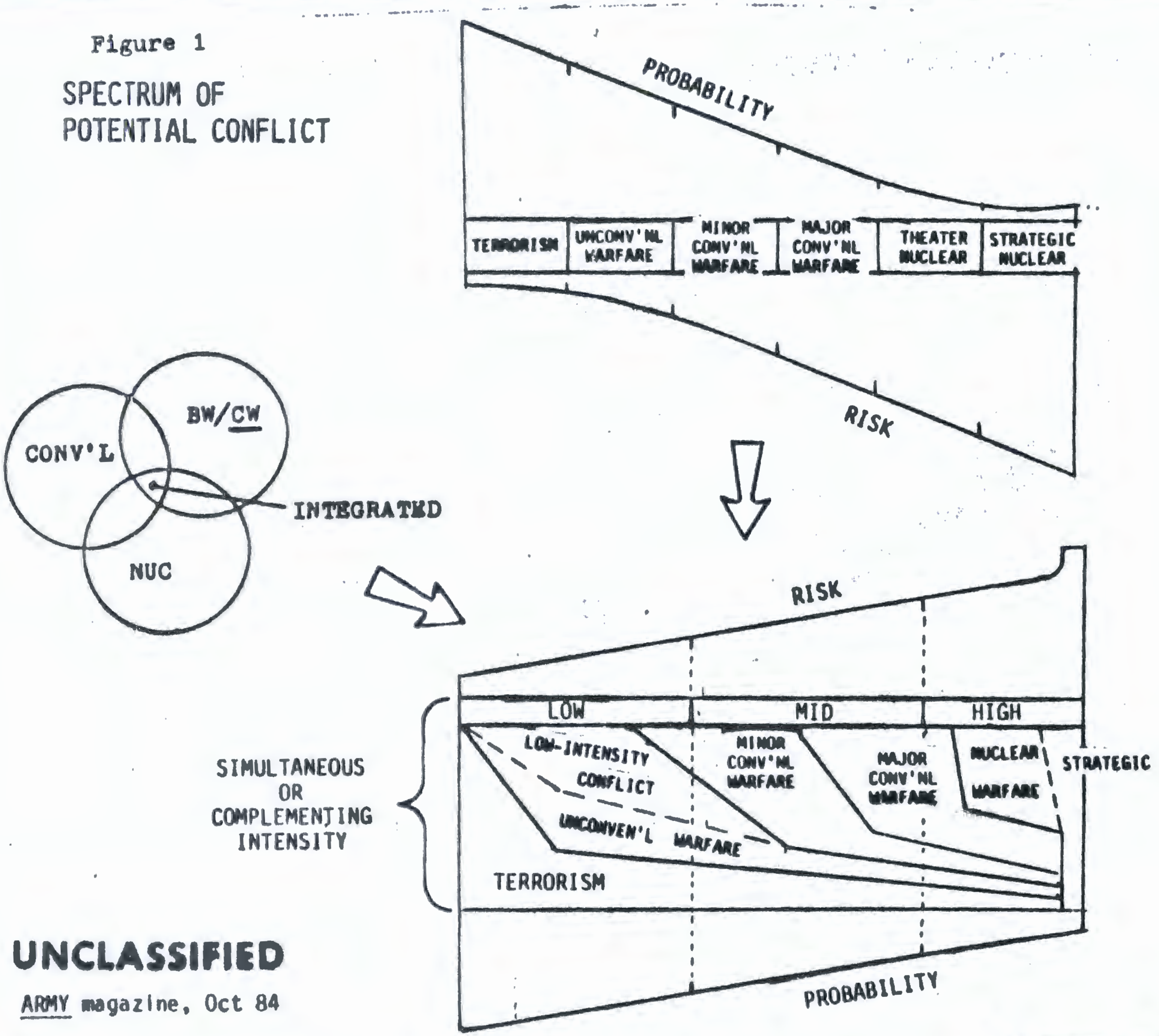
David A. Freiwald, Ph.D.

