Scientists Describe "Nuclear Winter"

Even a limited strike would produce dust clouds creating dire, long-term disruption of global climate and biota

First it was physicians telling the world that, in the event of a nuclear attack, there could be no adequate medical care for survivors. Now biologists and atmospheric physicists, bolstered by new calculations, say that the ecosystem itself would be gravely and permanently damaged by a full-scale nuclear war.

The findings were presented at a 2-day conference, "The World After Nuclear War," held in Washington at the end of October. The central figures were Cornell astronomer Carl Sagan and biologist Paul Ehrlich of Stanford.

Although policy questions were carefully avoided, there were at least two implications. One was that a single nuclear counterforce strike, even if unilateral, would be suicidal to the nation launching it. The other was that no one in the world would be unaffected by such an event. Some Third World nations would be compelled to abandon the idea that it would not be all bad to have the two great powers finish each other off.

Sagan, describing climatological effects, said things would be a lot worse than indicated by any prior calculations, including a 1975 report by the National Academy of Sciences. He and his colleagues, in a paper known as TTAPS*, evaluated numerous scenarios of attacks ranging from 100 megatons (the equivalent of 8000 Hiroshimas) to 10,000 megatons. In the 5000 megaton case—approximately that required for a preemptive counterforce strike—they predicted that clouds of dust would create a pall of darkness with sunlight about 5 percent of normal in the mid-latitudes of the Northern Hemisphere. Temperatures would drop precipitously to as low as −23°C and remain subfreezing for months. Radioactivity would be more lethal than previously estimated, with up to 250 rads—half the human lethal dose—covering 30 percent of the area. The atmosphere would be further polluted by poisonous fumes emanating from urban fires. Depletion of ozone by oxides of nitrogen would raise the level of ultraviolet radiation, damaging immune systems and causing blindness.

One of the major findings was that effects would not be confined to the Northern Hemisphere. Disturbances in global circulation patterns would result in the interhemispheric transport of hundreds of tons of nuclear debris, resulting in light and temperature reductions as well as radioactive fallout in the Southern Hemisphere as well.

"Perhaps the most striking and unexpected consequence" of the studies, said Sagan, is that even a small war could have devastating climatic effects if cities are targeted. If bombs totaling 100 megatons—0.8 percent of the combined strategic arsenals—were dropped on 100 cities, the smoke from firestorms consuming large stores of combustible materials would be pumped into the stratosphere, resulting in months of gloom and subfreezing temperatures. The threshold for dire long-term environmental effects, said Sagan, "is surprisingly low."

Ehrlich supplemented this picture with an accounting of biological consequences of a 5000-megaton exchange. Depicting most survivors in the Northern Hemisphere "starving to death in a dark, smoggy world," he said that the cooling alone would be "the worst catastrophe mankind has experienced." Livestock would die from the effects of radiation and cold; photosynthesis by plants would cease. Thick ice would cover bodies of standing water. Forest fires would rage through dead trees. Agriculture would be destroyed if the war occurred just before or during the growing season. Plagues of insect pests—the animal life best equipped to survive the disaster—would damage food and spread disease. Starvation would also afflict those in the Southern Hemisphere, not only in areas dependent on food imports, but because cold air would decimate delicate tropical growth and result in mass species extinction.

The conference was a result of a year of careful planning, and represented a remarkable consensus among more than 100 scientists involved. Sagan said it all began in 1971 when Mariner 9 arrived at Mars during a dust storm which created a significant warming of the martian atmosphere and took months to settle. He also observed that the worldwide effects of even a minimal lowering of temperature was demonstrated in 1815 when particulates from the eruption of a volcano in Indonesia lowered global temperatures by 1°C, resulting in "the year without a summer" in 1816.

More recently, scientists were inspired by a 1982 issue of the Swedish

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Aftermath of the blast

Nuclear explosion near city would ignite stores of oil, gas, and chemicals, creating toxic pall and destroying aquatic life.

*Named after the authors: R. P. Turco of Marina Del Ray, California; O. B. Toon, T. P. Ackerman, and J. B. Pollack of NASA Ames Research Center; and Sagan. The paper will soon be published in *Science* along with a 20-author paper on the biological consequences.

journal *Ambio* which contained new estimates on the climatic effects of nuclear war by Paul J. Crutzen of the Max Planck Institute. This led to the TTAPS effort, which was reviewed by scientists from around the world at a meeting in Cambridge, Massachusetts, last spring.

