turbulence surrounding the agreement, U.S. companies seem to be sanguine about prospects. As one industry source put it, "We feel that the problem's going to be solved." Until a nuclear cooperation agreement goes into effect, the NNPA prohibits the export of U.S. nuclear hardware and some kinds of technical information. Industry officials say that they can live with a further delay if they are permitted to provide the kind of information that will enable them to be active in preliminary negotiations. What is involved is known as "software," which denotes the sort of proprietary or unpublished technical information which, though not covered by the NNPA, is not available to the public. To give such information to the Chinese would require what in nuclear export parlance is called an "810 authorization," after the section of federal regulations which the Department of Energy (DOE) has the main responsibility for administering.

Under the software heading, companies might, for example, want to provide the Chinese information on such things as safety features, operating temperatures, or even the general design of a proposed plant. French and German vendors have apparently furnished the Chinese such software in ample quantities and U.S. companies are eager to do likewise. At present, a number of applications to DOE for authorizations to provide software to China are caught in what one observer called a "de facto freeze." He said that middle-level federal officials who handle the authorizations are aware of the current sensitivity of China–U.S. nuclear negotiations and the inevitable bureaucratic reaction in such cases is no action. U.S. companies immediate hope, therefore, is that the Administration will move to thaw the transfer of software technology.

The transfer of nuclear technology is a central concern on Capitol Hill. The potential opposition in Congress to the cooperation agreement comes mainly from a mixed party of liberal Democrats in the House and Senate and conservative Republicans in the Senate. The Democrats seek to hold the Administration rigorously to the letter and spirit of the NNPA in all matters affecting nuclear proliferation. In the case of China, the Republicans are highly skeptical about transfer of nuclear technology that would give an unwarranted military or economic boost to a Communist government.

Until the text is actually sent to Congress it will not be possible to tell whether even resolving the problem of China's Pakistan connection will clear the way for the agreement. Another possible sticking point is on the matter of U.S. consent rights should the Chinese wish to reprocess nuclear fuel. Reprocessing yields plutonium that can be readily converted to military purposes. Disagreement on consent rights is said to have persisted in negotiations.

When Congress will get a look at the text remains uncertain. At press time for *Science*, State Department sources were still saying that no decision had been made on the timing. And Speakes in his 22 June remarks allowed that the chances of the agreement reaching Congress this year "seem somewhat doubtful."—JOHN WALSH

Nuclear Winter Attracts Additional Scrutiny

Prodded by Congress, the Pentagon begins to examine the impact of soot on nuclear strategy

Last October, in a widely publicized press conference, a group of leading scientists presented an unusually harrowing portrait of the aftermath of a superpower conflict. At its heart was the novel theory that even a limited nuclear war will generate enough soot and dust to shield a substantial portion of the earth from sunlight, perhaps for months, potentially causing the extinction of numerous plants and animals, including man.

Although this announcement generated little government reaction at the time, it has since given rise to a host of official studies and a promise of additional research funds. It has also galvanized the Congress to demand what may effectively be the first formal environmental impact statement on the consequences of a nuclear holocaust. Similar provisions in the House and Senate versions of the latest defense bill order the Pentagon to produce a comprehensive public report by March 1985 on the latest scientific findings and their implications for nuclear weapons planning, procurement, deployment, targeting, and command, as well as for arms control and civil defense.

Congress approved the requirement after the Natural Resources Defense Council (NRDC), an environmental group in Washington, discovered that the government had by and large ignored the "nuclear winter" scenario depicted by the atmospheric and biological scientists last year. According to the scenario, an exchange of weapons with a total explosive force of 5000 megatons would set massive forest fires and generate voracious firestorms in virtually every major city, creating enough dust and soot to plunge the Northern Hemisphere into a lengthy period of icy darkness, with potentially cataclysmic biological consequences.* A climatic model suggested that a smaller exchange of 100 megatons, detonated in large cities, would also lead to a nuclear winter.