encl: a/s

cc: Erich Bloch, NSF
Frank Press, NAS

Figure 1

SPECTRUM OF POTENTIAL CONFLICT

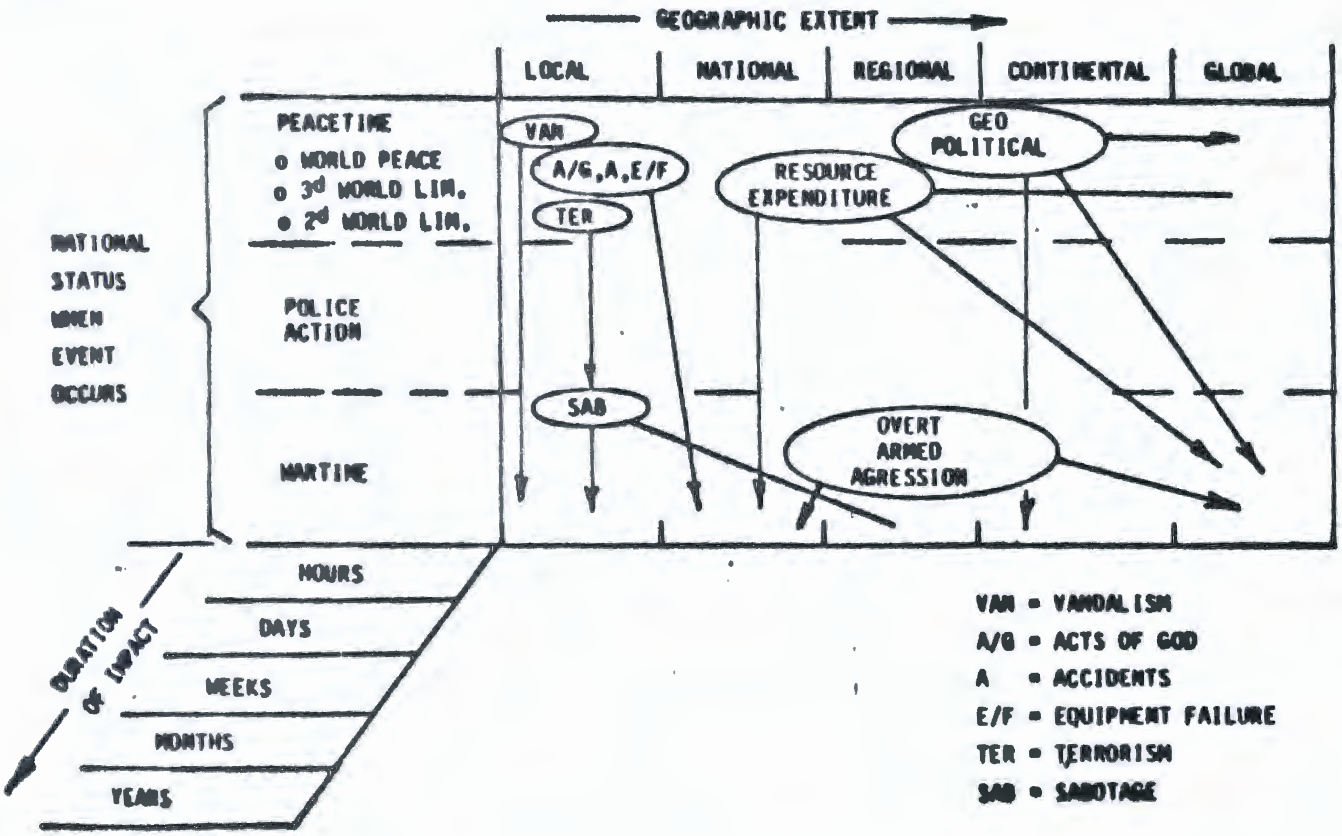


UNCLASSIFIED

ARMY magazine, Oct 84

Figure 2

MATRIX OF THREAT/EVENT CATAGORIES FOR ENERGY



VAN = VANDALISM
A/G = ACTS OF GOD
A = ACCIDENTS
E/F = EQUIPMENT FAILURE
TER = TERRORISM
SAB = SABOTAGE

Nucl. Winter

Awaiting address list frm Robin +/or Lois Hamaty, NSF p.11-6

THE WHITE HOUSE

WASHINGTON

June 10, 1985

Dear Mr. Wirth:

This letter explains the Administration's research program in response to the "nuclear winter" issue. I announced, in my February 4, 1985 news conference, that a coordinated nuclear winter research effort known as the Interagency Research Program had been developed. To oversee the program, I also announced the establishment of a Coordinating Committee.

The Committee is an advisory body with representation from Department of Defense (DOD), Department of Energy (DOE), National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), Office of Science and Technology Policy (OSTP), with ex-officio members from National Security Council (NSC) and Office of Management and Budget (OMB). The Office of Science and Technology Policy (OSTP) chairs the Committee which will oversee the Administration's sponsored research program. Based on the report proposed and coordinated by the National Climate Program Office (NCPO) of the National Oceanic and Atmospheric Administration (NOAA), the Committee will make recommendations on research topics to be pursued and facilitate the flow of information among participating agencies. The thrust of the research initially will be to answer scientifically based questions relative to atmospheric effects of nuclear war. The Committee will be the focal point for communicating with all interested parties. Program funds used to conduct this research will be administered by the respective agencies sponsoring the research.

Research projects recommended by the NCPO report represent research guidelines for an interagency research plan that addresses climatic effects of nuclear war and should not be considered a final program plan. It provides the base on which to identify priorities. The Committee will encourage further research to be carried out in a coordinated fashion to avoid duplication of effort and to address critical gaps in knowledge.