Russian scientists, who have been doing their own calculations, are also believed to be in fundamental agreement. This was dramatically illustrated at the meeting by a satellite hookup which showed Ehrlich and Sagan exchanging conclusions with four high-ranking members of the Soviet Academy of Sciences.

To what degree, if any, might this new perspective on nuclear war affect the deliberations of strategic planners? The overall impression from the conference is that nuclear war on any scale would be worse than anything it was meant to avoid. As keynote speaker Donald Kennedy of Stanford said, "It is no longer acceptable to think of sequelae in minutes, days, or even months. What biologists are telling us today is that the proper time scale is years."

Science asked several government spokesmen for their reactions to the scientists' findings. The general response is summed up by a Department of Defense official who said, "So what?" The government already knows nuclear war would be absolutely devastating, and the real question is how to prevent it. A State Department official was asked what the meaning of deterrence—that is, the threat of using a weapon—would be if its actual use would be suicidal. He said it's still a deterrent if the Russians believe we would use it. He added that if the Russians believed that we believed a first strike would be suicidal, they might relax a little and not put so much into their own first strike capabilities.

The only agency that seems to have been affected by the findings is the Federal Emergency Management Agency. A FEMA spokesman said that while they were unmoved by the physicians' message, which they thought "exaggerated," they were worried about problems of food supply, which appear to be "even more profound than we had anticipated." He said the problems of cold and dark were for the long-term planners and not part of FEMA's primary responsibility. In keeping with FEMA's job, which is to act as though every catastrophe is manageable, the spokesman pointed out that even in the worst case, only 5 percent of the nation's land area would be blown up; that 75 percent of what would be needed for a nuclear attack was already done for other assorted disasters; and that the United States has a much better transportation system than the Russians for pre-attack evacuation.

A National Academy of Sciences committee headed by George Carrier of Harvard University is currently winding up a 9-month study of the long-term atmospheric effects of nuclear war, commissioned by the Defense Nuclear Agency, which Sagan said is substantially in accord with his colleagues' findings.

Whether or not the government sees the information as significant, there is definitely an accelerating concern among scientists. The International Council of Scientific Unions is starting a 2-year study for which a series of meetings, starting this month, is being held in Stockholm. A scientific symposium is also planned in Tokyo.

It would appear that growing numbers are coming to agree with biologist Thomas Eisner of Cornell University who said at the meeting: "I no longer feel that a single biologist in this country or the world can be exempt from becoming involved in these issues."

—CONSTANCE HOLDEN

EPA Revs Up to Regulate Biotechnology

The agency's general counsel has already ruled that bacteria designed to prevent frost damage to plants are pesticides

With the likelihood that biotechnology research will soon be bearing commercial fruit, the Environmental Protection Agency (EPA) is gearing up to regulate some potentially important products of genetic engineering. Its entry into an already controversial area is creating anxiety in the biotechnology industry, and its authority is likely to be challenged in court.

EPA is moving to fill a gap in the federal government's power to monitor biotechnology. Currently, the recombinant DNA advisory committee at the National Institutes of Health (NIH) is the principal oversight group for genetic engineering research. It administers safety guidelines laid down by NIH. But the guidelines are binding only for federally funded researchers and do not address broader issues concerning the environmental impact or the health risks associated with commercial activities. Compliance by companies is voluntary. EPA believes it has the power to regulate industry and is even preparing to exercise some authority over the field-testing of pesticides produced by genetic engineering techniques. This could potentially put it in the business of regulating research.

Exactly how the agency will go about regulating biotechnology is not yet clear. EPA officials say the policy is still being worked out. During the past several months, they have been meeting with representatives of biotechnology companies to exchange ideas and, so far, both sides describe the discussion as open and cordial. By early next year, EPA plans to publish in the *Federal Register* a list of its concerns about genetically modified organisms and their impact on the environment. The list will be circulated to solicit public comments on the agency's potential regulatory role.

Donald R. Clay, acting assistant administrator of the office of pesticides and toxic substances, argues that EPA has clear authority to regulate genetically engineered pesticides under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). He also believes the agency can regulate some other applications of biotechnology, such as the use of genetically modified organisms to break down oil slicks, under the Toxic Substances Control Act (TSCA). But this is a controversial interpretation of the statute. "Companies have already promised that they'll sue me if I regulate under TSCA," Clay said in an interview.

EPA expects that applications to manufacture genetically engineered microbial pesticides will be filed in the next year or two. To meet requirements of FIFRA, companies will have to submit extensive test data to demonstrate that the organisms will not pose unacceptable environmental and health hazards.

According to Frederick Betz, a biologist and EPA policy analyst, the poten-