Despite the obvious relevance of these scenarios to military planning and civil defense, they were until recently unanticipated by the community of military officials and analysts who set U.S. nuclear strategy. "It really is a new thing," says Charles Zraket, chief operating officer for the MITRE Corporation, one of the Pentagon's principal contractors for nuclear command, control, and communications. "The Pentagon had either been totally unaware of this phenomenon, or it simply failed to consider it during planning. We at MITRE certainly never took it into account; I can say that first-hand." This assessment is corroborated by Richard DeLauer, the Pentagon's top scientist. "We should all perhaps be a little concerned that we did not recognize a little sooner the importance of the smoke to our calculation of nuclear effects," he told Carl Sagan, one of the participants in the nuclear winter study, in a recent letter.

Even after the study was published, few agencies exhibited interest in its implications for their work. "We have not done any work or studies relating to

*The theory is explained in detail in an article by R. P. Turco, O. B. Toon, T. P. Ackerman, J. B. Pollack, and Carl Sagan in the 23 December 1983 issue of *Science*, pages 1283–1292.

the atmospheric or climatic effects of nuclear war," said an official of the Federal Emergency Management Agency (FEMA), the nation's civil defense headquarters, in a letter to NRDC on 14 March. Similar replies were received from the Arms Control and Disarmament Agency, the Air Force, the Strategic Air Command, and the North American Air Defense Command.

A notable exception was the U.S. Navy. In an internal memo dated 7 November, Vice Admiral J. A. Lyons, deputy chief of naval operations, wrote that "in the long term, the [results] deserve serious study to see what, if any, changes in U.S. targeting policy are required. In the short term, however, [the] implications are primarily political. I anticipate that the Soviets will make extensive use of these results, especially in Europe, to demonstrate the dangers of the arms race." Lyons proposed that the Navy conduct a careful nuclear targeting study, while simultaneously vigorously rebutting any Soviet propaganda.

Another notable exception was the Department of Energy, which recently committed $3 million for a 2-year study of the nuclear winter phenomenon to be jointly carried out by the weapons laboratories at Livermore and Los Alamos. "At the moment, the calculations are highly simplified, and there are numerous uncertainties," says Michael MacCracken, an atmospheric scientist at Livermore. He notes in particular the need to improve models of climatic change wrought by a nuclear war. The initial nuclear winter presentation, for example, stemmed from a one-dimensional climatic model, which generally neglected local and seasonal atmospheric variations, as well as the moderating impact of the oceans on cooling over land. A subsequent analysis took these factors into account but neglected the effects of dust, the consequences of smoke movement from one locale to another, and the impact of aerosol scattering (*Nature*, 1 March, p. 21). All of the authors acknowledged a pressing need for more realistic models.

A substantial new research effort is also under consideration at the climate office of the National Oceanic and Atmospheric Administration. Alan Hecht, the office's director, is preparing a 5-year research plan that may call for annual expenditures as high as $10 million. In addition to improving climate models, he says, "we want to determine the amount of material that a nuclear explosion sets afire, the amount of smoke generated by the fire, and the proportion lofted high enough to block out sunlight. To do this, we need some large fire experiments—accurate measurements from controlled forest burns, uncontrolled brush fires, or large urban fires."

As a part of NOAA's effort, the Defense Nuclear Agency is planning to increase its funding for fire research from roughly $600,000 to $1 million annually. Prior to the nuclear winter revelation, the agency had essentially overlooked the climatic consequences of massive fires, concentrating instead on how they might be created. This will soon change, according to Marvin Atkins, the agency's deputy director for science and technology. The overall government plan will be submitted to the White House for approval in September.

