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Annals of Radiation By Paul Brodeur
The Hazards of Electromagnetic Fields—II: Something Is Happening
Cape Cod’s PAVE PAWS radar and the nation’s power lines quietly bathe communities in low-level fields, as evidence of biological risk mounts.

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AFTER twenty-three years at the University of California, Los Angeles, Dr. W. Ross Adey left in the spring of 1977 to become associate chief of staff for research and development at the Jerry L. Pettis Memorial Veterans’ Hospital, in Loma Linda, some eighty miles east of Los Angeles, and professor of physiology at the Loma Linda University School of Medicine. By that time, he and Suzanne M. Bawin, a neurophysiologist, had reported extensively on studies they had carried out showing that weak extra-low-frequency (ELF) fields of between one and a hundred hertz, and also ELF-modulated very-high-frequency (VHF) fields of 147 MHz, could alter the outflow of calcium ions from the isolated brain tissue of chickens, as well as from the brain tissue of living cats. With financial support from the Food and Drug Administration’s Bureau of Radiological Health, the two colleagues, along with the experimental psychologist Rochelle J. Gavalas-Medici, had also demonstrated that the same chemical changes could be effected by exposing the brain tissue of living cats to low-intensity microwave fields of 450 MHz, provided that the carrier frequency was modulated at the ELF frequency of sixteen hertz.

As it happened, this was extremely close to the frequency of a new type of radar that the Air Force was planning to install at the Massachusetts Military Reservation, on Upper Cape Cod—the Otis Air National Guard Base is part of the reservation—and at Beale Air Force Base, some thirty-five miles north of Sacramento, California. The new radar was called PAVE PAWS—an acronym for Precision Acquisition of Vehicle Entry Phased Array Warning System—and, unlike conventional radar, with its rotating antenna, PAVE PAWS was equipped with an array of more than ten thousand solid-state components, called radiating elements, which could be individually controlled by computers to form a single beam that, in turn, could be steered electronically and very rapidly in a large number of directions over a two-hundred-and-forty-degree field. The PAVE PAWS radar had been designed to detect sea-launched ballistic missiles; it was sufficiently powerful to resolve an object the size of a basketball at a distance of more than twelve hundred miles, and it operated at a carrier frequency of between 420 and 450 MHz, with a pulse-repetition rate of 18.5 hertz—very close to the sixteen-hertz modulation frequency of the 450 MHz radiation that Adey, Bawin, and Gavalas-Medici had used to change the brain chemistry of living cats.

In March of 1976, the Air Force had issued a two-hundred-and-fifty-page environmental assessment, which, except for a brief mention of the fact that emissions from PAVE PAWS might cause cardiac pacemakers to skip a beat or two, ignored the possibility that radiation emanating from PAVE PAWS might prove hazardous to human health. The Air Force assessment was, however, full of assurances that the radar would not harm the white-tailed

deer, the wood duck, or the Wilson’s petrel; indeed, the document appeared to have been written with the notion that the environment was something inhabited exclusively by birds and animals. An assertion by the chief of the Air Force’s Environmental Policy and Assessment Branch that PAVE PAWS would not have “a significant impact on the quality of human environment” furnished the Air Force with a convenient excuse for not preparing an environmental-impact statement, which, unlike an environmental assessment, must be submitted to the Environmental Protection Agency, circulated to federal agencies and the public for comment, and be rewritten to respond to those comments. In this way, the Air Force hoped, it could avoid holding public hearings on PAVE PAWS and having to answer questions about the radar.

During 1976, the Raytheon Company, the prime contractor for the PAVE PAWS system, was hard at work making the radar a reality on Cape Cod. As a result, long before Cape Codders became aware that radiation from PAVE PAWS might prove hazardous, the radar edifice—a hundred-and-five-foot-tall truncated pyramid of reinforced concrete, which had been designed to withstand a nuclear blast—loomed above the horizon only thirty-five hundred feet south of the mid-Cape highway. By contrast, in California, where construction of PAVE PAWS did not begin until April of 1977, the Air Force was compelled to answer questions about the safety of the radar as a result of local newspaper articles that disputed some of the claims made in the environmental assessment.

The manner in which the Air Force responded to these inquiries clearly revealed how anxious it was to allay any public fears about PAVE PAWS. On April 22, 1977, Lieutenant Colonel Paul T. McEachern, the director of the PAVE PAWS program, told a group of Californians that the radar would pose no health hazard. He also assured them that since the Air Force would have had over a year’s experience with PAVE PAWS on Cape Cod by the time the California installation was completed, “we’ll have a fairly good idea of the effects on the environment before we even turn it on here.”

Cape Codders were taken aback when they learned about the new radar. They soon communicated their concern to their representative, Gerry E. Studds, a Democrat from the Twelfth District of Massachusetts. On January 9, 1978, Studds asked the Air Force to document the research it had used to determine that long-term exposure to low-level microwave radiation would not endanger human health, and declared, “The burden of proof clearly lies on their shoulders.”

As things turned out, the burden proved somewhat heavy for John C. Mitchell, the chief of the Radiation Sciences Division of the Air Force’s School of Aerospace Medicine, in San Antonio, Texas, who represented the surgeon general of the Air Force that same week at a three-hour forum held in the auditorium of the Henry T. Wing Elementary School, in Sandwich, a town whose center lies less than two miles northeast of the PAVE PAWS radar. For most of the meeting, Mitchell maintained that the Air Force had taken a “conservative approach” toward possible biological hazards of microwave radiation. However, when a young woman in the audience asked him if he could guaran tee the safety of her two children from the effects of radiation from PAVE PAWS, he said that he was not going to guarantee her anything. “Then I ask you, who is my enemy?” she countered.

By that time, it was obvious that the Air Force had made a serious miscalculation in its handling of PAVE PAWS. The Air Force had expected that it could stick the radar on the best available piece of real estate, tell the locals that it would be good for business, assure the Audubon Society that it would not harm birds, and let everybody believe that it would merely scan the skies. At the end of January, however, the environmental groups that had sponsored the meeting formed the Cape Cod Environmental Coalition and retained a lawyer, and in March the Coalition filed suit in Federal District Court in Boston against Air Force Secretary John C. Stetson and several other Air Force officials, charging that the Air Force had violated the National Environmental Policy Act of 1969 by failing to submit an environmental-impact statement for the PAVE PAWS project.

In April, the Air Force announced that it had awarded a several-hundred-thousand-dollar contract to SRI International (formerly the Stanford Research Institute)—a consulting firm in Menlo Park, California—to prepare an impact statement for the radar. In August, Mitchell and an Air Force survey team, along with civilian monitors, set out to measure microwave-radiation levels emanating from the partly completed Cape Cod PAVE PAWS radar. The Air Force survey team diluted its measurements, however, by time-averaging the power density of the microwave radiation; that is, the team included in its calculations the intervals between the radar's short pulses, with the result that the average power calculated was only a small fraction of the peak pulse power. This expedient allowed the Air Force to say that it was adhering to the recommended standard for exposure to microwave radiation, of ten milliwatts per square centimetre, which was based upon the obsolete notion that its only harmful effect was the heat it could create in the body if it was generated at high power. Thus the Air Force was able to ignore mounting evidence that the instantaneous, nonthermal effect of being bombarded several hundred million times a second by powerful peak pulses of radiation, which penetrate deep into tissue, can have serious biological consequences.

By now, Representative Studds and the two Massachusetts Senators, Edward M. Kennedy and Edward W. Brooke of whom had previously written strongly worded letters to the Secretary of the Air Force expressing concern about the potential health hazards of PAVE PAWS and demanding that the Air Force produce an environmental-impact statement for the radar—had begun to distance themselves from the controversy. The stands these three politicians had taken earlier were prompted by letters, telegrams, and telephone calls of inquiry and alarm from their constituents. By the late summer of 1978, however, their mail and messages regarding the radar had dwindled, and there was little political mileage in their continuing to criticize the conduct of the Air Force, especially since the Air Force had agreed to produce an environmental-impact study. The politicians had correctly gauged the temper of their constituents. In November, the Cape Cod Environmental Coalition agreed to suspend its lawsuit in return for an opportunity to participate in further environmental studies of PAVE PAWS—an almost meaningless concession on the part of the Air Force, which had already commissioned environmental studies and was paying for them with several hundred thousand dollars of the taxpayers' money. Under he agreement, the Air Force was allowed to continue its construction of the

Cape Cod radar, and the citizens' group was given twenty-one days to amend its legal complaint once the Air Force had filed a final impact statement with the E.P.A. If within that period the Coalition failed to raise claims that the statement was insufficient, the court action would be dismissed.

Back in May, the Air Force had commissioned the National Academy of Sciences to determine whether preliminary measurements to be made of PAVE PAWS radiation could accurately predict the extent to which people living in towns surrounding the radar would be irradiated, and whether their exposure to the radiation emitted by PAVE PAWS would constitute a health hazard. The Academy's National Research Council established two separate committees to answer these questions—a seven-man engineering panel, to evaluate the predictions of how much radiation would be generated by PAVE PAWS, and an eight-man panel, to evaluate the biological effects of the radar system. Among the members of the bioeffects committee were Brockway McMillan, the vice-president in charge of military systems for the Bell Telephone Laboratories, which had been instrumental in setting up the ten-milliwatt standard during the late nineteen-fifties; George M. Wilkening, the director of environmental health at Bell Labs, who had sat on the Academy committee that sanctioned Project Seafarer, the Navy's huge ELF transmitter that was designed to provide communication with submerged nuclear submarines; and Ross Adey.

As Adey and his fellow committee members began the task of assessing the medical and scientific literature on the biological effects of microwaves, a sixteen-member team of researchers at SRI International, which had been doing the same thing, was putting together a four-hundred-page draft environmental-impact statement for the Air Force. The draft statement, which SRI submitted to the Air Force in November and the Air Force filed with the E.P.A. on December 22, 1978, said that the preponderance of biological effects was found at power densities in excess of two thousand microwatts per square centimetre, with a few scattered effects of "no medical significance" occurring at levels down to about five hundred microwatts. The fact was that because the military and the electronics industry had been allowed to maintain financial control over microwave research for two decades most of the studies of microwaves had been designed to look only at their heating effects. Among the relatively few low-level studies that had been conducted, however, some showed that changes in the bioelectric functioning of the brain, in brain chemistry, and in the immune system could occur at levels far below those capable of producing heat.

The authors of the draft statement went on to cite as inaccurate a 1962 study showing that mice irradiated with microwaves from an Air Force radar transmitter had developed leuke mia three and a half times as often as non-exposed control animals. "There is no evidence that the radio-frequency radiation caused leukemia in the mice," they stated. They omitted any reference to the fact that officials of the F.D.A.'s Bureau of Radiological Health had described this study as "the most discomfiting finding in the available literature." As for the extraordinary finding of Adey and Bawin that low-level radiation of the PAVE PAWS frequency of 450 MHz, when it was rhythmically modulated at a rate of sixteen hertz (close to the PAVE PAWS radar's repetition rate of 18.5 hertz), had produced changes in the chemistry of chick brains, the authors of the draft

statement called this effect “curious and scientifically interesting” but went on to note that it had been observed in chick brains that had been “removed from the animals and placed in incubation dishes.” They then declared that no observations existed on brains that had not been removed from the skull, and that “the significance of the findings for human health is unclear.” They were in error; Adey and Bawin had observed changes in calcium outflow in the cerebral cortex of living cats, and the significance of this finding for human health would remain unclear until studies were conducted of human beings who had been exposed to radiation emanating from PAVE PAWS to determine if they had undergone similar changes in brain chemistry.

On the evening of January 22, 1979, several hundred Cape Cod residents and observers attended a public hearing that was convened by the Air Force in the auditorium of the Sandwich Junior-Senior High School to discuss the draft environmental-impact statement. At the hearing, which was conducted by a military judge, Mitchell declared that measurements at twenty-one test sites showed that radiation levels from PAVE PAWS nowhere exceeded a fraction of a microwatt of average power. Lieutenant Colonel David Kanter, the project officer for the environmental-impact statement, then assured the audience that “no reliable evidence” existed to show that radiation from PAVE PAWS would have any ill effects on the surrounding population.

As the hearing progressed, a dozen or so speakers from the audience criti cized the draft impact statement. One of them pointed out that the statement highlighted biological studies of “doubtful validity” whenever they tended to support the Air Force’s contention that the radar would be safe. Another noted that although none of the civilian monitors who had accompanied Mitchell and the Air Force measurement team had a medical degree, or any other qualification enabling them to pass judgment on the safety of PAVE PAWS, statements issued by them had given “ordinary people the impression that a highly qualified authority had reached the conclusion that the emissions from PAVE PAWS could do no harm.” Someone else cited 1977 congressional testimony by Mitchell that the biological consequences of such radiation “may not be known for several years.”