The Administration has proposed funding in FY '86 to bring the level of effort to $5.5 million. The funding shares are: A) DOD ($2.5 million); B) DOE ($2.5 million); C) NSF ($500,000). Points of contact for the agencies are listed below:

Department of Defense

Col. Houston T. Hawkins
Special Assistant to the Assistant to the Secretary of Defense (Atomic Energy)
Department of Defense
Washington, D.C. 20301-3010
202/697-3060

National Oceanic and Atmospheric Administration

Dr. Alan Hecht
Director, National Climate Program Office
National Oceanic and Atmospheric Administration, Suite 108
11400 Rockville Pike
Rockville, MD 20852
301/443-8646

Department of Energy

Ms. Isabel Neddow
Defense Programs
Department of Energy
DP-223, MAIL STOP A-362
Germantown, MD 20545
301/353-5115

Mr. Ted Harris
Policy
Department of Energy
PE-16, Room 4G-036
Forrestal Building
Washington, D.C. 20585
202/252-2066

National Science Foundation

Dr. Eugene W. Bierly
Director, Division of Atmospheric Sciences
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550
202/357-9874

If there are further science policy questions related to the Interagency Research Program or the role of the Coordinating Committee, my staff and I are ready to assist. For more information, please contact my Deputy Director, Dr. Bernadine Healy, through the Coordinating Committee, by writing to:

Office of Science and Technology Policy
Executive Office of the President
Attn: Interagency Research Program Coordinator
Washington, D.C. 20506

or calling:

(202) 395-3170 or 395-7326 and asking for the Interagency Research Program Coordinator.

Thank you for your interest in supporting this important research effort.

Sincerely,

G. A. Keyworth
Science Advisor to the President

Honorable Timothy E. Wirth
United States House
of Representatives
Washington, D.C. 20515

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Clarence J. Brown Dept of Commerce	DATED: March 18, 1985
SUBJECT: Thank you for sending a cc of your ltr to Alan Hecht re Nuclear Winter research program.	
RECEIVED: March 20, 1985	ACTION BY: Executive Director/alb
ACTION COPY TO: NAN	
INFORMATION COPIES TO: Lynch MJ Roesch	
SUSPENSE DATE:	

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ______________________.

( ) No action necessary.

( ) Other

File Nucl. Winter

OSTP FORM 9

THE DEPUTY SECRETARY OF COMMERCE
Washington, D.C. 20230

March 18, 1985

Dr. George A. Keyworth
Science Advisor to the President
The White House
Washington, D. C. 20500

Dear Jay,

Thank you for sending me the copy of your letter to Dr. Alan Hecht, in which you expressed your appreciation for his support of the "nuclear winter" research program. It is always a pleasure to read such positive comments about our employees. I enjoy learning of the dedicated and professional service they provide in interagency work.

Sincerely,

Clarence J. Brown

CJB/ARC/mdh

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Richard C. Raymond	**DATED:** March 5, 1985
SUBJECT: Copy of a letter sent to the President regarding nuclear winter.	
RECEIVED: March 12, 1985	**ACTION BY:** Executive Director/lsj
ACTION COPY TO: NAN	
INFORMATION COPIES TO: Lynch Roesch mf	
SUSPENSE DATE:	

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ______________________.

( ) No action necessary.

( ) Other

File Nucl. Winter

Richard C. Raymond
422 Consuelo Drive
Santa Barbara CA 93110
5 March 1984

Dear Mr. President:

How can you press for $4 Billion for the MX, while you cannot recommend a puny $10 million for research on nuclear winter?

Belief in the risk of nuclear winter is changing our needs for military forces drastically. We need less nuclear forces and far more non-nuclear forces than we are planning.

If the best current estimates are anywhere near the mark, we cannot use more than a small fraction of our existing nuclear weapons without a serious risk of suicide - perhaps even extinction.

At the same time, the risk of nuclear winter makes our nuclear deterrence of Soviet aggression in Europe much less credible. If NATO's non-nuclear forces cannot deter intimidation by the enormous armies of the Warsaw Pact, we shall be faced with gradual "Finlandization" of Germany, France and other allies. Our nuclear forces will "save" Europe about as well as they have "saved" Afghanistan.

We must know as much as possible as soon as possible about nuclear winter. The specter has been raised. If it cannot be exorcised, we face a dramatic shift in our defense priorities. Nuclear force reduction will be a matter of pure self interest. We can do it right away without any negotiations. All of the savings, and probably more, are urgently needed to bring NATO's non-nuclear forces to levels of strength and readiness to take over the deterrent role in Europe.

If you persist on your present course, you may become one of the heroes in a sequel to Barbara Tuchman's excellent book, The March of Folly.

In friendly exasperation,

Dick

President Ronald Reagan
The White House
Washington DC 20500-0001

copies: Senator Cranston
Congressman Lagomarsino
Senator Wilson
Dr. George Keyworth II

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Timothy E. Wirth
House of Representatives

DATED: September 9, 1985

SUBJECT:

Writing in regards to federal support for independent scientific research of the nuclear winter theory.

RECEIVED: September 13, 1985

ACTION BY: Executive Director/lsj

ACTION COPY TO: Roesch

INFORMATION COPIES TO: Lynch

SUSPENSE DATE: September 20, 1985

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ____________________.