The Pentagon, which was largely caught unawares by the "nuclear winter" presentation, has been critical of the assumptions in the climatic models developed to date. As MacCracken says, "most of these scenarios are simply not very convincing to people who work in this area." Richard DeLauer, for example, objects to the depiction of scenarios involving the deliberate targeting of cities, which he describes as neither "credible" nor "moral." He and others correctly note that nuclear weapons are today aimed primarily at nuclear weapons and associated military targets. But Sagan replies that many military targets are near large population centers, that some key industries in urban centers are also targeted, and that smaller nuclear powers, such as France, primarily target cities. The present *Force de Frappe* "may itself be sufficient to trigger a global Nuclear Winter," Sagan recently wrote in *Foreign Affairs*.

Another Pentagon argument is that any plausible conflict would exploit less than 5000 to 6500 megatons, the primary estimate used in both the initial nuclear

Soviets Offer Little Help

When Vice Admiral John Lyons, the deputy chief of naval operations, drafted a memo on the "nuclear winter" press conference last October, he noted that Dr. Vladimir Alexandrov of the Soviet Academy of Sciences had presented an extremely advanced climate model, representing "a quantum jump in detail over the work of [Carl] Sagan and his colleagues." It appears that "considerable scientific and computational resources have been devoted to this problem by Soviet academicians," Lyons wrote.

Actually, says Richard Turco, a coauthor of the original "nuclear winter" paper in *Science*, the Alexandrov presentation was "a very weak piece of work, crude and seriously flawed." Turco, an atmospheric scientist with R&D Associates in Marina del Rey, says that the sophisticated Soviet climate model is actually "a primitive rendition of an obsolete U.S. model." Starley Thompson, a scientist at the National Center for Atmospheric Research who coauthored a second major article on nuclear winter, agrees. "Alexandrov's model, which was developed in the United States in the early 1970's, contains a number of defects, and one of his major conclusions is apparently incorrect," Thompson says. In truth, Turco told *Science*, "the Soviets have contributed little to the international 'nuclear winter' study effort thus far, and quite a few people are extremely disappointed."

Turco explains that he and 20 other Western scientists were highly optimistic about potential Soviet contributions when they went to a recent conference in Leningrad sponsored by the International Committee of Scientific Unions. In particular, they hoped to see data on Siberian forest fires, as well as unclassified data on Soviet atmospheric bomb tests, of the type freely available to scientific researchers in the United States. They also hoped to learn the details of a much-discussed Soviet fire experiment. "Instead, we sort of got a rehash of Alexandrov's work. Not only that, but there was no evidence of experimental planning," Turco says.

Turco now suspects either that the Soviets are incapable of contributing meaningful scientific information, or that their goal is to manipulate the issue for potential political gain. How the latter might be accomplished is unclear, as nuclear winter is clearly a global, not a uniquely Western, threat. Recently, the Defense Nuclear Agency decided to take a detailed look at Soviet views of the nuclear winter phenomenon, as part of an ongoing analysis of Soviet research on nuclear effects. But the analysis, to be written by Science Applications Inc., will be classified.—**R.J.S.**

winter presentation and a forthcoming report by the National Academy of Sciences. Most experts agree that this dispute can only be resolved by experience. A final and clearly legitimate complaint is that all of the models developed thus far assume no geographical overlap between nuclear detonations. In practice, each side would explode at least two and probably more warheads on a given target, just for insurance. This analytical defect may be eliminated in forthcoming studies by Livermore. The entire issue is also scheduled for a thorough review by a newly formed Defense Science Board nuclear winter task force.

Zraket believes that the discovery of nuclear winter has a number of important implications beyond its potential use for propaganda and nuclear targeting revisions. "Assuming that it withstands additional scrutiny, nuclear winter suggests that it is not possible to build a command, control and communications network for a protracted war involving large numbers of nuclear weapons—as some have urged. If you feel—as some do—that a nuclear war can successfully be fought for months, then this should dissuade you. It will reinforce the existing belief that a first strike makes no sense, because it may be suicidal. And it renders the notion of a real civil defense program, which is already in disrepute, even more disreputable."

Zraket, of course, does not have his finger on the nuclear button. The extent to which these views are shared by those who do should become evident in March 1985, with the release of the report that Congress has now ordered.