The final environmental-impact statement, released by the Air Force in May of 1979, contained more than two hundred pages of letters and comments from federal, state, and local agencies and also from interested individuals. The tone of the letters and comments ranged from complete approval of to complete disbelief in the Air Force’s conclusion that PAVE PAWS posed no threat to the health of people in the surrounding communities. Only one Cape Cod physician—Dr. Charles D. Johnson, of Falmouth—submitted a comment for the record. “Biological studies on mice, chicks, and monkeys which indicate that microwaves have real and serious effects on the blood-brain barrier, brain chemistry and on white blood cells are discounted in the draft EIS,” Dr. Johnson told the Air Force. “The final EIS should acknowledge the importance of these studies, and admit that the longterm bio-effects of low level RFR’s [radio-frequency radiation] are not known. It should also state that very little is known about the bio-effects of pulsed RFR of the type emitted by the PAVE PAWS radar system.”

However, the final impact statement did no such thing. On page 2 of the summary section, its authors declared that “no scientific evidence was discovered to indicate that any ill effects will result from long-term exposure to the PAVE PAWS emissions.” They buttressed this assertion by announcing that the National Academy of Sciences had concluded that “it is improbable that exposure will present any hazard to the public.” The Academy had already submitted its own report on PAVE PAWS, entitled “Analysis of the Exposure Levels and Potential Biologic Effects of the PAVE PAWS Radar System,” to the Air Force, and the Air Force had plucked this phrase from its concluding section in such a way as to make it not only self-serving but also misleading. The final paragraph of Chapter 3, “Summary and Conclusions,” which appears on page 81 of the Academy’s report, reads:

In conclusion, the PAVE PAWS radar may be anticipated to expose a limited number of members of the general public intermittently to low intensities of pulse-modulated microwave fields with maximal instantaneous intensities of 100 μW/cm2 [100 microwatts per square centimetre] or less and time-averaged intensities lower by two orders of magnitude. There are no known irreversible effects of such exposure on either morbidity or mortality in humans or other species. Thus, it is improbable that exposure will present any hazard to the public. In view of the known sensitivity of the mammalian CNS [central nervous system] to electromagnetic fields, especially those modulated at brainwave frequencies, the possibility cannot be ruled out that exposure to PAVE PAWS radiation may have some effects on exposed people. Because these effects are still hypothetical, it is not feasible to assess their health implications. Such assessment will require additional research and surveillance and must be addressed in future evaluations of the potential exposure effects of PAVE PAWS and other high-power-output radar systems.

Thus did the National Academy of Sciences acknowledge that members of the general public exposed to radiation from PAVE PAWS would become participants in a biological experiment whose outcome would be ascertained by future evaluation. Some of the rest of Chapter 3 was equally unsettling in its assessment of the future well-being of Cape Codders who would be living in the spillover of the giant radar’s beam. On page 80, for example, the authors of the report got down to the particulars of the brain-wave frequency that had been used by Adey and Bawin in their pioneering experiments. “Data from both in vivo and in vitro studies suggest maximal sensitivity of neural systems to fields modulated at mammalian brain wave frequencies (i.e. 1-20 Hz), which include the predominant PAVE PAWS modulation frequency at 18.5 Hz,” they wrote. “Because of the aforementioned possibility of field-intensity windows and the lack of adequate data on mammalian systems, it is not known whether such effects will be induced in humans under the anticipated exposure conditions.”

The report went on to put the best possible face on this scary possibility. “The effects of such exposures of members of the public, if they occur, will, on the basis of available data and the known interaction mechanisms with biologic systems, be reversible or transient,” its authors wrote. “Thus, the possible exposure effects of PAVE PAWS should be restricted to transient, reversible functional alterations in the CNS that

may or may not be perceived by the exposed persons.” Having suggested a new version (“What you don’t perceive won’t hurt you”) of an old folk saying, the authors, as if worried by the absurdity of their conclusion, qualified it with a confession of ignorance. “Whatever the effects of exposure on the human central nervous system are, it is not known whether the effects are deleterious to health,” they wrote. “It has not been established, for example, that such effects involve impairment of judgment or alterations in mood that would impose psychologic or physiologic burdens on those affected.”

Copies of the Academy’s report were available in some Cape Cod libraries, but it is not known how many local people read it, or ever heard about the admission of the committee members that they had no idea what the ultimate effects upon human health of the PAVE PAWS radiation would be. It is a fact, however, that no newspaper on the peninsula saw fit to report on, let alone reprint, this admission.

During the summer and the autumn of 1979, the will and the wherewithal to resist the imminent startup of the radar dissipated like smoke in the wind. In September, a group called Sandwich Citizens Rallied Against PAVE PAWS revived the lawsuit that had been filed by the Cape Cod Environmental Coalition, and asked the Federal District Court to find that the Air Force’s final environmental-impact statement was inadequate. On December 6th, however, Federal District Judge Joseph Tauro granted a motion by the Air Force to dismiss the case. In a four-page decision Judge Tauro ruled that “the relevant provisions of the National Environmental Policy Act do not empower this court to make substantive decisions regarding technical matters disputed by the parties.” He also ruled that two affidavits stating that microwave radiation might be a health hazard were not relevant, on the ground that they represented “the speculations of experts.” (One of the affidavits had been given by Ruth Hubbard, a professor of biology at Harvard.) It is not known whether Judge Tauro read the conclusions of the National Academy of Sciences’ report before reaching his decision, or, if he did, whether he found them, too, to be irrelevant. It is known, however, that the Air Force’s PAVE PAWS radar system had already become operational, and had begun to irradiate the inhabitants of the four towns surrounding it—Sandwich, Mashpee, Bourne, and Falmouth—with low-level microwave radiation pulsed at a frequency and modulation that had been shown in repeated laboratory experiments conducted by Adey and his colleagues to be capable of changing the chemistry of brain cells in living creatures.

BACK in early February of 1979, Adey had written a letter to John M. Richardson, the chief scientist of the National Telecommunications and Information Administration and the chairman of its Electromagnetic Radiation Management Advisory Council—a group that had been established in 1968 by the President’s Office of Telecommunications Policy to advise the President on the biological hazards of microwave and radio-frequency radiation—and had sent copies to Carlos Stern, an Air Force environmental official, and to several other members of the Council. Adey told Richardson that each PAVE PAWS transmitter operated in excess of a thousand megawatts of time-averaged power, and that its sidelobes—the sidewise radiation spilling from the main beam, which could be expected to irradiate inhabited areas—”require careful evaluation from the viewpoint

of human safety, particularly in the light of a system life-expectancy of up to 20 years.” He informed Richardson that the modulation characteristics of any radio-frequency signal “are powerful determinants of the nature and extent of tissue interactions,” and that “this aspect of PAVE PAWS requires careful evaluation, since certain of its modulation modes closely resemble those known to react strongly with tissues of the central nervous system.” He added, “The Air Force’s need for this type of radar is unquestioned, but the choice of the Cape Cod site may reflect a grave lack of good judgment.”

Adey apparently hoped that by sending Stern a copy of his letter to Richardson he could influence the Air Force and SRI to do a thorough and evenhanded job of rewriting the draft impact statement. But the authors of the final statement simply added brief references to studies they had omitted—among them a single-sentence reference to Adey’s cat study—in the middle of a section entitled “PAVE PAWS and Safety to Human Populations.” They concluded, “We see no evidence that the low levels of general public exposure to PAVE PAWS RFR are hazardous.” As for the National Academy report, Adey and his fellow committee members apparently hoped that by expressing uncertainty about the ultimate effect of PAVE PAWS radiation on human health they could influence the Air Force and SRI to acknowledge as much in the final impact statement. That did not happen. Instead, their carefully qualified doubts merely served as camouflage for the fact that, when all was said and done, they were conferring the imprimatur of the National Academy of Sciences upon the installation and operation of the radar system.

In early January of 1980, Adey appeared at the annual meeting of the American Association for the Advancement of Science, in San Francisco, as an invited speaker at a symposium on the biological effects of microwave radiation. On that occasion, he described some recent studies he had conducted with Richard A. Luben, a cell biologist at the University of California, Riverside, which demonstrated that low-frequency magnetic fields pulsed at either fifteen or seventy-two times a second could affect the ability of parathyroid hormones to trigger the activity of adenylate cyclase, a metabolic enzyme inside the cell membrane which plays a crucial role in the formation of new bone. Adey said that the power of the external fields was far too low to alter cell chemistry by itself, but he suggested that the ability of the cell membranes to sense the weak external signals might trigger large changes in cell behavior.

Toward the end of his presentation, he laid down a heavy barrage of criticism against the Air Force, saying that it had shown a “lack of integrity” in its assessment of possible health hazards of the radiation emanating from PAVE PAWS. He pointed out that the characteristics of the electromagnetic radiation he had used in his experiment were almost identical to those of the radiation being beamed from the radar; and he went on to suggest that the Air Force had tried to discount the value of his work by claiming that it had been performed with isolated chick-brain cells, although Air Force officials could easily have learned that he and his colleagues had produced the same chemical changes in the brains of living cats.

After the San Francisco meeting, articles about Adey's pioneering research and his denunciation of the Air Force appeared in a number of newspapers across the nation, among them the San Francisco Chronicle and the Boston Globe. Curiously, not a word on the subject found its way into the Cape Cod Times—the Cape's largest newspaper, with a circulation of thirty-seven thousand. Indeed, the Times had carried little news about the radar since June 2, 1979, when it ran an editorial expressing the hope that no major flaws would be found in the Air Force's final environmental-impact statement, and that "all can agree PAVE PAWS poses no major health or safety threat to the community."

Almost no mention of the health effects of PAVE PAWS appeared in the Cape Cod Times during 1980 and 1981. On December 31, 1982, however, the newspaper ran another story about the radar. It appeared under the headline "PAVE PAWS: WHERE HAS THE CONTROVERSY GONE?" and contained the paper's first mention of the reservations about the safety of the radar which had been expressed three and a half years earlier by the authors of the National Academy of Sciences' report. The story quoted John Mitch ell, who pointed out that the radiation levels from PAVE PAWS measured by the Air Force were extremely low. Once again, Mitchell refused to guarantee that those levels posed no health hazard. "There's no way you can ever guarantee anything," he declared. He then told the Cape Cod Times that scientists at the University of Washington, in Seattle, were conducting a study of the long-term effects of low-level microwave radiation. The study was being financed by the Air Force to the tune of some four million dollars, and was being carried out by Professor Arthur W. Guy, an engineer and the director of the Bioelectromagnetics Research Laboratory at the University of Washington's School of Medicine. Dr. Chung-Kwang Chou, associate director of the laboratory, told the Cape Cod Times that the Seattle study consisted of exposing a hundred rats around the clock for two years to low levels of microwave radiation similar to those being emitted by PAVE PAWS. Chou said that the exposed rats would be examined and compared with a non-irradiated control group, in order to determine whether the radiation had affected their blood chemistry, their body weight, or their behavior.

Meanwhile, Adey was pushing on with research aimed at finding out how weak electromagnetic fields might trigger amplified changes in brain chemistry. Since his earlier work with Leonard K. Kaczmarek, a biochemist, on calcium ions had suggested that highly non-linear effects must be involved—effects that would allow large releases of chemical energy to be triggered by tiny stimuli—he now proposed a three-stage model based upon the amplification of weak cell-surface events. In the first stage, the cell membrane senses the arrival of a weak field and reacts to it by initiating, in domino fashion, a release of calcium bound to the protein strands that protrude from the membrane surface. (Because of the domino effect, the energy released by the altered calcium binding is far greater than that of the initiating chemical or electric triggers.) In the second stage, this released energy is transmitted, in the form of signals that travel along the protein strands, to the interior of the cell. In the third stage, the cell interior reacts to the arriving signal by stimulating or inhibiting intracellular enzymes—protein molecules that act as chemical catalysts.

During 1981 and 1982, Adey and Daniel B. Lyle, a research immunologist at the University of California, Riverside, together with two associates, demonstrated that the PAVE PAWS carrier frequency of 450 MHz modulated at the electrical-distribution-system frequency of sixty hertz could significantly suppress the ability of cultured T-lymphocyte cells from mice to kill cultured cancer cells; and when the four researchers published their findings in the journal Bioelectromagnetics, in 1983, they noted that progressively smaller suppression occurred when the microwave radiation was modulated at forty, sixteen, and three hertz. These findings had possibly serious implications, of course—not only for the tens of thousands of people living close to PAVE PAWS but also for the tens of millions of people living in the vicinity of power lines and electrical-distribution wires. Indeed, when Lyle later repeated the study, using simulated sixty-hertz high-voltage power-line fields, he again observed a large suppression of the killing capacity of T-lymphocyte cells—a chilling finding in the context of the 1979 study by the epidemiologist Nancy Wertheimer and the physicist Ed Leeper which found an increased incidence of cancer in children in the Greater Denver area who had been exposed to low-level magnetic fields from high-current electrical-distribution wires.