( ) No action necessary.

( ) Other

Filed Nucl. Winter

OSTP FORM 9

TIMOTHY E. WIRTH
2D DISTRICT, COLORADO

COMMITTEES:
ENERGY AND COMMERCE
CHAIRMAN, SUBCOMMITTEE ON TELECOMMUNICATIONS, CONSUMER PROTECTION AND FINANCE
SUBCOMMITTEE ON HEALTH AND THE ENVIRONMENT
SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

CONGRESS OF THE UNITED STATES
HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

WASHINGTON OFFICE:
2262 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
(202) 225-2161

DISTRICT OFFICE:
3489 WEST 72D AVENUE
SUITE 112
WESTMINSTER, CO 80030
(303) 650-7900

September 9, 1985

Dr. George A. Keyworth II
Special Adviser to the President
and Director
Office of Science and Technology Policy
Old Executive Office Building
Washington, D.C. 20506

Dear Dr. Keyworth:

I am writing in regard to federal support for independent scientific research of the nuclear winter theory. As chairman of the interagency panel which devised a program for such research, you are very familiar with this matter, which is why I direct my inquiry to you.

Your panel recommended a scientific research program managed outside of the Department of Defense (DOD) and funded up to a level of $10 million per annum. Unfortunately, despite your efforts on behalf of the recommended program, it has failed to materialize. As a result, there is only a limited amount of research being undertaken on this important new theory of the consequences of nuclear war. At present, DOD and the Department of Energy (DOE) are each contributing $2.5 million towards nuclear winter research, while the National Science Foundation is contributing $500,000, although much of that research is related to other fields of research which would probably be conducted irrespective of the discovery of nuclear winter. Moreover, because the independent program has yet to be realized, the majority of research is being done in DOD and DOE laboratories, as opposed to independent and university laboratories.

The result of this limited and concentrated funding has been a narrow research program. Most of the work has been centered on computer modeling of nuclear war-fighting simulations and their aftermaths. There have been minimal resources available for the laboratory and field work -- such as mesoscale and fire research -- that would contribute to a greater understanding of the first phases of the nuclear winter phenomenon.

Given the potential significance of nuclear winter for our strategic nuclear policies and the broad scientific interest -- as reflected by your report -- in this theory, I am concerned about the sparse support which research on the theory has received thus far. What deepens my concern is the disparity between funding for nuclear winter research -- at $5.5 million -- and expected FY 1986 funding for the President's Strategic Defense Initiative -- $2.7 billion. While the latter program may be deserving of federal support, there is no justification for the gross inequity in research funding for theories of arguably comparable importance.

Dr. George A. Keyworth II
September 9, 1985
Page Two

Judging from your work on the interagency panel, you share my concerns about the inadequate resources devoted to nuclear winter. I would greatly appreciate a clarification of the reasons for the lack of action in establishing an independent research program. I would also be interested in any further actions OSTP may be taking, or planning to take, to remedy this situation. Your responses to these queries would be most helpful in assessing the obstacles to a more substantial national scientific inquiry into nuclear winter.

Sincerely yours,

Tim Wirth

Timothy E. Wirth

TEW:js

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Carl Sagan
Cornell University

DATED: August 12, 1985

SUBJECT:

Letter requesting information on Nuclear Winter funding and the organization of a Coordinating Committee on the subject.

RECEIVED: August 19, 1985

ACTION BY: Executive Director/lsj

ACTION COPY TO: ~~Kornack~~ Change to Roesch

INFORMATION COPIES TO: 20-8

Lynch

SUSPENSE DATE: September 9, 1985

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ______________.

( ) No action necessary.

( ) Other

Filed Nucl. Winter

OSTP FORM 9

CORNELL UNIVERSITY
Center for Radiophysics and Space Research
SPACE SCIENCES BUILDING
Ithaca, New York 14853 - 0355

Telephone (607) 256-4971

12 August 1985

Laboratory for Planetary Studies

Dr. George A. Keyworth
Science Advisor to the President
The White House
Washington, DC

Dear Dr. Keyworth:

Many thanks for your letter of June 10th on Nuclear Winter funding and the organization of a Coordinating Committee on the subject. I wonder if you could tell me (a) if the funding level is still at 5.5 million as mentioned in your letter; (b) how much of this money is new -- that is, in addition to money obligated, say, in the previous fiscal year for research of this nature; and (c) what fraction of the total money has been or is likely to be obligated to other than government laboratories and organizations that are mainly supported by the Departments of Defense or Energy.

With many thanks for your attention to this matter,

Cordially,

Carl Sagan

CS/np

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Casper Weinberger The Secretary of Defense	**DATED:** July 1, 1985

SUBJECT:

Letter thanking Dr. Keyworth for his letter of June 10, 1985 explaining the Administration's research program in response to the "nuclear winter issue" and the role of the Interagency Research Program Coordinating Committee in overseeing the execution of hte program.

