Foreword

Beginning in the summer of 1982, approximately 300 scientists from more than 30 countries and a wide range of disciplines, under the auspices of the International Council of Scientific Unions (ICSU), joined in a deliberative effort to appraise the state of knowledge of the possible environmental consequences of nuclear war. Although it has been recognized since the first nuclear explosions over Hiroshima and Nagasaki in 1945 that multiple detonations could cause massive destruction on people and their culture, the effects of life support systems of air, water, and soil and on organisms received relatively little emphasis in public discussion.

In the mid-1970s, attention began to turn to the whole range of consequences that might be expected to follow a large-scale exchange of nuclear weapons. This reflected a growing recognition of the immense number and yield of thermonuclear devices in the arsenals of the nuclear powers. The renewed activities also reflected concern with effects beyond the direct destruction of cities and human life. While interest still centered on the well-studied issues of direct blast, thermal effects, and radioactive fallout from ground and air bursts, scientists began to consider the large-scale consequences (e.g., from possible global depletion of ozone and from perturbations to the atmosphere). This concern was manifested in studies of information that had accumulated from the detonations at Hiroshima and Nagasaki and the subsequent series of nuclear tests, and with extrapolation of these data to situations in which the current nuclear arsenal might be used. Among the analyses were those by the U.S. Senate Committee on Foreign Relations (1975), the U.S. National Academy of Sciences (1975), the Office of Technology Assessment of the U.S. Congress (1979), the United Nations Environment Programme (1980), the United Nations (1980), and A. Katz (1982).

In 1982, several organizations and individual scientists launched new examinations of anticipated global effects, including those of the American Association for the Advancement of Science, the U.S. National Academy of Sciences, and the World Health Organization. Appraisals commissioned

by the Royal Swedish Academy of Sciences published in Ambio in April 1982 were particularly influential. A paper in that issue by P. Crutzen and J. Birks had been intended to deal with possible effects on the stratospheric ozone layer and regional air quality. While it did suggest that ozone changes might be of significance, the new suggestion was that smoke and soot generated by large urban and forest fires might cause reductions in light at the Earth's surface, inducing profound changes in weather. These suggestions stimulated a new round of research and appraisal around the world. Not since the 1960s, when agitation about the consequences of delayed radioactive fallout from bomb tests in the 1950s resulted in the signing in 1963 of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and Under Water, had as much thoughtful attention been marshalled by scientists and citizens.

At its General Assembly in Ottawa in June 1982, the Scientific Committee on Problems of the Environment (SCOPE)—one of the ten Scientific Committees of the International Council of Scientific Unions (ICSU)—concluded that "the risk of nuclear warfare overshadows all other hazards to humanity and its habitat" and asked its Executive Committee to consider what further action might be appropriate for SCOPE. In September 1982, the General Assembly of ICSU passed the following resolution:

> *Recognizing* the need for public understanding of the possible consequences of the nuclear arms race and the scientific competence that can be mobilized by ICSU to make an assessment of the biological, medical and physical effects of the large-scale use of nuclear weapons.
>
> *Urges* the Executive Board to appoint a special committee to study these effects and to prepare a report for wide dissemination that would be an unemotional, nonpolitical, authoritative and readily understandable statement of the effects of nuclear war, even a limited one, on human beings and on other parts of the biosphere.

Accordingly, a Steering Committee for the SCOPE–ENUWAR (Environmental Effects of Nuclear War) study was established, with responsibility to initiate the study requested by ICSU and to oversee the selection and recruitment of participants. A SCOPE–ENUWAR coordinating office was established at the University of Essex. From the outset it was agreed that the report would not deal explicitly with questions of public policy, but would focus on scientific knowledge of physical effects and biological response. International aspects of the direct medical effects have already been dealt with explicitly by the World Health Organization, and thus are not taken up in this study.

The SCOPE–ENUWAR process involved the active collaboration of scientists, bringing together the insights and skills of numerous disciplines. Preparatory workshops were held in London and Stockholm, and major

workshops were convened in New Delhi, Leningrad, Paris, Hiroshima and Tokyo, Delft, Toronto, Caracas, Melbourne, and finally at the University of Essex in an attempt to arrive at a consensus. Smaller groups gathered in a variety of other places, chiefly in connection with meetings of International Scientific Unions. Meanwhile, new findings were becoming available as noted in appropriate parts of this report, and further studies of likely effects were published (Turco et al., 1983; Ehrlich et al., 1983; Aleksandrov et al., 1983; Openshaw et al., 1983; World Health Organization, 1984; Covey et al., 1984; London and White, 1984; United Nations, 1984; Harwell, 1984; National Research Council, 1985; The Royal Society of Canada, 1985; The Royal Society of New Zealand, 1985).