The results of a study that was performed in 1983 by Craig V. Byus, an assistant professor of biomedical sciences and biochemistry in the Department of Biochemistry of the University of California, Riverside, together with Adey and two researchers from Byus's department, gave cause for further concern about the future well-being of the inhabitants of Upper Cape Cod. Byus and his colleagues exposed cultures of human-tonsil lymphocytes for periods of up to sixty minutes to low level 450 MHz radiation modulated at ELF frequencies ranging from three to a hundred hertz. They found that the activity of certain protein-kinase enzymes within the lymphocyte cells was sharply reduced when the microwave field was modulated at certain frequencies between sixteen and sixty hertz. Because the effect upon the activity of the protein kinase was transient, Byus and Adey were cautious in their assessment of it when they and their associates published their findings, in Bioelectromagnetics, in 1984. They warned, however, that their observations regarding the effects of ELF-modulated radiation on human-tonsil lymphocytes, together with the findings of the earlier mouse-lymphocyte study, required additional and careful assessment.

On August 18, 1984, the Cape Cod Times published a front-page article about the final results of Guy and Chou's study. It started out by saying, "A five-year study on the long-term effects of low levels of microwave radiation has sparked a new debate over the safety of the Air Force's PAVE PAWS microwave radar station in Bourne." The article went on to quote Ruth Hubbard, the Harvard biology professor whose affidavit warning of the dangers of PAVE PAWS radiation had been dismissed as irrelevant five years earlier by Federal District Judge Tauro. Hubbard suggested that people living near the giant radar had become guinea pigs, and called upon the Air Force to conduct a study of the long-term biological effects of PAVE PAWS radiation on those people. The Cape Cod Times then quoted the ever-optimistic John Mitchell, who declared, "There's no question that PAVE PAWS is safe," and said that the radiation levels from PAVE PAWS were so low that such a study "would not be practical." Once again, however, Mitchell refused to say that no long-term adverse health effects would be

caused by microwave radiation from PAVE PAWS. “You can’t guarantee anything today,” he told the newspaper. Tucked away toward the end of the article was the revelation that sixteen malignant tumors had been observed among rats exposed to radiation similar to that emitted by PAVE PAWS, compared with only four cancers among non-irradiated control animals.

By contrast, a story about the same study that had appeared a day earlier in the Boston Globe went into detail about a report by Louis Slesin, in the newsletter Microwave News, which disclosed that no fewer than seven of the malignant tumors in the exposed animals involved the endocrine system, compared with only one endocrine tumor in the controls, and that seven of the exposed animals had developed benign adrenal tumors, while one had been found in the control rats. On the day that the Globe published this startling information, an Associated Press report carrying similar information about the study appeared in newspapers around the nation and the world. It quoted the epidemiologist Dr. Samuel Milham, Jr., of the Washington State Department of Social and Health Services, who had recently found increased rates of leukemia among power-station operators, telephone linemen, and other workers who were chronically exposed to electric and magnetic fields. “It looks like the microwave radiation may have been a tumor promoter,” Milham said. “It didn’t initiate the cancers, but once some cancer cells got going it promoted growth of the tumors.”

In the light of the worldwide attention accorded the University of Washington study, one can only wonder what the editors of the Cape Cod Times—the one newspaper in the nation whose readers should have been informed in minute detail about the findings of Guy and Chou—were thinking of when they omitted so many important aspects of the story. Whatever it was, it seems unlikely that they did not know that virtually every leading newspaper in the nation—and the CBS Evening News as well—had covered the story and its profoundly serious implications for the public health in far more depth than they had.

Six months later, the findings of Guy and Chou’s rat-cancer study were supported by those of the largest epidemiological investigation of the effects of radio frequency and microwave radiation ever undertaken. This was a two-year survey of cancer in Polish military personnel which had been conducted by Dr. Stanislaw Szmigielski, an internationally known researcher on the biological effects of non-ionizing radiation, and some colleagues at the Center for Radiobiology and Radioprotection, in Warsaw. They found that servicemen exposed to non-ionizing radiation were almost seven times as likely to develop cancer of the blood-forming organs and lymphatic tissue as those who were not exposed, and that the odds of their developing thyroid tumors were more than four times as great. They also found that younger exposed personnel—those between the ages of twenty and twenty-nine—had a risk of being stricken with cancer five hundred and fifty per cent greater than that of their unexposed counterparts. Over all, servicemen who worked with or near radiation-emitting devices were more than three times as likely to develop cancer as unexposed personnel, in other military occupations.

Louis Slesin, to whom Szmigielski had sent the results of his as yet unpublished findings, believed them to be so important that he distributed a news release about them to newspapers and magazines across the nation.

As a result, a story appeared on the front page of the Boston Globe on March 15, 1985, beneath the headline “STUDY LINKS CANCER, MICROWAVE RADIATION.” Boston is only sixty-five miles from Hyannis, where the Cape Cod Times is written and published, and it is safe to assume that every senior editor on that newspaper reads the Globe every day, to keep up with important national, international, and regional events. Not a word about Szmigielski’s findings ever found its way into the Cape Cod Times, however, except for a passing reference more than a year later: in June of 1986, the newspaper mentioned the Polish study as being one of several that “link long-term exposure to low levels of microwaves to certain health disorders, including cancer, high blood pressure, headaches, loss of memory, and brain damage.”

BY this time, the subject of cancer was nevertheless very much on the minds of the residents of the Upper Cape towns of Sandwich, Bourne, Falmouth, and Mashpee, for in March of 1986 the Massachusetts Department of Public Health had released a report revealing that between 1979 and 1981 women living in the four towns had died of leukemia at a rate that was twenty-three per cent higher than that of other women in Massachusetts, and had died of cancer of the liver, bladder, and kidney at a rate that was sixty-one per cent higher. An accompanying memorandum showed that between 1982 and 1983 women living in the four towns developed liver, bladder, and kidney cancers at a rate almost four times as high as that of women living in the eleven other towns on Cape Cod, and that during this period men and women living on the Upper Cape developed cancer of all types at a rate sixteen per cent higher than that of the residents of the rest of the Cape.

As it happened, the Air Force and the Massachusetts Air National Guard had been dumping toxic chemicals into waste-disposal sites at the military reservation for forty-six years. Late in March, some Cape people who were attending a public meeting about the Upper Cape’s elevated cancer rate inquired whether radiation from PAVE PAWS could have anything to do with it. They were told by state officials that environmentally induced cancer takes at least ten years to develop. The officials implied that the radar facility had not been in operation long enough to affect the rate. (They were obviously unaware that if radiation from PAVE PAWS were acting not as a tumor initiator but as what Milham called a tumor promoter, the latency period for the development of cancer could be less than ten years.) In June, however, the question was raised again—this time in an article that appeared in the Cape Cod Times, under the headline “PAVE PAWS BEAMS STILL SPARK FEAR IN NEIGHBORS.” The article quoted a variety of people, some of them for and some against the radar. Ruth Hubbard, the Harvard biology professor, repeated her suggestion that Upper Cape residents were “guinea pigs,” because the long-term effects of microwave radiation were largely unknown. Jerome Krupp, the chief of biological effects for the Radiation Sciences Division of the Air Force’s School of Aerospace Medicine, tried to play down the results of the study conducted for the Air Force by Guy and Chou. According to Krupp, the microwave levels emanating from PAVE PAWS were far too low to be a health hazard. “It’s almost like sitting under a light bulb,” he said.

During the summer of 1986, it became apparent that the chemical contamination at the Massachusetts Military Reservation was far worse than

anyone had suspected. On June 30th, the National Guard Bureau, the federal organization of the National Guards, held a press conference to announce that the E. C. Jordan Company, of Portland, Maine—an environmental consulting firm it had hired to evaluate the military reservation—had found no fewer than forty-six significant hazardous-waste sites there, and that more than a million gallons of aviation fuel had been dumped into the ground between 1955 and 1970. In January of 1987, the Massachusetts Department of Environmental Quality Engineering classified the entire twenty-one-thousand-acre military reservation as a hazardous-waste-disposal site.

Meanwhile, back in September, the Air Force, obviously worried that microwave radiation from PAVE PAWS might be implicated in the high cancer rates among Upper Cape residents, departed from a long-standing position of refusing to monitor radiation levels, and measured them at fifteen places in the surrounding towns. On September 22, 1986, Lieutenant Colonel Gayle White, the commander of PAVE PAWS, said that the data so far showed microwave levels to be only one thousandth the recommended state and federal safety standards, which is similar to what John Mitchell had told Cape Codders eight and a half years earlier. White said that the measurements should help to prove that the radar was not contributing to the unusual increase of cancer among the residents of the Upper Cape. “They can put that issue to bed,” he declared. A year later, in October of 1987, the Department of Public Health announced that the Upper Cape’s unusually high cancer incidence had continued during 1985, and that the residents of Barnstable, to the east of the radar, as well as Bourne, Falmouth, Mashpee, and Sandwich, had a rate of cancer seventeen per cent higher than that of other residents of Massachusetts.

In the spring of 1987, it had come to light that the Air Force had been planning to quadruple the power output of the Cape Cod PAVE PAWS but had decided to hold off for a while. Around that time, too, the Air Force announced that the maximum time-averaged radiation level found in the communities surrounding PAVE PAWS was slightly less than one and a half microwatts per square centimetre. The Air Force said that none of the other microwave power densities measured in the towns exceeded three-tenths of a microwatt per square centimetre at a height of six feet. All this sounded fine, but in fact time-averaging had skewed the latest Air Force measurements of the radiation from PAVE PAWS in the same way that it had skewed the measurements in the summer of 1978. And again the Air Force assessed the effects of the radiation on human health only in terms of the thirty-four-year-old thermal theory, which was now considered inappropriate by many of the leading scientists in the field. In short, the Air Force was citing an obsolete exposure guideline in order to assure the residents of Upper Cape Cod, who surely knew it to begin with, that they were not being cooked. (Skeptics who had watched the Air Force pull this stunt time and again over the years called it the English-muffin standard, because of the implication that microwave radiation was harmless as long as you didn’t turn brown or feel toasty.)

As for Jerome Krupp’s contention that exposure to microwave levels emanating from PAVE PAWS was no more harmful than sitting under a light bulb, it was called into question in the summer of 1988, when it was revealed that the Air Force was considering relocating a PAVE PAWS radar

that had been constructed at Robins Air Force Base, in Georgia, in 1986, in order to reduce the danger of explosion in airplanes flying through its main beam. According to Raytheon, the manufacturer of PAVE PAWS, the high energy contained in the radar's peak pulses "may pose a hazard to electro-explosive devices (EEDs) carried on military and commercial aircraft." As a result, the company warned that airplanes carrying such devices should stay at least one nautical mile from the radar, and that when the Air Force increased the power output of PAVE PAWS the airspace "hazard zone" should be increased to three nautical miles. Raytheon said nothing about how the high-energy peak pulses of PAVE PAWS might be affecting the delicate electrochemical balance of the human brain.

REASON for suspecting that chronic exposure to low-level radiation from PAVE PAWS might act to increase the incidence of cancer in people who are already at risk because they have been exposed to cancer-producing chemicals can be found in the 1983 discovery by Adey and Byus that 450 MHz radiation modulated at the ELF frequency of sixteen hertz sharply reduces the activity of certain protein-kinase enzymes within human lymphocytes. This finding raises disturbing questions about the effect of such radiation upon the human immune system, which is the body's first line of defense against the development of cancer, because one of the affected enzymes—protein-kinase C—is a specific receptor at the cell membrane for a class of extremely powerful cancer-promoting substances called phorbol esters, which are found in a vegetable plant of the Euphorbiaceae family.

Adey has pointed out that it is important to distinguish between substances that promote cancer and substances that initiate it. "The accepted model of tumor formation involves at least two and possibly three stages," he said recently. "They are initiation, promotion, and progression. Initiation occurs when the DNA in the nucleus of a cell is damaged by ionizing radiation, such as gamma rays and X rays, or by certain chemicals—mostly coaltar derivatives—such as benzo-a-pyrene, which is found in cigarette smoke. The damaged cell has undergone mutation, and is now capable of passing its damaged DNA to daughter cells. It is therefore a cancer cell, but it may not necessarily form a tumor. The next phase in carcinogenesis is promotion of tumor formation. This involves unregulated growth. Cancer promoters include plant derivatives, such as phorbol esters; tobacco proteins; polychlorinated biphenyls, called PCBs; DDT and other chlorinated hydrocarbons."