RECEIVED: July 2, 1985	**ACTION BY:** Executive Director/lsj

ACTION COPY TO:

Roesch

No action required

INFORMATION COPIES TO:

Lynch

Roesch 5-1

SUSPENSE DATE:

July 22, 1985

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ________________.

( ) No action necessary.

( ) Other

Filed Nucl. Winter

OSTP FORM 9

THE SECRETARY OF DEFENSE

WASHINGTON, THE DISTRICT OF COLUMBIA

01 JUL 1985

Honorable George A. Keyworth
Science Advisor to the President
Old Executive Office Building
Washington, D.C. 20506

Dear Dr. Keyworth: Jay

Thank you for your letter of June 10 explaining the Administration's research program in response to the "nuclear winter issue" and the role of the Interagency Research Program Coordinating Committee in overseeing the execution of the program.

We look forward to working with you and the coordinating committee in carrying out the interagency program to provide scientifically-based answers on the atmospheric effects of nuclear war. You may be assured of the cooperation and support of the Department of Defense in this important effort.

Sincerely,

Nucl. Winter

THE WHITE HOUSE

WASHINGTON

June 18, 1985

Dear Mr. Stallings:

This letter explains the Administration's research program in response to the "nuclear winter" issue. I announced, in my February 4, 1985 news conference, that a coordinated nuclear winter research effort known as the Interagency Research Program had been developed. To oversee the program, I also announced the establishment of a Coordinating Committee.

The Committee is an advisory body with representation from Department of Defense (DOD), Department of Energy (DOE), National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), Office of Science and Technology Policy (OSTP), with ex-officio members from National Security Council (NSC) and Office of Management and Budget (OMB). The Office of Science and Technology Policy (OSTP) chairs the Committee which will oversee the Administration's sponsored research program. Based on the report proposed and coordinated by the National Climate Program Office (NCPO) of the National Oceanic and Atmospheric Administration (NOAA), the Committee will make recommendations on research topics to be pursued and facilitate the flow of information among participating agencies. The thrust of the research initially will be to answer scientifically based questions relative to atmospheric effects of nuclear war. The Committee will be the focal point for communicating with all interested parties. Program funds used to conduct this research will be administered by the respective agencies sponsoring the research.

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The Administration has proposed funding in FY '86 to bring the level of effort to $5.5 million. The funding shares are: A) DOD ($2.5 million); B) DOE ($2.5 million); C) NSF ($500,000). Points of contact for the agencies are listed below:

<u>Department of Defense</u>

Col. Houston T. Hawkins
Special Assistant to the Assistant to the Secretary of Defense (Atomic Energy)
Department of Defense
Washington, D.C. 20301-3010
202/697-3060

<u>National Oceanic and Atmospheric Administration</u>

Dr. Alan Hecht
Director, National Climate Program Office
National Oceanic and Atmospheric Administration, Suite 108
11400 Rockville Pike
Rockville, MD 20852
301/443-8646

Department of Energy

Ms. Isabel Neddow
Defense Programs
Department of Energy
DP-223, MAIL STOP A-362
Germantown, MD 20545
301/353-5115

Mr. Ted Harris
Policy
Department of Energy
PE-16, Room 4G-036
Forrestal Building
Washington, D.C. 20585
202/252-2066

National Science Foundation

Dr. Eugene W. Bierly
Director, Division of Atmospheric Sciences
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550
202/357-9874

If there are further science policy questions related to the Interagency Research Program or the role of the Coordinating Committee, my staff and I are ready to assist. For more information, please contact my Deputy Director, Dr. Bernadine Healy, through the Coordinating Committee, by writing to:

Office of Science and Technology Policy
Executive Office of the President
Attn: Interagency Research Program Coordinator
Washington, D.C. 20506

or calling:

(202) 395-3170 or 395-7326 and asking for the Interagency Research Program Coordinator.

Thank you for your interest in supporting this important research effort.

Sincerely,

G. A. Keyworth
Science Advisor to the President

Honorable Richard H. Stallings
Committee on Science and Technology
United States House of Representatives
Washington, D.C. 20515

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: Aydano B. Carleial Instituto de Pesquisas Espaciais	DATED: April 25, 1985
SUBJECT: Copy of letter to Professor S. Fred Singer regarding global-scale effects of a nuclear war on weather and climate.	
RECEIVED: May 14, 1985	ACTION BY: Executive Director/lsj
ACTION COPY TO: Kornack	
INFORMATION COPIES TO: Lynch	
SUSPENSE DATE:	

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ______________.

( ) No action necessary.

( ) Other

Filed Nucl. Winter

OSTP FORM 9

23 April 1985

(55)(123)22997
ext 406*
or 440

Prof. S. Fred Singer
George Mason University
Fairfax, Virginia
U.S.A.

AYDANO B. CARLEIAL
Department Head
Space Technology Department
Telecommunications
Instituto de Pesquisas Espaciais
INPE Caixa Postal 515
São José dos Campos, SP 12200 Brazil

This is the MIT of Brazil

Dear Prof. Singer

I have just read your letter to Scientific American, published in the April 1985 issue, concerning global-scale effects of a nuclear war on weather and climate.