Support for the project came from individual donations of time and from organizational grants. The Steering Committee is particularly grateful to those who committed the extensive time and effort to prepare the two volumes reporting these important scientific results. Barrie Pittock, Thomas Ackerman, Paul Crutzen, Michael MacCracken, Charles Shapiro, and Richard Turco have been responsible for preparation of the volume on physical and atmospheric effects. Mark Harwell, Thomas Hutchinson, Wendell Cropper, Jr., Christine Harwell, and Herbert Grover have played the major role in preparing the volume on ecological and agricultural effects. Both sets of authors were assisted by many colleagues, listed elsewhere in these volumes, who collaborated with them and generously gave of their time to participate in discussion, analysis, writing, and review. It was very much a cooperative, voluntary effort.

The collaboration among these scientists was made possible by financial contributions covering the costs of travel, assistance by post-doctoral fellows, workshop arrangements, and secretarial support. Initial grants making possible the planning of the project came from the SCOPE Executive Committee, using contributions from its 36 member academies of science, and from ICSU. The Royal Society of London hosted the preliminary and concluding workshops and funded the SCOPE–ENUWAR office. Other workshops were hosted by the Royal Swedish Academy of Sciences, the Indian National Science Academy, the Academy of Sciences of the U.S.S.R., la Maison de Chimie of France, the T.N.O. Institute of Applied Geosciences of the Netherlands, the Australian Academy of Science jointly with the Royal Society of New Zealand, the United Nations University and the Venezuelian Institute of Scientific Investigation. Major grants for travel and other expenses were provided by the Carnegie Corporation of New York, The General Service Foundation, The Andrew W. Mellon Foundation, the W. Alton Jones Foundation, and The Rockefeller Brothers Fund.

Recognizing that the issues dealt with in this report transcend science and technology and involve moral and ethical issues, SCOPE–ENUWAR co-sponsored an *ad hoc* meeting of scientists and scholars of ethics and

morality at the Rockefeller Conference and Study Centre, Bellagio, Italy, in November 1984. The conference took note of the preliminary findings that a significant nuclear exchange could lead to an unprecedented climatic perturbation, killing crops and threatening countries distant from the target areas with mass starvation. A statement called for the development of more effective cooperative efforts for dealing with common interests and problems and urged collaboration between science and religion in the "... quest for a just and peaceful world" (*Bulletin of Atomic Scientists,* April 1985, pp. 49–50).

The Steering Committee has elected to publish the results of the SCOPE–ENUWAR studies in two volumes. The first volume deals with the physical aspects of the environmental impact of a nuclear war. The second volume addresses the biological impacts, principally the ecological and agricultural effects. As further background for the reader, each volume includes the Executive Summary of the companion volume, with its explanation of findings and research recommendations, as an appendix. In addition, the Committee has commissioned a less technical account intended for wide international distribution to fulfill the ICSU request for a "... readily understandable statement of the effects of nuclear war." It is anticipated that this third volume will be translated into several languages.

The two volumes present a general consensus among the scientists concerned with the study. There is not unanimity on all points, but a concentrated effort has been made to describe those remaining points at issue. These unresolved issues suggest research that should be pursued in order to reduce the present degree of uncertainty. The report should be regarded as the first attempt by an international scientific group to bring together what is known, and what must still be learned, about the possible global environmental effects of nuclear war. It should not be the last. It should be taken as a point of departure rather than as a completed investigation.

A recurring issue in the recent discussion of the long-term, global environmental consequences of a nuclear war has been the degree to which uncertainties preclude a conclusion regarding the plausibility of severe effects. These uncertainties are of two kinds: (1) those resulting from the nature of human actions (e.g., number of weapons, yields, targets, height of detonation, time of conflict, accidents resulting from technological failure, societal response to an outbreak of hostilities); and (2) those resulting from an incomplete state of knowledge concerning physical and biological processes and the limited ability to simulate them faithfully by mathematical models.

Clearly, the specific circumstances of a large-scale nuclear war cannot be predicted with confidence, and the history of past wars reminds us that even carefully planned military actions rarely develop as expected. Thus, detailed scenarios of possible nuclear exchanges must remain highly specu-

lative. Wherever practicable, as a basis for estimating environmental effects, the report considers specific ranges of physical parameters and responses—such as a given mass of smoke injected into the atmosphere, or the occurrence of a freezing episode—that are consistent with the detailed technical analyses, yet are not peculiar to any specific war scenario. In the absence of a nuclear war, many of the specific effects will continue to be in doubt.