When Adey and Byus learned that phorbol ester specifically modifies the activity of protein-kinase C, especially in combination with ELF-modulated fields, they recognized its significance for their further studies. "As it happened, Craig Byus had had long experience in assaying an enzyme called ornithine decarboxylase—ODC for short—which is essential for growth in all cells," Adey has explained. "ODC participates in the synthesis of DNA protein by forming polyamines, which are the building blocks for DNA. For some time now, it has been known that all cancer promoters increase ODC activity. However, not all substances that increase ODC activity are cancer promoters. Nevertheless, in clinical studies high levels of ODC are a reliable index of malignancy—as, for ex ample, in the human prostate. In 1985, Byus and I, together with Susan E. Pieper and Karen Kartun, both of whom were junior researchers in Byus's lab, found that when we modulated a 450 MHz microwave field at sixteen hertz, and generated it at a power

intensity of one milliwatt per square centimetre, we could increase ODC activity up to fifty per cent in cultured liver and ovary cells of Chinese hamsters and in cultured human melanoma cells. We also found that when the ELF-modulated field and the phorbol ester acted together, their joint effect on ODC activity was about twice that of either alone. As a result, we cautiously hypothesize that exposure to low-level radiation and environmental chemical pollutants may be joint factors in increasing the incidence of human cancer. It should be emphasized that our suggestion is speculative, and must be substantiated through experimental evidence, which can be obtained only by conducting extensive animal studies."

The extraordinary discovery by Byus, Adey, and their two young colleagues that radiation similar in carrier frequency and modulation characteristics to that emanating from PAVE PAWS increases ODC activity in cultured human melanoma cells, and may therefore promote cancer, was published in August of 1988 in Cancer Research. However, because of the difficulty of obtaining research funds, only one animal experiment is under way to substantiate their four-year-old finding—unless one believes that an experiment is being conducted upon the thousands of human beings residing in Sandwich, Mashpee, Bourne, and Falmouth, who have undergone chronic exposure to low-level, ELF-modulated radiation from PAVE PAWS for nearly a decade and have been found to be developing cancer at an unusually high rate. Even more disturbing are the findings of a subsequent study by Adey, Byus, and Pieper, conducted in the winter of 1986. At that time, they discovered that a one-hour exposure to a sixty-hertz electric field of between one-tenth of a millivolt and ten millivolts per centimetre produced a fivefold increase in ODC activity in cultured human lymphoma cells. They also found that between one and two hours of exposure to the same power-line field produced a two-to-three-fold increase in ODC activity in mouse myeloma cells. These results were pub lished in Carcinogenesis in October of 1987.

"We have no explanation for the different responses to the sixty-hertz field on the part of different cell types," Adey has said. "We feel that it is highly significant, however, that only short, intermittent exposure to the sixty-hertz field was required to elevate ODC activity. We can now hypothesize that exposure to low-energy fields, such as those emanating from power lines, may provide a tumor-promoting stimulus, in the manner of phorbol-ester compounds. Once again, it should be emphasized that such a relationship is based upon indirect evidence, and awaits direct experimental confirmation."

Adey's willingness to hypothesize that exposure to weak, sixty-hertz electromagnetic fields such as those surrounding power lines may promote cancer is something that should be taken very seriously by public-health officials across the nation. After all, an alternating-current electric field of at least one-tenth of a millivolt per centimetre is present in the tissue of a human being who is standing beneath a typical overhead high-voltage power line.

ALTHOUGH the pioneering experiments of Adey and his colleagues have been accepted and praised by many of their peers in the medical and scientific community, there have been relatively few attempts to replicate them. A significant exception has been the work of Carl F. Blackman, a research

biologist in the E.P.A.’s Health Effects Research Laboratory, at Research Triangle Park, in North Carolina. Blackman is a tall, lean man of forty-eight, with a Lincolnesque face and a serious demeanor. Born in Annapolis, he went to Colgate, where he studied physics and mathematics. Then he studied at Pennsylvania State University, where he received his M.S. and Ph.D. in biophysics. In 1970, he went to work at the F.D.A.’s Bureau of Radiological Health, in Rockville, Maryland, and began to investigate the genetic effects of microwave radiation. A few months later, he was transferred to the recently created E.P.A., where he continued this line of research.

After hearing about Bawin and Adey’s 1974 experiments showing that a 147 MHz ham-radio carrier wave, when modulated at brain-wave frequencies, could alter the outflow of calcium ions from chick-brain tissue, Blackman and some colleagues undertook to repeat them. In 1976, they were able to confirm Bawin and Adey’s finding of a sixteen-hertz-frequency “window” in which the outflow of calcium ions from chick-brain tissue was most likely to occur. At the same time, they expanded upon the finding by showing that there was a narrow window in the power-intensity range in which the release of calcium was enhanced. In 1979, they performed a similar experiment with 50 MHz radiation—another ham-radio frequency—and found that when its amplitude was modulated at sixteen hertz it, too, enhanced the release of calcium ions from chick-brain tissue, though at different power intensities from those which had been effective with 147 MHz radiation. In the same year, Blackman teamed up with William T. Joines, an electrical engineer in the Department of Electrical Engineering of Duke University, in nearby Durham, to determine why the two different carrier frequencies required different power intensities to produce the calcium-efflux effect. They found that the two frequencies, though they were generated at different power, produced identical electric-field intensities within the chick-brain tissue. Hence they concluded that the internal-field intensity was what provided the critical parameter for the effect.

The following year, Blackman and Joines studied the influence of a sixteen-hertz field on chick-brain tissue in the absence of a higher-frequency carrier wave. They found that the sixteen-hertz field increased calcium outflow at two different power intensities, but that fields of one and thirty hertz produced no response. When Blackman reported the findings of his latest study at the third annual meeting of the Bioelectromagnetics Society, in August of 1981, he noted that they constituted “a solid case of a response that cannot be explained by a general heating mechanism.” Later that year, he and Joines extended their low-frequency experiments with chick-brain tissue to cover the range from one to a hundred and twenty hertz. They found a strong response to fields of fifteen, forty-five, seventy-five, and a hundred and five hertz, and a much weaker response to fields of thirty, sixty, and ninety hertz. All these responses were obtained at power intensities far below those necessary to produce heating.

Back in 1979, while Blackman was trying to imagine what might account for the unusual ability of radio-frequency radiation modulated at sixteen hertz to alter brain chemistry, he remembered a course in magnetic resonance he had taken as a graduate student at Penn State. “During the

course, we learned that electrons and the nuclei of certain atoms can interact differently with various conditions of high-intensity static magnetic fields," he said recently. "So I wondered if it might be possible for similar interactions to occur with low-intensity static magnetic fields, such as the geomagnetic field of the earth. The geomagnetic field generally has a strength of about five hundred milligauss, but it can change strength from place to place—sometimes within a few feet—depending upon factors like the presence of iron-containing rock, or of steel girders in buildings, which can act as conductors of magnetic fields. In fact, the strength of the local geomagnetic field at a given site can range from less than one hundred to more than two thousand milligauss. I was on a fishing expedition, of course, but I went down to the local K mart and bought a couple of hula hoops. Then I went to an electrical-supply store and bought some ordinary speaker wire. When I got back to the laboratory, I wrapped the speaker wire in the grooved channels running along the inner circumference of the hula hoops, and made myself a Helmholtz coil—a device named after the nineteenth-century German physicist who invented it—which generates magnetic fields. Before I got around to doing anything with it, however, I decided that the whole business was just a nutball hunch, so I stuck the hoops away in a false ceiling in the laboratory and forgot about them."

Three years later, Blackman was trying to figure out why fields with frequencies of fifteen, forty-five, seventy-five, and a hundred and five hertz should have a strong effect on calciumion outflow from chick-brain tissue, while fields of thirty, sixty, and ninety hertz produced only a weak effect. In the autumn of 1982, he went to James R. Rabinowitz, a physicist in the Health Effects Research Laboratory, and asked for his help in explaining this disparity. Rabinowitz took a book titled "Introduction to Solid-State Physics" off a bookshelf in his office and showed Blackman an equation for cyclo tron resonance—a phenomenon that occurs when a static magnetic field causes moving charged particles to go in circles. Rabinowitz told Blackman that the frequency at which this circular motion is produced is directly related to the strength of the static magnetic field.

"Suddenly, the lights went on in my head," Blackman recalls. "I went back to my lab, pulled the hula hoops out of the compartment in the false ceiling, and aligned them in a way that would allow me to either increase or decrease the strength of the local geomagnetic field present in the room. Early in 1983, Joines, Rabinowitz, and I conducted a series of experiments to determine whether the ability of a fifteen-hertz field to increase calcium-ion outflow in chick-brain tissue would be altered if we changed the strength of the local geomagnetic field. And, lo and behold, we found that if we cut the strength of the geomagnetic field in half, the fifteen-hertz field no longer produced the calcium-efflux effect. This introduced a new concept into the mystery of how low-level electromagnetic fields could operate to affect the chemistry of the brain."

Blackman and his colleagues went on to perform additional experiments showing that the thirty-hertz signal they had previously found to be ineffective would enhance calcium outflow if they altered the strength of the local geomagnetic field. In July of 1984, Blackman described his latest findings at the annual meeting of the Bioelectromagnetics Society,

in Atlanta. He told his audience that the intensity of the local geomagnetic field was an important variable in the calcium-efflux phenomenon, and that the results of the experiments he and his associates had conducted appeared to describe a resonance-like relationship, in which the frequency of the electromagnetic field that can induce changes in calcium-ion outflow was proportional to the strength of the local geomagnetic field. Blackman suggested that the phenomenological findings of these experiments might provide a basis for evaluating the apparent lack of reproducibility of some studies showing that biological effects could be caused by low-level electromagnetic fields. Indeed, he pointed out, if the underlying mechanism of the calcium-efflux response in chick-brain tissue proved to be a universal response in the tissue of other biological systems, including that of human beings, research into the health effects of power-line radiation and other sixty-hertz fields in the ambient electromagnetic environment might be subject to unnoticed and uncontrolled influences, depending upon the strength of the static geomagnetic field in the vicinity of the laboratories where the research was being conducted.

As might be expected, a number of prominent scientists in the field were interested. Among them was Abraham Liboff, a physicist at Oakland University, in Rochester, Michigan, who, together with Dr. John Thomas and Dr. John Schrot, psychologists at the Naval Medical Research Institute, in Bethesda, Maryland, had been conducting a study of the effect of sixty-hertz electromagnetic fields on animal behavior for the New York State Power Lines Project. This was a five-million-dollar research program, overseen by the New York State Department of Health, to investigate the effects of power-line fields and to replicate the study by Nancy Wertheimer and Ed Leeper showing that children who live in homes near high-current wiring develop cancer twice as often as children who live in homes near low-current wiring. Liboff, Thomas, Schrot, and some colleagues had been working for a year without observing any significant results, but after hearing of the findings of Blackman and his associates Liboff hypothesized that some ions in the brain could be in cyclotron resonance with external magnetic fields, and he and his associates tested his theory by adjusting the local geomagnetic field to two hundred and seventy milligauss—the level at which lithium ions resonate—and found that rats exposed to sixty-hertz fields of less than a hundred milligauss exhibited impaired timing discrimination.

ON the morning of October 29, 1985, Adey, Wertheimer, and six other researchers in the field of bioelectromagnetics gathered by invitation at the National Academy of Sciences headquarters, in Washington, D.C., to discuss their work at a oneday meeting that was being held by a six-member Advisory Committee on Nonthermal Effects of Nonionizing Radiation. During the morning session, Adey reviewed the experiments that he and his colleagues had performed, which demonstrated that weak, ELF-modulated fields could alter brain chemistry and the activity of human lymphocyte and melanoma cells. He also discussed the data indicating that weak fields might act as tumor promoters. Later, Wertheimer discussed a study she and Leeper had recently conducted, indicating that pregnancies among couples exposed to the sixty-hertz magnetic fields generated by electric blankets and electrically heated water beds appeared to be more likely to end in miscarriage than pregnancies among couples who did not heat their beds

electrically. She told the members of the advisory committee that fetuses conceived in electrically heated beds had a slightly slower growth rate than other fetuses. She added that similar findings held true for couples whose homes were equipped with ceiling-cable electric heating. She then declared that further studies—especially an investigation of the possible association between the use of electric blankets and the development of cancer—were essential.

When the National Academy of Sciences released its advisory committee's report, in April of 1986, it was apparent that the committee members were not much impressed by what Wertheimer and Adey had told them. They noted at the outset that while investigators had produced an abundance of empirical data to show that non-ionizing radiation was capable of causing low-level effects, the information "fails to provide a consistent picture of the nature of the effects." They went on, "In the absence of a scientific conceptual framework that brings meaning to a measured result, the temptation arises to create significance by postulating adverse effects from the interaction of nonionizing radiation with biological tissues and cells."