I have much interest on the subject — which is not in my research area — but I have never read a paper that presents a point of view different from the "nuclear winter" theory. In fact, I have heard some people present NW here as undisputed.

Amazing! Disinformation

If you have any papers, written by yourself or others, presenting other views, I would be most grateful to receive copies of them. I am particularly — but not exclusively — interested on effects on the Southern Hemisphere.

Yours,

Aydano Carleial

INPE Caixa Postal 515

LETTERS

To the Editors:

Richard P. Turco, Owen B. Toon, Thomas P. Ackerman, James B. Pollack and Carl Sagan (TTAPS) ["Letters," SCIENTIFIC AMERICAN, January] accuse me of "erroneously" expecting a significant greenhouse effect instead of a nuclear winter in my *Wall Street Journal* editorial essay (February 3, 1984). They then state: "Deficiencies in Singer's article were pointed out in a subsequent issue of the *Wall Street Journal* (February 16, 1984)." They fail to inform the reader, however, that the "pointing out" was done not by an independent scientist but in a letter to the editor written by Carl Sagan, who is hardly an unbiased referee.

Not only are TTAPS unfairly disguising the source of criticism by using the passive tense but also they are misrepresenting what I wrote. The "nuclear summer" (as I have called it) is not the expected but simply a possible outcome of plausible assumptions fed into a TTAPS-like model. Whether the warming is more likely than the extreme freeze I cannot say—nor can anyone else, in the absence of reliable data and more appropriate models. I can only state that V. Ramanathan of the National Center for Atmospheric Research (NCAR) has independently pointed to the possibility of surface heating due to a greenhouse effect, and that Robert D. Cess of the State University of New York at Stony Brook and V. Ramaswamy and Jeffrey T. Kiehl of NCAR have papers in publication that show warming is possible.

To quote from my essay: "My purpose is to illustrate the extreme difficulty of making accurate predictions of the global environmental effects of a nuclear exchange. Prof. Sagan's scenario may well be correct, but the range of uncertainty is so great both because of the set of assumptions used and what has been left out in discussing the physics of the situation that the prediction isn't particularly useful."

S. FRED SINGER

George Mason University
Fairfax, Va.

To the Editors:

An experience I had a number of years ago leads me to question the assertion of Philip H. Brownell ["Prey Detection by the Sand Scorpion," SCIENTIFIC AMERICAN, December, 1984] that scorpions occupy a terminal position in the food chain.

THE WHITE HOUSE

WASHINGTON

March 6, 1985

MEMORANDUM FOR DISTRIBUTION

FROM: JAY KEYWORTH

SUBJECT: Coordinating Committee Meeting for the Interagency Research Program

This memorandum announces the organizational meeting of the Coördinating Committee for the Interagency Research Program established in accordance with our agreed to course of action for responding to the nuclear winter issues. This meeting will be held March 19, 1985, in the Office of Science and Technology Policy Conference Room, the New Executive Office Building, Room 5026, from 2:00 PM - 3:30 PM.

The following is an outline of the subjects to be discussed:

Introduction

Role of Coordinating Committee

Required Infrastructure

Policy and Procedures

Summary

It is important that you or your designated representative be present at this meeting to ensure that your recommendations are included in the foundation of this committee. Please confirm your attendance with my office by contacting Dr. Bernadine Healy Bulkley at 395-5101.

Thank you for your assistance.

Distribution:

The Honorable Clarence J. Brown
The Honorable James Wade
VADM John Poindexter
MGen. (Ret) William Hoover
Dr. Erich Bloch
Dr. Alton G. Keel, Jr.

Nucl. Winter

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EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

January 16, 1985

MEMORANDUM FOR G. A. KEYWORTH

FROM: MAURIE ROESCH *Very Respectfully, Maurie*

SUBJECT: Briefing Memorandum - Meeting with Dr. Richard Wagner, DOD; Mr. Donald Ofte, DOE; Capt. William Wright, NSC; Dr. Erich Bloch, NSF; Mr. Clarence J. Brown; DOC (Deputy Secretary); and Mr. Robert E. Howard, OMB, on Thursday 17 January 1985 at 11:00

PURPOSE: To finalize plans for the Nuclear Winter Research Program with the principals involved.

BACKGROUND: This meeting is the culmination of our ongoing efforts to establish a Nuclear Winter Research Program. The two key issues are the funding and management of the Program. The goal is to get a commitment of $2M from both DOD and DOE and $500K from NSF which is the funding level the science plan recommends. The bottom line is to get $1M apiece from DOD and DOE. The management approach we've been pursuing is making NSF be overall responsible and transferring the augmentation funds to NSF to carry out the research. Reluctance on the part of DOD (and somewhat on DOE and OMB) indicates that an alternative approach of establishing an executive committee, "EX COM," to oversee the research that is financially managed by DOD and DOE. The "EX COM" would be the civilian overseer and provide the creditability to the expanded program.