Although uncertainties associated with knowledge of physical and biological processes could be substantially reduced by further research, some of these uncertainties are bound to remain large for many years, as explained in the report.

The report does not attempt to provide a single estimate of the likely consequences for humans and their societies of the physical and biological changes projected to be possible after a nuclear war. One reason is that the combinations of possible environmental perturbations are so large and the varieties of environmental and human systems are so numerous and complex that it would be an impossible task to look with detail into all of the ways in which those perturbations might result in an impact. Further, the environmental disruptions and dislocations from nuclear war would be of a magnitude for which there is no precedent. Our present interdependent, highly organized world has never experienced anything approaching the annihilation of people, structures, resources, and disruption of communications that would accompany a major exchange, even if severe climatic and environmental disturbances were not to follow it. The latter could aggravate the consequences profoundly. How the environmental perturbations which would occur at unprecedented scales and intensities would affect the functioning of human society is a highly uncertain subject requiring concerted research and evaluation. Nevertheless, whatever the uncertainties, there can be no doubt that there is a considerable probability a major nuclear war could gravely disrupt the global environment and world society. All possible effects do not have the same probability of occurrence. Sharpening these probabilities is a matter for a continuing research agenda.

The bases for these statements are to be found in the report, along with references to supporting or relevant information. From them we draw the following general conclusions:

1. Multiple nuclear detonations would result in considerable direct physical effects from blast, thermal radiation, and local fallout. The latter would be particularly important if substantial numbers of surface bursts were to occur since lethal levels of radiation from local fallout would extend hundreds of kilometers downwind of detonations.

2. There is substantial reason to believe that a major nuclear war could lead to large-scale climatic perturbations involving drastic reductions in light

levels and temperatures over large regions within days and changes in precipitation patterns for periods of days, weeks, months, or longer. Episodes of short term, sharply depressed temperatures could also produce serious impacts—particularly if they occurred during critical periods within the growing season. There is no reason to assert confidently that there would be no effects of this character and, despite uncertainties in our understanding, it would be a grave error to ignore these potential environmental effects. Any consideration of a post-nuclear-war world would have to consider the consequences of the *totality* of physical effects. The biological effects then follow.

3. The systems that currently support the vast majority of humans on Earth (specifically, agricultural production and distribution systems) are exceedingly vulnerable to the types of perturbations associated with climatic effects and societal disruptions. Should those systems be disrupted on a regional or global scale, large numbers of human fatalities associated with insufficient food supplies would be inevitable. Damage to the food distribution and agricultural infrastructure alone, (i.e., without any climatic perturbations) would put a large portion of the Earth's population in jeopardy of a drastic reduction in food availability.

4. Other indirect effects from nuclear war could individually and in combination be serious. These include disruptions of communications, power distribution, and societal systems on an unprecedented scale. In addition, potential physical effects include reduction in stratospheric ozone and, after any smoke had cleared, associated enhancement of ultraviolet radiation; significant global-scale radioactive fallout; and localized areas of toxic levels of air and water pollution.

5. Therefore, the indirect effects on populations of a large-scale nuclear war, particularly the climatic effects caused by smoke, could be potentially more consequential globally than the direct effects, and *the risks of unprecedented consequences are great for noncombatant and combatant countries alike.*

A new perspective on the possible consequences of nuclear war that takes into account these findings is clearly indicated. In these circumstances, it would be prudent for the world scientific community to continue research on the entire range of possible effects, with close interaction between biologists and physical scientists. It would be appropriate for an international group of scientists to reappraise those findings periodically and to report its appraisal to governments and citizen groups. Increased attention is urgently required to develop a better understanding of potential societal responses to nuclear war in order to frame new global perspectives on the large-scale,

environmental consequences. This task is a special challenge to social scientists.

In arriving at these conclusions, we have been moderate in several respects. We have tried to state and examine all challenges to theories about environmental effects of nuclear war, to minimize speculative positions and to factor valid criticisms into discussions and conclusions. Uncertainties in the projections could either reduce or enhance the estimated effects in specific cases. Nevertheless, as representatives of the world scientific community drawn together in this study, we conclude that many of the serious global environmental effects are sufficiently probable to require widespread concern. Because of the possibility of a tragedy of an unprecedented dimension, any disposition to minimize or ignore the widespread environmental effects of a nuclear war would be a fundamental disservice to the future of global civilization.

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