Wertheimer had conducted her study of electrically heated beds in 1983 and 1984. "I had wanted to do such a study since 1979, because it was apparent to me that electric blankets and heated water beds were often major sources of intense, repeated exposure to magnetic fields," she said recently. "When Ed Leeper and I measured the magnetic fields produced by various household appliances, we had found that although some of these fields were strong in the immediate vicinity of the appliances, they diminished sharply within a short distance of their source. However, when we measured the magnetic field in the vicinity of an electric blanket that had been turned on to any power setting from one to ten we usually got a reading of between ten and twenty milligauss next to the blanket, and five to ten milligauss six inches away. This, of course, was the field strength to which someone sleeping under the blanket would be exposed."

Wertheimer explained that electric blankets produce relatively high magnetic fields because, although the current that flows through the S pattern of parallel wires in the middle of the blanket is balanced by current flowing in the opposite direction, thus tending to cancel out the magnetic fields, the current is unbalanced at the outer edges of the blanket. The imbalance causes a significant magnetic field to be generated. "The same holds true for the heating element of a water bed," she said. "But since it is on the underside of the bed, the magnetic-field reading we usually got for them was around five milligauss. Considering the fact that children with cancer in our original 1979 study had been exposed to an ambient magnetic field of only about one or two milligauss, while the typical ambient alternating-current magnetic field to which a person in the Denver-Boulder area is exposed is only about half a milligauss, I was naturally interested in investigating whether the use of electric blankets and water beds affected cancer rates. The trouble was that such a study would necessitate extensive interviews with cancer patients, and require considerable time and money to conduct, and I was not in a position to get a grant to finance it. So I had to give up the idea of conducting a cancer investigation. I did, however, find a

relatively inexpensive way of looking at the effects that using electric blankets and heated water beds might have on fetal development.”

Wertheimer began her investigation by combing Greater Denver newspapers for all birth announcements that had been placed from two Denver-area hospitals during 1982. She found that out of four thousand two hundred and seventy-one families giving birth in the two hospitals during that year, eighteen hundred and six (forty-two per cent) had published birth announcements. She was then able to reach thirteen hundred and eighteen (seventy-three per cent) of these families by tele phone and to ask them whether they had used electric blankets or heated water beds during the previous eight years, and, if so, when, and at what preferred temperature settings. After the telephone survey was finished, she obtained routinely recorded data on the twelve hundred and fifty-six published births for which she had gathered information about parental use of electric blankets and heated water beds, and also on five hundred and twenty-eight of six hundred and ninety-two prior births to the same parents since the beginning of 1976. These data included such information as the date of the mother’s last menstrual period; the date of birth and the birth weight of the child; and the date of the most recent fetal loss, if any. In order to minimize the possibility of including induced abortions in her study, Wertheimer investigated only those abortions which occurred in the year preceding the conception of live births to the same couples—a method that provided evidence that those parents were not averse to having a child.

When Wertheimer compared the rate of reported miscarriages among users of electric blankets and heated water beds from September through June with the rate of miscarriages in the same group of people during July and August—the two months in the Denver region when electric blankets and heated water beds are not generally used—she found that the users reported proportionately more miscarriages during the colder months than in the two summer months, while the rate of miscarriage reported by nonusers remained fairly constant throughout the year. She also found that miscarriages among users were reported most frequently between September and the end of January, rather than over the entire period from September through June. Wertheimer believed that the younger the fetus is, the more susceptible it might be to adverse effects from electromagnetic-field exposure, and she knew that most spontaneous abortions are thought to occur before a woman even knows that she is pregnant. For this reason, Wertheimer hypothesized that between September and the end of January—a period of increasing cold weather—a susceptible embryo might survive early exposure to the magnetic field of an electric blanket or heated water bed, because that exposure was relatively low, only to be aborted later, when it was subjected to greater exposure as the weather turned colder. She hypothesized, further, that since these comparatively late miscarriages were the ones most easily recognized by the mother, they would also be the ones that ended up being reported in the birth records, whereas many miscarriages that took place between the end of February and the end of June, a period of decreasing cold, would go unrecognized, for the simple reason that during this period the highest exposure of the fetus to magnetic fields from electric blankets and heated water beds—and thus, presumably, the greatest risk of miscarriage—was likely to occur during the first weeks after conception.

When Wertheimer and Leeper published the findings of their study in Bioelectromagnetics, in 1986, they pointed out that since seasonal patterns in the spontaneous-abortion rates were seen only in users of electric blankets and heated water beds, electrical bed heating “may have a direct effect on fetal development.” They added that this effect “could be due to excessive heat or to electromagnetic field exposure.” They concluded their paper by suggesting that increased use of electric blankets and electrically heated water beds might have contributed to an unexplained increase in childhood disability that was reported to have occurred since 1960.

“The results of the electric-blanket study increased my confidence in our original hypothesis that alternating-current magnetic fields from high-current electrical-distribution wires could have serious health effects,” Wertheimer said not long ago. “Until then, I had been nagged by the idea that, in spite of my effort to avoid it, I might have inadvertently introduced bias into my previous studies by failing to blind-code the wiring-configuration data. But I had done the electric-blanket study completely blind, because when I telephoned the families who had placed birth announcements in the newspapers I had absolutely no knowledge of whether they’d had a spontaneous abortion or not. However, the study contained a built-in confounder that might have influenced its results. This was the fact that, in addition to generating electromagnetic fields, the blankets generate heat, which, if it is excessive, is known to have an adverse effect upon sperm. As it happened, I had heard about ceiling-cable electric heating, and had learned that, because of the proximity of cheap hydroelectric power, ceiling-cable heating was routinely installed in a great many homes built in Eugene, Oregon, during the nineteen-sixties and seventies. Since ceiling-cable heating is essentially like a big electric blanket that has been installed in the ceiling, current flowing at the outer edges of the cable pattern is unbalanced, just as it is in electric blankets, and thus produces quite strong magnetic fields. However, unlike the heat from an electric blanket, the heat generated by a ceiling-cable system is not likely to raise body temperature excessively.”

As with her three previous studies, Wertheimer had no financing to help her investigate the effect of ceiling cable electric heating. Undeflectable, as always, she visited the Oregon Center for Health Statistics, in Portland. There she obtained data from the records of all those legitimate births for 1983 and 1985 which listed the mothers’ addresses as being in Eugene or in the neighboring city of Springfield. Among other information, each birth certificate contained the date of the most recent fetal loss, if any, and whether it had occurred before or after twenty weeks of gestation. She then went to the Lane County Assessor’s Office, in Eugene, and obtained microfiche records giving the type of heat and the address of each single-family home in the Eugene-Springfield postal area. Using telephone books for 1977 through 1984, she traced the families whose birth records she had already obtained, in order to discover, whenever she could, the addresses at which those families had lived at the time of conception and at the time of any previous fetal loss. Finally, she compared those addresses with the assessor’s microfiche records to determine which were homes with ceiling-cable heat.

As Wertheimer had done in the electric-blanket study, she now looked at the seasonal pattern of spontaneous abortion. She observed an increase in fetal loss reported by families living in ceiling-cable-heated homes during the colder months of the year (in Oregon, October through May), which did not appear among families living in homes with other types of heating. Moreover, as in the electric-blanket study, the excess loss was most apparent in the months when cold weather was increasing. For this reason, Wertheimer was able again to hypothesize that although there was probably an increased rate of unrecognized spontaneous abortion caused by magnetic-field exposure throughout the colder months, many more such abortions were recognized, and thus reported, during the months of increasing cold.

THE failure of the National Academy of Sciences either to appreciate the significance of Wertheimer's electric-blanket study or to understand the public-health threat posed by exposure to power-line radiation and other electromagnetic fields was underscored in 1986 by a series of stunning disclosures. In February, the Electric Power Research Institute (EPRI), an organization sponsored by major utility com panies across the nation, released the report of a study of the effects of sixty-hertz electric fields on three generations of miniature swine, which had been carried out between 1978 and 1981 by Richard D. Phillips and several associates at Battelle Pacific Northwest Laboratories, in Richland, Washington, and published two months earlier. (Miniature swine had been selected for the study because their body weight approximates that of the average human being.) After Phillips completed the swine study, in 1981, he discussed its findings at the 1982 meeting of the Institute of Electrical and Electronics Engineers' Power Engineering Society, in New York City. According to Phillips, EPRI officials had viewed these findings as "a major bombshell," however, and had delayed their publication for nearly four years by conducting what he claims was "excessive peer review," and by insisting on repeated revisions in Battelle's final report. Because he considered these actions unwarranted interference, Phillips left Battelle in October of 1984, to take up the post of director of the E.P.A.'s Experimental Biology Division, in Research Triangle Park, North Carolina, where Carl Blackman works.

When EPRI finally decided to allow the results of the three-generation swine study to be published, the reason they might have been considered a bombshell was not hard to understand. The first- and second-generation progeny of female swine that were born and bred in sixty-hertz electric fields of thirty thousand volts per metre and then mated with unexposed males not only had lower body weights than the third-generation progeny of unexposed female swine but were afflicted with almost twice as many birth defects.

A few months after EPRI's tardy publication of the results of the miniature-swine study, another important revelation was made at a meeting of the Biolectromagnetics Society, in Madison, Wisconsin. David Savitz, an epidemiologist at the University of North Carolina's School of Public Health, and some colleagues at the University of Colorado, who were replicating Wertheimer's childhood-cancer study for the New York State Power Lines Project, reported that detailed magnetic-field measurements supported the claim by Wertheimer and Leeper that magnetic-field exposure

could be accurately estimated by examining the electrical-distribution wiring near a given home. Their finding was confirmed by Richard Stevens, an epidemiologist at Battelle, and some colleagues who were conducting a study for the project to see if leukemia in adults was associated with alternating-current magnetic fields. Indeed, both study groups concluded that magnetic fields were determined by sources outside the house and were not affected by household wiring or power use. This not only provided belated corroboration for what Wertheimer and Leeper had been saying all along but also was an epitaph for the discredited premise that common household appliances and household wiring gave off strong magnetic fields that were capable of contaminating the home environment.

While Wertheimer and Leeper's wiring-configuration concept was being confirmed, further disquieting revelations concerning the apparent link between power-line fields and cancer came from Jerry L. Phillips, a research scientist at the Cancer Therapy and Research Center, in San Antonio, Texas. Phillips had conducted a series of experiments showing that cultivated human colon-cancer cells exposed to sixty-hertz electric and magnetic fields in combination, and to sixty-hertz magnetic fields alone, proliferate more easily and are more resistant to attack by immune-system lymphocytes than unexposed colon-cancer cells. He told Microwave News that sixty-hertz fields were "capable of producing significant permanent changes in cellular structure and function," and that he considered his experiments "very much in concert with the epidemiological studies that have been published."

In September of 1986, three hundred people gathered in Toronto for a week-long International Utility Symposium on the Health Effects of Electric and Magnetic Fields, sponsored by Ontario Hydro and utilities-industry groups. At that time, the utilities industry's confidence in continuing the policy of stonewalling the power-line health problem was severely shaken by the answer that Richard Phillips gave to a hypothetical question from a member of the audience at an evening session of the symposium. The question was: If you had a family with two young children, would you buy a house next to a high-voltage transmission line if that house were twenty-five thousand dollars cheaper than an identical house situated farther away from the line? Phillips replied that he would not buy such a house, because he felt that it was probable that health hazards were associated with living so close to a transmission line. That answer was especially troubling to the utilities industry because Phillips, the editor-in-chief of the Bioelectromagnetics Society's journal, had long been thought of as having a conservative and non-controversial attitude toward the possibility that power-line radiation might pose a health hazard.

Far and away the greatest blow to the effort of the utilities industry to deny that sixty-hertz electric and magnetic fields could pose a health hazard came on November 20, 1986, when Savitz and his colleagues announced the results of their long-awaited replication of Wertheimer's childhood-cancer study: their findings showed that "prolonged exposure to low-level magnetic fields may increase the risk of developing cancer in children." Indeed, Savitz not only found a statistically significant association between all types of childhood cancer and external magnetic fields but also determined that for children in certain high-exposure groups—for

example, children who had lived very close to high-current wires—the risk was more than five times that of the control population.

Savitz's study was all the more convincing because, although it covered the same geographical area as Wertheimer's, it covered a different time period and, therefore, did not include any of the same cancer cases. In addi tion, Savitz and his colleagues had taken great pains to investigate all possible confounders, and to answer the major points of criticism that had been levelled against Wertheimer's work. For example, they conducted interviews with as many case and control parents as possible, in order to obtain information about such potentially important factors as family cancer history, residential history, social class, parental-occupation history, parental tobacco use and alcohol consumption, exposure of the child in utero to X rays and medication, and illnesses of the mother during pregnancy. They also measured the electric and magnetic fields inside residences that had been occupied before the time of diagnosis. Moreover, the coding of the wiring configuration at all addresses was done in blind fashion—in other words, by a researcher who was unaware of the case or control status of the occupants. Wertheimer had been financially unable to engage such a researcher, and the fact that her study was therefore not blind—except the sample confirmation of her coding which she did at the end—had been the basis of much of the criticism of her work. As for Wertheimer's response to the news that Savitz had confirmed her earlier findings, she made a simple comment to Microwave News that could have served as a fitting rebuke to the National Academy of Sciences: "It is time to accept that something is happening and to find out under what conditions it happens."