Participants: Dr. Richard Wagner, DOD
Mr. Donald Ofte, DOE
Capt. William Wright, NSC
Mr. Erich Bloch, NSF
Mr. Clarence J. Brown, DOC (Deputy Secretary)
Mr. Robert E. Howard, OMB

OSTP Staff - Maurie Roesch
Sam Wyman

Issue: Nuclear Winter Research Program (see attached agenda)

Nuclear Winter Meeting Agenda
17 January 1985

Requirement for Nuclear Winter Research Program

- Need Science Answers
- Necessary to Administration

What Constitutes Research Program

- DOD Effort
- DOE Effort
- Augmentation Based on NCPO Report
  - Modeling
  - Experimental Studies
  - Atmospheric Science
- "Enhanced Federal Research Program"

Funding Aspects

- Ongoing Efforts
  - DOD - $1.6M
  - DOE - $1.9M
  - $3.5M
- Recommended Augmentation $4.0 1 year

Management

- Executive Committee Guidance/Coordination
  - NSF, NOAA, DOD, DOE, etc.
- Programs (funds) Managed by Organizations

Announcement of Research Program

- Official Statement from White House - "Enhanced Federal Research Program"

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

FROM: S. Fred Singer
National Advisory Committee on Oceans & Atmosphere

DATED: January 25, 1985

SUBJECT:

Follow-up letter to a 1/31/84 letter regarding NACOA's review of the Federal research effort on the consequences on global climate of a nuclear war.
Encl: A review on the current activities and on the management of a Federal research program.

RECEIVED: February 4, 1985

ACTION BY: Executive Director/lsj

ACTION COPY TO:

~~Kornack~~ ← Change to ROESCH!
Annie Tillchange 2/6/85

INFORMATION COPIES TO:

Kornack
Lynch

SUSPENSE DATE:

February 25, 1985

REMARKS: FOR APPROPRIATE ACTION

Please indicate action taken below and include date of action.
If written correspondence was sent, please attach a copy.

( ) Written correspondence.

( ) Telecon.

( ) Action transferred to ____________________.

( ) No action necessary.

( ) Other

File Nucl. Winter

OSTP FORM 9

NATIONAL ADVISORY COMMITTEE ON OCEANS AND ATMOSPHERE
3300 Whitehaven Street, N.W.
Washington, DC 20235

January 25, 1985

Dr. G. A. Keyworth, II
Director, Office of Science
and Technology Policy
Old Executive Office Building
17th and Pennsylvania Ave., NW.
Washington, DC 20506

Dear Dr. Keyworth:

The National Advisory Committee on Oceans and Atmosphere (NACOA) has continued its review of the Federal research effort on the consequences on global climate of a nuclear war. As a follow-up to our January 31, 1984 letter to you on this issue, we are forwarding our review on the current activities and on the management of a Federal research program. We strongly emphasize the role the Office of Science and Technology Policy must play in such a research program to ensure its success.

I would be happy to meet with you to further discuss our views.

Sincerely,

S. Fred Singer

S. Fred Singer
Acting Chairman

Enclosure

NATIONAL ADVISORY COMMITTEE
ON
OCEANS AND ATMOSPHERE
3300 Whitehaven Street, N.W.
Washington, DC 20235

January 25, 1985

NACOA Statement on Nuclear Winter Research

In January 1984, the National Advisory Committee on Oceans and Atmosphere (NACOA) reviewed the Federal research effort on the global climate consequences of a nuclear war. Urban and forest fires, releasing large quantities of smoke, could blot out the sun over much of the globe for a long enough time to cause widespread subfreezing temperatures. NACOA concluded (January 31, 1984) that the scientific uncertainties surrounding the issue were so significant that no quantitative prediction was possible, and that more research was necessary to provide adequate data and to develop more appropriate models. Moreover, our review indicated that, while considerable work was going on in this country and overseas, little information was being exchanged on the actual research work being done. We recommended that for the time being no formal research coordinating group be established, but that the National Science Foundation be given responsibility for setting up an "information clearinghouse" to facilitate the exchange of information about the various research programs on nuclear winter.

We have followed this issue during the past year. The National Academy of Sciences/National Research Council (NAS/NRC) released its long-awaited report, "The Effects on the Atmosphere of a Major Nuclear Exchange," in December 1984. We attended the symposium on nuclear winter held in conjunction with the annual meeting of the American Meteorological Society in January 1985, and held an open meeting in which we heard several experts comment on the issue and especially on the recent NAS/NRC Report.

Our conclusion at this time, one year later, is that the uncertainties about the climate consequences of nuclear war still remain as numerous and as large as they were last year. In fact, recent research has uncovered even more uncertainties.