—R. JEFFREY SMITH

Static at EPA Over Broadcast Transmitters

Some officials push for tough restrictions, contending low-level electromagnetic fields pose potential health risks, but others are not convinced

For years, radio and television transmitting towers have sprouted up across the nation, virtually unrestricted in their power to broadcast the latest newscast or ball game. But now the Environmental Protection Agency (EPA) is considering a proposal to limit the power of these transmitters. The proposed curbs stem from concern by some EPA authorities that exposure to the radiation created by the towers may pose health risks to humans.

For now, the proposal is on hold because of vexing scientific and policy questions. The potential hazards of low-level, nonionizing radiation to humans are the subject of intense debate among researchers. At present, EPA officials are at odds with each other about whether to regulate at all, and, if so, at what levels of emission.

The broadcasting industry is watching the regulatory developments with interest. If tough restrictions are adopted, compliance could cost broadcasting companies millions of dollars as antennas are redesigned or relocated. David E. Jones, Jr., director of EPA's office of radiation programs, estimates that as many as 1000 of the nation's 4500 frequency-modulation (FM) towers might be affected by the proposed limitations, especially those in urban areas.

Recent animal studies have shown that weak electromagnetic fields can produce subtle changes in the nervous and immune systems, in blood, and in behavior. But the medical significance of these changes to humans is hotly disputed because of uncertainty about the relevance of the animal models to humans, and the dearth of epidemiological data.

Sources of nonionizing radiation range from low-frequency, low-power appliances, such as personal radios, to high-frequency, high-powered equipment, such as microwave radar systems. Since radiation diminishes dramatically with distance from a source, most people are exposed to amounts of nonionizing radiation that are considered harmless. But individuals who live or work within a radius of about 150 feet of the 1000 FM transmission towers believed to be trouble spots are of particular concern, according to Richard A. Tell, chief of EPA's nonionizing radiation branch.

Industry currently follows voluntary guidelines for emission and exposure set in 1982 by the American National Standards Institute. This spring, however, the National Council on Radiation Protection and Measurements, a private corporation chartered by Congress, approved an exposure guideline for the general population that is five times more stringent than the institute's guidelines. A few states and local communities have approved or are considering regulations that are more strict than the voluntary guideline.

This has led to a regulatory patchwork and, as a result, the broadcasting industry has been urging the federal government to develop a national standard. The industry obviously did not expect the EPA staff to propose such a tough plan.

The current voluntary guideline recommends an emission limit of 1000 microwatts per square centimeter ($\mu W/cm^2$) and an exposure level of 0.4 watt per kilogram (W/kg). Exposure at 4 W/kg is considered adverse. According to EPA documents, the agency's office of radiation programs has recommended emission restrictions ten times more stringent than the voluntary guidelines and would limit emissions from FM towers to 100 $\mu W/cm^2$ and exposure to 0.04 watt per kilogram (W/kg). This is more stringent than any existing state or local standard.

The radiation office based its proposal on an extensive survey of the scientific literature. The findings, recently released in a 500-page report, were judged by an EPA science advisory board comprised of outside scientists to be a fair and adequate review of published studies and a basis to develop federal regulations. The report asserts that, based on recent animal experiments, biological effects can occur at an absorption level lower than 4 W/kg, the threshold at which adverse effects previously have been observed. According to the report, several findings were significant:

- Tests showed that absorption of radio-frequency radiation of less than 4 W/kg caused a rise in animal body temperature. The elevation was associated with alterations in the blood, immune, and endocrine systems. In guinea pigs and rabbits, low absorption levels were linked to an increase in white blood cells. In several studies, rats tested at similar levels showed increases and decreases in various hormone concentrations on the blood.
- Data from one laboratory "raised the possibility" that radio-frequency radiation at 2 to 3 W/kg can act as a cancer promoter or cocarcinogen in mice, the EPA report says. The findings, however,