At about the same time Savitz announced the results of his study, Stevens and his colleagues at Battelle reported that they had found no link between acute non-lymphocytic leukemia among adults in Washington State and their exposure to ELF electric and magnetic fields at home. Stevens acknowledged, however, that his investigation was weak, because nearly a third of the people who had developed acute non-lymphocytic leukemia were unavailable for study. Moreover, when Wertheimer and Leeper subsequently analyzed his data they found that adults who lived in high-current homes and also used electric blankets, electric mattress pads, or electrically heated water beds did in fact have a significantly increased risk of developing non-lymphocytic leukemia, compared with people who did not live in high-current homes or heat their beds electrically. Indeed, Wertheimer and Leeper estimated that, if the associations they saw in the data were causal, exposure to electromagnetic fields from power lines and/or electrically heated beds could account for twenty-five per cent or more of this type of leukemia in Washington State.

TWO months before Savitz made his announcement, an attempt was made to play down the health hazards posed by low-level electromagnetic fields. This occurred when Scientific American published an article in its September, 1986, issue entitled "The Microwave Problem" and written by Professor Arthur Guy, of the University of Washington, and Kenneth R. Foster, a professor in the Department of Bioengineering at the University of Pennsylvania. Guy and Foster suggested that public concern about microwave radiation was being heightened by unsubstantiated reports that low-level exposure could have adverse biological effects. To prove their

point, they described the rat study that Guy had conducted for the Air Force during the late nineteen-seventies and the early eighties. After declaring that the results of the study “revealed few differences” between the rats that had been exposed to low-level microwave radiation and the control rats, they admitted that “one difference was striking: primary malignant tumors developed in eighteen of the exposed animals but in only five of the controls.” They then said that although this difference was “statistically highly significant,” it should not be interpreted to mean that low levels of microwave radiation could cause cancer, because, as they put it, “the exposed animals had an excess of tumors only in comparison with the controls, not in comparison with the rate of tumor development generally observed in this strain of animals.”

Guy and Foster went on to say that “no single type of tumor predominated,” but they added, “If some specific type of tumor had predominated, that finding would have made a much stronger case for a carcinogenic effect from low levels of microwave energy.” They then found themselves able to conclude that “the finding of excess cancer is provocative, but whether it reflects a biological activity of microwave radiation is not certain,” and that “although some hazard from weak microwave fields might be proved in the future, there is currently little evidence for the presence of such a hazard.” They then recommended that “some criteria must be developed for determining when to halt research on a given topic, open questions notwithstanding.”

In its December, 1986, issue Scientific American published a letter from Louis Slesin, of Microwave News. “Contrary to what Guy reports about his own results, the malignant tumors were heavily concentrated in the rats’ endocrine systems: nine in the exposed animals compared with only two in the controls,” Slesin wrote. He then made a devastating comment. “That a principal investigator for a $4.5-million study should obscure his own positive results points to a basic feature of the ‘microwave problem’: the domination of military funding for biomedical research on non-ionizing radiation and the reliance on engineers rather than biologists to do the research.” He noted that both Guy and Foster were engineers.

Meanwhile, the electronics industry had also been trying to play down the hazards of electomagnetic fields. In October of 1982, the Electronic Industries Association co-sponsored, with the National Association of Broadcasters (N.A.B.) and the Association of Home Appliance Manufacturers, a three-day seminar entitled “RF Radiation: Legal and Policy Implications” at the Homestead, in Hot Springs, Virginia. In their letter of invitation the sponsors of the seminar wrote, “Today in the United States there is an irrational fear of radiation energy associated with electrical/electronic systems operating at frequen cies from 60 Hz to the highest microwave frequencies.” They went on to warn that “the cost to the public and industry in terms of money, time, and unnecessary fear continues to grow as litigation, quasi-litigation and public opposition to electrical technology grows.” The seriousness with which they took their mission is evident from the last two sentences: “To permit a free exchange of thoughts on this sensitive subject, the meeting will not be opened to the press, and no records of the proceedings will be issued. For the same reason, cameras and recording devices will not be permitted in the meeting rooms.”

The organizing committee for the Hot Springs seminar had thirteen members, who included its chairman, John Osepchuk, of Raytheon; George A. Kiessling, the director of product safety at the RCA Corporation, in Cherry Hill, New Jersey; John Mitchell, of the Air Force; Ronald C. Petersen and Max M. Weiss, of the Bell Telephone Laboratories, who had conducted studies purporting to show that no harmful radiation was being given off by video-display terminals (VDTs); and representatives of the Electronic Industries Association, the N.A.B., and the Association of Home Appliance Manufacturers. In 1973, Osepchuk, testifying before the Senate Committee on Commerce in behalf of the Association of Home Appliance Manufacturers, had quoted with approval someone describing the radiation hazards of microwave ovens as being “about the same as the likelihood of getting a skin tan from moonlight.” In 1982, at the Hot Springs seminar, he pushed hard for the formation of an alliance to counter public fear of the health hazards of non-ionizing radiation, and in February of 1984 the Electromagnetic Energy Policy Alliance (E.E.P.A.) was organized. Its founding members were A.T. & T.; GTE; the MCI Telecommunications Corporation; Motorola; the N.A.B.; RCA; Rockwell/Collins; and Raytheon. By the summer of 1985, the E.E.P.A. had been joined by CBS, NBC, I.B.M., and Rockwell International. Some seventy-five representatives from leading electronics and communications firms across the nation attended the E.E.P.A.’s second annual meeting, held in May of 1986, in Washington, D.C. Among their chief preoccupations were how to deal with litigation and public concern over low-level radiation.

One of the speakers at a session on microwave lawsuits was John Mitchell. He described in detail how the Air Force had used Representative Studds in 1978 to assure Cape Codders that they could depend upon the Air Force to do an honest and accurate job of measuring microwave-radiation levels. “We decided that we would go through the congressional office out there, since it [the problem] had a lot of congressional attention, and that we would suggest to them that they gather some of their local smart guys, their local citizens, people that the community would have some trust in, and let them go with us and make these measurements,” Mitchell said. “As a matter of fact, we said, we will let you pick the spots and you go with us and you check everything we do, and when we’re done you give the data to your fellow citizens and see if we can’t have a little closure on at least the facts of what the radiation levels are.” Mitchell went on to tell his listeners that the observers had gone back to their fellow-citizens and said, “Yes, it’s true, the Air Force does have a good measurement system.” He then boasted that the Air Force had repeated this maneuver with citizens in California who were concerned about the potential health hazard of radiation from the PAVE PAWS radar constructed at Beale Air Force Base. “We made the measurement s, talked about data, how it related to the radiation levels, and eventually that did quiet them down,” he said, and he added that the Air Force was continuing to provide such assurances to citizens worried about the health effects of PAVE PAWS radars that were nearing completion in Georgia and West Texas. Mitchell said that a question had been raised about whether it was safe for a local rancher to fly his private plane in and out of a small airstrip that was situated very close to the PAVE PAWS radar in Texas, but he assured his listeners that after making appropriate measurements from a helicopter the Air Force had decided that flying in the vicinity of PAVE PAWS posed no

hazard. It was two years after he gave this assurance that the Air Force found it necessary to consider moving the PAVE PAWS at Robins Air Force Base, in Georgia, in order to reduce the danger of explosion in airplanes flying through its main beam.

A featured speaker at the E.E.P.A.'s fourth annual meeting, held in April of 1988, in Alexandria, Virginia, was Dr. David 0. Carpenter, of the New York State Department of Public Health, who had served as the executive secretary of the Power Lines Project. Carpenter minced no words in describing the results of the Savitz study to the hundred or so members of his audience, who included representatives from a dozen major utility companies. Savitz, he told them, had found that leukemia, lymphoma, and brain tumors—the most common forms of cancer in children—were twice as likely to occur among children living in homes near high-current-distribution lines, and that "the basis for the hypothesis that magnetic fields cause cancer is now established." Carpenter then suggested to the E.E.P.A. members that it was not ethical for them to sit around for another ten years before doing something about the problem, because fully twenty per cent of the homes in the Greater Denver area had been found to have elevated magnetic fields. "We are where we were with cigarette smoking and cancer twenty-five years ago," he said. Research money for studying the problem had "almost totally dried up," and most of the work was now being financed by EPRI, which had a built-in conflict of interest, because it was supported by the utilities industry. In conclusion, he urged that the additional research be financed by federal agencies in an atmosphere "clearly independent of partisan influence."

Carpenter was followed by Edwin L. Carstensen, a professor of electrical engineering, radiation biology, and biophysics at the University of Rochester. Carstensen said that the strength of the magnetic fields given off by transmission lines was very low, and that a person could be exposed to fields of between twelve and eighteen milligauss simply by sleeping under an electric blanket. He did not mention the findings of the electric-blanket study by Wertheimer and Leeper.

As it happens, Carstensen had played a major role in a Texas lawsuit that was causing tremendous anxiety among officials of the electric-utility industry. It was a case in which the Houston Lighting & Power Company had sued the Klein Independent School District, of Houston, over a 345-kilovolt transmission line that crossed school property. The problem had begun in 1981, when the company instituted condemnation proceedings for eight and a half acres of the school district's land, and built a power line that ran within three hundred feet of an elementary school, a hundred and thirty feet from an intermediate school, and less than two hundred and fifty feet from a high school. From the outset, Donald Collins, the superintendent of the district, had raised questions about the possible health effects of the power line, and when he received no satisfactory answers to his queries the school board had refused to grant Houston Lighting & Power a right-of-way, and the company sued.

The lawsuit went to trial on November 10, 1985, before Judge Edward J. Landry, in Harris County Civil Court-at-Law No. 1, in Houston. That day, H. Dixon Montague, a thirty-three-year-old attorney with the Houston law firm of Vinson & Elkins, which represented the school district, called

Carstensen, who was the chief expert witness for the Houston Lighting & Power Company, to the stand as an adverse witness for the defendant. (In a condemnation proceeding, the burden of proof is on the property owner, so Montague opened the case for the defense.)

Early in his direct examination, Montague asked Carstensen if it was true that he had given testimony on the health effects of transmission lines in approximately twenty previous administrative or judicial hearings.

“That’s approximately correct, yes,” Carstensen replied.

“Now, in every instance you were testifying for a power-line company?” Montague asked.

“Yes, I believe so,” Carstensen said.

After establishing that none of the hundred and sixteen publications listed on Carstensen’s résumé dealt with the health effects of magnetic fields emitted by transmission lines, Montague got Carstensen to acknowledge that he and Charles J. Bennett, the supervising engineer of Houston Lighting & Power’s engineering-planning department, had measured the electric and magnetic fields from the power line in question on a Sunday morning, when their strength was only about a third of what it would have been during the week. Later, Carstensen said that even if children were exposed to a magnetic field of from six to fifteen milligauss for seven to eight hours a day over the entire school year he could see “no basis to conclude that they would have a higher risk of cancer than any other population.”

When Montague finished examining Carstensen as an adverse witness, he called Marvin L. Chatkoff, an associate professor of engineering at the University of Texas at San Antonio, who had been retained by the Klein Independent School District to make magnetic-field measurements in the district, and to calculate what the increased strength of those fields would be when the 345-kilovolt power line became fully operational. Professor Chatkoff told the jurors that he had measured magnetic fields of five milligauss in front of the elementary school and nearly ten milligauss at the intermediate school, and had found a level of more than fifteen milligauss in the school-district’s parking lot and in front of the high school. He estimated that if Houston Lighting & Power were to activate the transmission line to full capacity, magnetic-field-strength levels at the elementary school would be at least twelve milligauss, and could be as high as twenty-five milligauss at the intermediate school.

Following Chatkoff’s testimony, Nancy Wertheimer took the stand and described the results of her childhood-cancer study. When Montague asked her whether she believed that children attending schools in the Klein Inde pendent School District would face any risk of developing cancer as a result of being exposed to the magnetic fields that had been measured and estimated by Chatkoff, she said she thought that it was “indefensible to expose those children to that experiment.” Under cross-examination by Ross Harrison, an attorney with the law firm of Baker & Botts, which was representing the Houston Lighting & Power Company, Wertheimer acknowledged that she had no absolute proof that exposure to electromagnetic fields

would cause cancer. “My own belief is it’s more likely that it keeps the body from fighting off cancer, or from protecting itself against cancer,” she said.