During 1984, the National Climate Program Office (NCPO), an interagency office housed in the National Ocean and Atmospheric Administration (NOAA), put together a research plan to deal with these uncertainties and to improve the assessment of the climate effects of a nuclear exchange. While the plan has not yet been released to the public, it is our understanding that this Interagency Research Plan developed under the guidance of NCPO, and reviewed by the Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP), calls for a significant increase in funding which has been at the level of $4 million during the past two years. NACOA believes that such an increase in the research effort can be justified on several grounds:

1) A better understanding of the behavior of the Earth's climate under unusual forcing conditions, such as might be produced not only by nuclear war but also by volcanic eruptions or meteorite impact.

2) A general improvement in our ability to model the atmosphere on several scales, including the mesoscale.

3) A contribution which will advance predictive work on other important problems, e.g., the climate consequences of the carbon dioxide increase or of the El Nino-Southern Oscillation (ENSO) phenomenon.

4) As an aid to developing a scientific basis for a nuclear conflict strategy, for arms limitation negotiations and similar foreign policy issues.

5) As a contribution to international cooperation, both scientific as well as political, providing also a better understanding of the possible effects of nuclear explosions on non-belligerent nations.

<u>Research Issues</u>

In order to achieve these objectives the research must be appropriately conducted. NACOA is concerned about the following issues:

1) <u>While nuclear winter is a topic of considerable scientific interest, there are other climate problems of great significance.</u> As an example, we mention ENSO, which only recently had a multi-billion dollar impact on the U.S. economy, and an even greater worldwide impact. We would wish for better predictability of the onset time and severity of the ENSO effect. Ideally, we would like to discover the trigger and ways of defusing them.

2) <u>The balance in the effort to improve general circulation models versus mesoscale models, or research to obtain better physical data to be used as inputs into these models</u>. It appears to us that an efficient research program must address directly the more difficult and uncertain parameters, and try to reduce their range

of uncertainty, before spending substantial resources on refining further the items that are well understood. The program should strengthen the weakest links in the chain. As examples we note some issues, which the NAS Report simply alludes to or neglects, that could play a vital role in predicting the climate effects of nuclear exchanges:

i) There are great differences in the estimates of the amount of smoke generated. For example, as brought out in the nuclear winter symposium on January 8, 1985, during the annual meeting of the American Meteorological Society, Cotton gives estimates of 15 percent of the NAS value for urban firestorms. At our meeting on January 9, 1985, we heard that Small and Bush give estimates of 10 percent of the NAS value for forest fires during the summer and of only 1 percent during the winter.

ii) The lifetime of smoke particles determines the duration of the climate perturbation. The NAS Report gives the halflife as short as 3 days and as long as several months (partly depending on the altitude of the smoke cloud in the troposphere). But the long halflives imply great atmospheric stability, which may not occur if the patchy smoke clouds lead to the creation of large horizontal temperature differences. Such instability may lead to a more rapid removal of smoke.

iii) The infrared opacity of the smoke cloud is usually assumed to be quite small; but it may not be, if and when the size distribution changes due to agglomorations, or if we start with superdense clouds. Under some circumstances it is held to be possible that the surface may warm instead of cool, leading to a "nuclear summer" scenario.

3) Finally, there is always the possibility that some important physical effect may have been overlooked. No efficient research program can afford to neglect this possibility. Some of the effects brought to our attention are:

   i) Electrostatic effects which might lead to rapid coagulation of smoke particles.

   ii) The generation of combustion gases in urban and forest fires which lead to infrared absorption and therefore to a greenhouse effect that offsets the postulated cooling effects, at least partially.

   iii) Chemical interactions between the smoke particles and reactive gases, such as ozone.

   iv) The "snow-out" effect which removes particles much more efficiently than rainout (i.e. capture by liquid drops).

Management

The management of a national program on nuclear winter is another issue we would like to address. There are several management options available. One of these is to let the National Climate Program Office (NCPO), an interagency office staffed and funded by several agencies, manage the program. These agencies include the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Department of Agriculture, Department of Energy, National Science Foundation (NSF), and Department of Defense. The one concern we have about this recommendation is that NOAA, the parent office of NCPO, is presently under great budgetary constraints. It therefore becomes necessary for the Director of OSTP to support a high priority for the program in budget negotiations with OMB.

Under the present National Climate Program, the various agencies get funds for their programs individually. NCPO provides guidance and coordinates the program. It would be better from a management standpoint if NCPO were to receive funds and then decide which agency programs to supplement to provide necessary balance. However, we believe this is an unrealistic expectation in view of the highly structured agency-OMB-Congress budget process. Moreover, long-range research planning by participant agencies would probably be made more difficult without some assurance of long-range support.

Some have indicated that NSF or NASA might well handle the management responsibilities, despite potential interagency problems. NSF is very capable in attracting the range of disciplines needed to address the uncertainty involved in the nuclear winter issue. And, NASA has scientific expertise in global habitability, comparative planetary climatology, and atmospheric research, with a great scientific resource in the Goddard Space Flight Center and other laboratories.

However the management issue is resolved, we stress the strong role that the Director of OSTP must play in generating the necessary priorities at high Administration levels to ensure balanced implementation of interagency nuclear winter research plans in the context of the total national climate research effort.