Later, Montague called Dr. Harris Busch, an oncologist, who had been the chairman of the Department of Pharmacology of the Baylor College of Medicine, in Houston, for twenty-five years. A former editor of the distinguished American Journal of Cancer Research, Busch placed a metronome on the railing of the witness stand, set it in motion, and said that he would like to use it to explain how a magnetic field might work to promote cancer. “A metronome is just a device which in essence moves in two directions,” he told the jurors. “And a sixty-hertz field is a field where first the magnetic wave moves in one direction and then it moves in another direction, just like this device is doing. Only it happens sixty times a second.”

Busch explained that this meant that “any kind of molecule that is in this person’s brain, or in this person’s body, is being twisted sixty times a second up and back.” After reminding the jurors that the schoolchildren would be exposed to strong magnetic fields from the power line for about eight hours each day during the school year, for periods of up to thirteen years, he informed them that nothing could obstruct the passage of electromagnetic fields. “These fields go through glass,” he said. “They go through concrete. They simply are not stopped by anything in the environment.”

When Montague rested the case for the defendant, Harrison called as the first witness for the plaintiff Allen B. Hague, a research analyst in Houston Lighting & Power’s engineering-planning department. Hague testified that two of his five daughters attended the intermediate school, and that he did not believe that the transmission line posed any health hazard. Later, Harrison called Charles Bennett, Hague’s superior, who had already testified that part of his corporate responsibility was to keep abreast of the scientific literature on the health effects of transmission lines, and now said that he had been unable to find any evidence that would lead him to conclude that the lines could have harmful effects. Under voir-dire examination by Montague, Bennett acknowledged that the Sunday when he measured the magnetic fields on the Klein school district’s property with Carstensen was the first time he had made magnetic-field measurements.

Resuming his direct examination of Bennett, Harrison sought to play down the magnetic-field hazard from the high-voltage transmission line in the Klein In dependent School District by showing that strong magnetic fields could also be generated by ordinary low-voltage distribution lines. In so doing, he drew attention to something that the utilities had been hoping to keep under wraps ever since Nancy Wertheimer published her findings on childhood cancer, in 1979.

“Do some distribution lines put out magnetic fields in such a manner that a person who’s exposed to them would be exposed to magnetic fields equal to or similar to magnetic fields put out by the transmission lines?” Harrison asked.

“Yes, sir,” Bennett replied.

“You testified earlier that distribution lines are quite often in imbalance,” Harrison said. “Is that correct?”

“Yes, sir.”

“And imbalance causes magnetic fields to be greater,” Harrison said. “Is that correct?”

“Yes, sir.”

“What features are there about distribution lines that would cause them to have large magnetic fields?”

“ ‘Large’ in the sense that distribution lines are closer to where people live, where they go to school,” Bennett said. “So that’s what I mean by ‘large.’ If a transmission facility put out, say, more magnetic fields than the distribution facilities, by the time it gets to the actual place where you are concerned, they are probably, you know, the same order of magnitude.”

“Distribution lines run through people’s back yards?” Harrison inquired.

“Yes,” Bennett said.

“Down neighborhood streets?”

“Yes.”

“And are located closer to homes than transmission lines might be located to these schools,” Harrison said. “Is that correct?”

“Of the eighteen thousand miles of distribution lines that we have in our service area, I would say on average distribution lines are located closer to homes because that’s where they are headed,” Bennett replied.

After Montague and Harrison presented their final arguments, Judge Landry delivered his charge to the jury, instructing the jurors to answer seven questions on specific issues relating to the case. The jury retired, and deliberated for about four hours before returning its verdict. To begin with, the jury found that the Houston Lighting & Power Company had “abused its discretion” in taking approximately eight and a half acres of the Klein Independent School District’s property for its power line, and that this constituted a “willful and unreasoning action.” The jury proceeded to award the school district $104,275 as compensation for actual damages that it had sustained as a result of the utility’s use of school-district land for some three and a half years. The jurors also found that in constructing and operating the power line on school property Houston Lighting & Power had acted with “reckless disregard” and with “conscious indifference to the rights and welfare of the persons affected.” As a result, they awarded the school district twenty-five million dollars in punitive damages “as an example that [the utility’s] conduct will not be tolerated.” The jury went on to find that the reasonable cost to the

school district of replacing or restoring its property and facilities to their original condition would be $42,113,120. (What the jurors had been asked to decide was how much compensation the school district was entitled to receive if Houston Lighting & Power had not acted with reckless disregard, and were to be allowed to keep its power line on school property; their answer was, in effect, that it would cost somewhat more than forty-two million dollars for the school district to move its facilities to a new site.)

Given the jury's verdict, Judge Lan dry issued a mandatory injunction ordering Houston Lighting & Power to shut down its power line and remove it from school property. The utility quickly asked a three-judge Court of Appeals for permission to keep the power line in operation while the rest of the case was on appeal. Early in 1986, the Appeals Court told Judge Landry that he must allow the utility to turn the line back on. Montague appealed this ruling to the Texas Supreme Court, and at the end of 1986 that court unanimously overruled the Appeals Court by upholding Judge Landry's injunction to shut the power line down.

A year later—in November of 1987—the Appeals Court reversed the twenty-five-million-dollar punitive-damages award, on the ground that when Houston Lighting & Power took the school-district land for its power line it had been in technical compliance with the Texas Property Code, and, since it was not guilty of trespass, it could not be held liable for punitive damages. (Montague appealed this decision to the Texas Supreme Court, where it was turned down in May of 1989.) At the same time, the Appeals Court judges upheld the rest of the trial jury's verdict, ruling that the jury had been correct in finding "clear and convincing evidence" of potential health hazards caused by electromagnetic fields and in concluding that Houston Lighting & Power had abused its discretion in siting a 345-kilovolt power line on school property. Meanwhile, during the summer of 1987, Houston Lighting & Power had removed the power line and rerouted it, at a cost of more than eight and a half million dollars. Since then, the members of a family whose land had been condemned by Houston Lighting & Power for the right-of-way of the same 345-kilovolt transmission line have sued the utility, alleging that electromagnetic fields from the line were responsible for a brain tumor that one of them developed in 1987.

ON July 1, 1987, the scientific advisory panel of the New York State Power Lines Project issued a final report of the five-year, five-million-dollar research program that had been undertaken as a result of an agreement between the New York State Public Service Commission (P.S.C.) and the Power Authority of the State of New York, following power-line hearings that ended in 1977. The report was entitled "Biological Effects of Power Line Fields," and it was poorly organized, equivocal in its assessments, and contradictory in its conclusions; it was apparently designed to persuade the public that sixty-hertz radiation could cause only a few effects, and that the significance of those effects would have to await further study. The report's flaws emerged in the introductory "Non-Technical Summary." The lead paragraph declared that most of the research groups in the study program had reported "no effects of concern." (The fact was that no fewer than twelve of the seventeen projects in the research program had reported statistically significant biological

effects, but the members of the scientific advisory panel did not get around to acknowledging this until much later in their report.) The second paragraph said that there were some “small but consistent” changes in behavior and brain function, and that changes had been observed in the ability of rats to learn. The third, and final, paragraph read:

A more serious concern comes from a study of cancer in children suggesting that children with leukemia and brain cancer are more likely to live in homes where there are elevated 60-Hz magnetic field levels than are children who do not have cancer. Although much more research is needed before the question whether the magnetic fields actually cause or promote cancer can be resolved, the basis for such an hypothesis is now established. At this time no risk assessments can be made because only four studies of this question have been made and the two which report an association are from the same geographic region. More research on cancer as a function of magnetic fields is needed, both in homes and for on-the-job exposure.

At the bottom of page 85 of their report, the members of the scientific advisory panel concluded that if the wiring-code distribution that had been observed by Savitz in Denver proved to be valid for other parts of the nation, and if the assumption that magnetic fields cause cancer in children held true, “this would mean that 10-15% of all childhood cancer cases are attributable to magnetic fields.” In the final section of their report, though, they performed an intricate dance of avoidance on the hot coals of this astonishing possibility. “Research sponsored by this project and related research has demonstrated a variety of effects of electrical and magnetic fields,” they wrote. “These findings do not readily translate into concrete regulatory recommendations on width of right-of-way, line heights, or location of lines near homes.”

In refusing to draw any conclusions from the research undertaken by the Power Lines Project, the scientific advisory panel was leaving the unpleasant task of recommending preventive measures to a six-member Power Lines Project evaluation task force, which was made up of staff members of the P.S.C. On January 11, 1988, after studying the problem for several months, the task force sent the Public Service Commissioners a twenty-nine-page report analyzing the scientific advisory panel’s final report. At the beginning of the new report, the task-force members took note of the P.S.C.’s ten-year-old decision that the strength of the electric field at the edge of all future transmission-line rights-of-way should not exceed sixteen hundred volts per metre, and that there would be a moratorium on higher electric fields until the results of the Power Lines Project research programs could be further evaluated. They also noted that in 1978 the commissioners had selected the interim sixteen-hundred-volt-per-metre limit so that “the risks, if any, of long-term exposure to transmission line electric fields would be no greater than those which society has implicitly accepted of long-term exposure to the 345 kV lines operating for many years throughout the State.” Under the heading “Project Results” they passed on to the commissioners the equivocal evaluation that had been made by the members of the scientific advisory panel:

Twelve of the 17 projects reported statistically significant biological effects under certain sets of laboratory test conditions. However, neither

the researchers nor the Panel identified any adverse human health effects from the laboratory studies. Although the sponsored research and other research reviewed by the Panel demonstrated a variety of subtle effects of electric and magnetic fields, the Panel was unable to make any concrete regulatory recommendations on width of rights-of-way, line heights, or location of lines near homes. Because most of the experiments used high field levels typical of transmission line rights-of-way, most researchers were not able to examine whether an effect persisted at lower field intensities or whether there was a threshold below which an effect disappeared.

The last sentence was scientifically suspect, for two reasons. First, high levels of exposure—whether to toxic chemicals, asbestos, or radiation—are used in animal experiments to increase the possibility that biological effects, if they are to occur, will occur in the relatively few rats, rabbits, or guinea pigs that are available for study. The high-dose observations in the test animals can then be extrapolated mathematically to equate the lower-dose levels to which a huge human population may be exposed. Second, the fact that most researchers were unable to determine whether the effect persisted at lower levels was irrelevant, because, as a simple matter of prudent public-health policy, the panel and the task force should have assumed that the effect would persist at lower levels, and should have held to that assumption until it had been conclusively demonstrated that the effect did not. A further absurdity of the panel's caveat was revealed two pages later, when the authors of the task-force report repeated the estimate that ten to fifteen per cent of all childhood cancer cases might be attributable to the magnetic fields found in many homes.

The six members of the task force did not venture to say whether they believed that parents had "implicitly accepted" the extraordinary potential risk of childhood cancer—a risk associated with exposure to magnetic fields of only two and a half milligauss—in the same way that they were supposed to have recognized and accepted the hazard of long-term exposure to magnetic fields in the hundreds of milligauss from 345-kilovolt power lines. Instead, they chose to cite a form letter that Dr. Carpenter, the executive secretary of the Power Lines Project, had been sending out in response to inquiries about the Savitz study. In his letter Carpenter pointed out that children who live in homes where parents smoke face a far greater risk of developing cancer than they face from the effects of magnetic fields. Invoking parental cigarette smoking to diminish concern about childhood exposure to alternating-current magnetic fields is hard ly scientific, not the least of the reasons being that children exposed to magnetic fields are prone to develop leukemia, lymphoma, and cancer of the brain (as Carpenter himself had pointed out at the E.E.P.A. meeting), not lung cancer.

In the end, the members of the task force advised the commissioners to continue the ten-year-old interim electric-field standard of sixteen hundred volts per metre at the edge of transmission-line rights-of-way, and recommended that they "adopt an interim edge of right-of-way magnetic field standard to ensure that future transmission lines do not produce magnetic fields greater than the fields typical of the many existing 345

kV lines operating throughout the state.” They then undertook to defend their recommendation with this tortured paragraph:

Central in the minds of individuals familiar with the Power Lines Project is the epidemiological study of childhood cancer. Clearly, if this research had established a causal link between cancer and magnetic field exposure, a careful risk assessment (to put the increased risk of cancer in proper perspective compared to other risks society tolerates) and appropriate regulatory action would be required. Further, because the magnetic fields associated with the increased cancer risk (on the order of 2.5 milligauss) are equivalent to those found in many homes, the appropriate regulatory response could involve fundamental changes in the way electrical energy is distributed and used in society. But a causal link has not been established. Additional research in this area is needed.

In the last three pages of the report, the task force not only concurred with the panel’s conclusion that the findings of the Power Lines Project’s research program “do not readily translate into concrete regulatory recommendations on width of rights-of-way, line heights, or location of lines near homes” but declared that the research “revealed no evidence that magnetic fields pose a health hazard.” This highly dubious assertion paved the way for the final two paragraphs of the report. The first paragraph read:

An interim magnetic field standard should ensure that magnetic fields at the edge of future transmission line rights-of-way are no greater than the fields typical of the many existing 345 kV lines operating throughout the State. Based on a limited number of measurements of transmission lines in New York State, the proper interim limit may be about 100 milligauss. However, if the Commission chooses to adopt an interim magnetic field standard, additional information about existing transmission lines would be needed to determine the proper interim magnetic field limit. Since the limit would not be directly related to biological effects, information about the effects of magnetic fields would not be required.

Because the last sentence of this paragraph might cause anyone to wonder what an interim magnetic-field limit could be directly related to, if not to the biological effects of magnetic fields, the task force gave a final paragraph of advice to the Public Service Commissioners, which brought them full circle to the conclusion that the commissioners themselves had reached ten years earlier:

If a magnetic field limit is adopted, it should be made clear that magnetic fields have not been shown to be hazardous and that the purpose of the limit is to ensure that exposures to magnetic fields in future transmission line designs would be no greater than those which society has implicitly accepted for the 345 kV lines operating for many years throughout New York State.

On February 24, 1988, the Public Service Commissioners met in Albany and issued an order continuing the ten-year-old transmission-line electric-field standard and directing that an interim magnetic-field standard be developed. The commissioners noted that their staff had suggested an interim limit of one hundred milligauss, but said that additional

information about the magnetic-field strength of existing transmission lines was needed before the standard could be set. As a result, the commissioners announced that they would convene a technical conference and direct New York State's electric utilities to provide data concerning the magnetic fields being generated by the state's 345-kilovolt transmission lines. Their next sentence indicated that they, too, had decided to participate in the ballet: "Other parties will be welcome to participate in this conference, but since the interim standard will not be directly related to biological effects, information about the effects of magnetic fields will not be considered at the conference." As if concerned that they might be accused of failing to protect the civil rights of magnetic fields, they added that "although we are considering the option of an interim magnetic-field standard, we emphasize that magnetic fields have not been shown to be hazardous, and that the purpose of any standard would be to ensure that exposures to magnetic fields in future transmission line designs would be no greater than those which now exist for the many 345 kV lines operating for years throughout New York State."

What would have been laughable about such posturing were its consequences not so potentially disastrous was that the interim standard the commissioners were considering was not only thirty to fifty times as great as the magnetic-field levels demonstrated to be associated with a twofold increase in the development of fatal cancer in children but also far greater than the alternating-current magnetic fields that were being generated by thousands upon thousands of miles of ordinary low-voltage distribution lines throughout New York State. Indeed, such fields undoubtedly exist in many homes, residential neighborhoods, school buildings, and business districts from one end of the state to the other.

WHILE the New York Public Service Commission was failing to deal with the power-line problem, Congress did take a belated step toward coming to grips with it. On October 6, 1987, the House Subcommittee on Water and Power Resources, whose chairman was Representative George Miller, a Democrat from California, held a one-day hearing on the health risks associated with transmission lines. At that time, Dr. Robert 0. Becker, who had warned the P.S.C. nearly fourteen years earlier about Navy research showing that ELF radiation could cause adverse biological effects, together with Jerry Phillips, David Savitz, and Ross Adey, called for a congressionally mandated research program that would be conducted by a team of appropriately skilled and independent scientists. The subcommittee members then heard testimony from Dr. Leonard Sagan, the manager of EPRI's radiation-studies program, who told them that Savitz's replication of Wertheimer's childhood-cancer study was not clearcut or conclusive. "All we know about the exposure of those children was the size of the lines passing the house," Sagan said. "We don't know about electric blankets, or hair blowers, or what they experienced at school or elsewhere. So there is a good deal of uncertainty in our minds."

In addition to uncertainty, there was apparently a good deal of apprehension in the minds of Sagan and his colleagues at EPRI. Ten months earlier, an EPRI senior vice-president was said to have described the debate over the health effects of power-line radiation as "a jugular issue for the industry," and Sagan himself had been quoted in the December 3, 1986, issue of the Energy Daily, a utility-industry newsletter, as saying

that the link between transmission lines and cancer was worrying the industry and needed to be resolved. “Lawyers know about this stuff,” he told the newsletter. “Reporters will know about it soon enough. We don’t have a choice.”

When the hearing was over, Representative Miller wrote to Sagan and other witnesses, asking them to follow up their testimony by supplying written answers to a number of detailed questions. “In 1979, Dr. Nancy Wertheimer found results which some considered startling,” Miller wrote in his letter to Sagan. “Why didn’t EPRI agree to fund a repeat of the Wertheimer study to confirm or deny her findings?”

Sagan’s response to Miller’s question seemed both evasive and misleading. “EPRI was not asked to fund a repeat of the Wertheimer study,” he maintained. “We chose not to take an initiative to repeat this work because the New York Power Lines Project undertook a replication, the results of which are now available.” Sagan not only failed to tell Miller that EPRI had attempted to discredit Wertheimer’s study but also neglected to mention that back in 1982 EPRI had sent a highly critical (and, it turned out, inaccurate) assessment of her findings to the scientific-research coordinator of the Power Lines Project, whose scientific advisory panel was then in the process of deciding whether to replicate her work.

DURING 1988, an important legal battle over power lines began in Goshen, New York, where fifty-eight landowners had filed a sixty-six-million-f ive-hundred-thousand-dollar lawsuit in the New York State Court of Claims against the New York Power. Authority, as the Power Authority of the State of New York was now called. The plaintiffs in the case alleged that a two-hundred-and-seven-mile-long, 345-kilovolt transmission line, called the Marcy South line, which the Power Authority had built from Marcy, in Oneida County, to East Fishkill, in Dutchess County, and had gone into operation in May of 1988, had created a “cancer corridor,” which had destroyed the market value of the land adjacent to its right-of-way.

In preparation for the trial, Crow-ell & Moring, a law firm in Washington, D.C., that represents the Power Authority, hired eight scientists as expert witnesses. They submitted writ ten testimony in June that no significant health effects would result from exposure to the Marcy South line. According to Microwave News, none of those scientists had ever performed any research on the biological effects of sixty-hertz electric or magnetic fields. In the July/August issue of the newsletter, Slesin provided a synopsis of the conclusions that seven of the eight had drawn in their written testimony.

Dr. Stuart Aaronson, the chief of the laboratory of cellular and molecular biology at the National Cancer Institute (a division of the National Institutes of Health), in Bethesda, Maryland, reported that there was “no scientific basis for concluding that power frequency elec tric and magnetic fields induce any consistent effects on cell growth properties in culture or in vivo that are associated with the acquisition of malignant properties.” (In arriving at this opinion, Aaronson declared that Jerry Phillips’ studies showing that cultured human cancer cells proliferate in the presence of such fields were seriously flawed.)

Dr. Richard Bockman, a researcher and attending physician at the Memorial Sloan-Kettering Cancer Center, in New York City, stated that “no endocrine or metabolic disorders can be demonstrated in animals or man exposed to EMF fields at the levels generated by electric power lines.” (His statement ignored studies conducted by Richard Phillips and his associates at Battelle, showing that ELF radiation could inhibit the pineal gland’s secretion of melatonin, the hormone that regulates circadian rhythms and has been shown to inhibit tumor growth.)

Roswell Boutwell, a professor in the Department of Oncology of the University of Wisconsin, in Madison, concluded that “there is no scientific basis for the assertion that power frequency electric and/or magnetic fields are either cancer initiators or promoters.” (This ran counter to the conclusions drawn by Wertheimer, Milham, and Savitz on the basis of their epidemiological studies, and by Adey, Jerry Phillips, and others on the basis of experimental investigations.)

Dr. Edmund A. Egan II, a professor of pediatrics and physiology at the University of Buffalo, concluded, “with confidence,” that “electric and magnetic fields associated with electric power generation, transmission and use have had no ill effects on reproduction or prenatal development.” (He found himself able to draw this conclusion despite the fact that the three-generation mouse study conducted by Andrew Marino, the biophysicist who had played an instrumental role in the New York State power-line hearings, had been partly confirmed by the three-generation swine study and other experiments conducted by Richard Phillips, at Battelle.)

Dr. Lucius Sinks, a specialist in pediatric cancer at the National Cancer Institute, reported that “after consideration of genetics, hematology, immunology, and epidemiology taken as a whole, it is my opinion that there is no causal relationship between exposure to power frequency electric and magnetic fields and childhood cancer.” (Sinks arrived at this opinion despite the fact that three out of the four studies of childhood cancer published in the medical literature have shown an association between cancer in children and their exposure to alternating magnetic fields from nearby electrical-distribution lines.)

Dr. Margaret Tucker, an epidemiologist at the National Cancer Institute, declared that research had yielded “no persuasive scientific evidence of increased risk of cancer in children or adults from exposure to power frequency electric and/or magnetic fields.” (Tucker has also testified in behalf of the Potomac Electric Power Company in a hearing involving a 500-kilovolt power line in Maryland; in behalf of the Mississippi Power Company in another lawsuit involving power-line radiation; and in behalf of utilities in Colorado and Arizona.)

Herbert S. Terrace, a professor in the Department of Psychology of Columbia University, reported, “Efforts to show that power frequency electric fields influence the performance of learned behavior have proved nil.” (Professor Terrace’s review failed to include a study that had been conducted for the New York State Power Lines Project by Kurt Salzinger, of Polytechnic University, in Brooklyn, who had found significant permanent changes in the learning ability and performance of rats exposed in utero and after birth to sixty-hertz electric and magnetic fields. Terrace told

Microwave News that he had read Salzinger's study but had "theoreti cal and procedural" problems with it.)

The trial opened, before Judge Peter A. McCabe, on September 8, 1988. In a pretrial report Professor Chatkoff, of the University of Texas, had testified for the plaintiffs that a magnetic field of three milligauss or more in strength would be present at a distance of five hundred feet or more from the Marcy South line. At the trial, Andrew Marino testified that in his opinion no institutional review board in the United States would approve an experiment in which human beings were exposed to such electromagnetic fields if their informed consent had not first been obtained. Jerry Phillips testified about his experiments showing that cultured human cancer cells proliferate when they are exposed to power-line electric and magnetic fields. Dr. Harris Busch, the oncologist, said he believed that it was "dangerous" to live in an area where the magnetic-field strength was three milligauss or more. The final witness for the landowner plaintiffs was Dr. Lennart Tomenius. He described his study linking childhood cancer in Sweden with exposure to power lines, and also stated that he believed three milligauss to be a hazardous level of exposure.

Professor Terrace testified in behalf of the New York Power Authority that there was no reasonable scientific basis for people to fear transmission lines. When he was asked whether any of the studies he had reviewed had found negative effects in animals, he replied, "None whatsoever." Terrace's opinion was supported by Dr. Kenneth Zaner, an assistant professor of medicine at the Harvard Medical School. He testified that from a biophysical point of view there was no evidence of a health risk from power-line electric and magnetic fields.

During the autumn, the Power Authority complied with a request from Louis Slesin that it inform him of the exact amount that it had paid to each of its expert witnesses, and Slesin pub lished the tally in Microwave News. Dr. Aaronson, of the National Cancer Institute, received $70,250.98 for his testimony; Dr. Bockman, of the Memorial Sloan-Kettering Cancer Center, $56,950.70; Boutwell, of the University of Wisconsin, $74,256.74; Dr. Egan, of the University of Buffalo, $24,338.92; Dr. Sinks, of the National Cancer Institute, $41,083.42; Terrace, of Columbia University, $54,153.69; Dr. Zaner, of the Harvard Medical School, $33,512.74; and Dr. Tucker, of the National Cancer Institute, $12,978.04 on the basis of preliminary billing.

The total amount of money that was paid to those eight witnesses was over three hundred and fifty thousand dollars. The plaintiffs paid their five witnesses a total of just over sixty thousand dollars: Dr. Busch received twenty thousand dollars; Chatkoff between six thousand and seven thousand dollars; Marino twenty thousand dollars; Phillips approximately six thousand five hundred dollars; and Dr. Tomenius nine thousand dollars.

On December 29, 1988, Ross Adey wrote a letter to Dr. James B. Wyngaarden, the director of the National Institutes of Health (N.I.H.), in Bethesda, telling him that Drs. Aaronson, Sinks, and Tucker, of the National Cancer Institute, had testified at the trial, and how much they had been paid for doing so. (Adey also informed Wyngaarden that Dr. Mark Israel, the chief

of the National Cancer Institute's Molecular Genetics Section, had testified for a power company.) He then quoted from N.I.H. regulations dealing with outside work and activities, which state, "Total compensation from consulting with profit-making organizations, including industry and law firms, and from testimony in private litigation, is limited to $25,000 per year, with no more than $12,500 from any individual or law firm."

After reminding Wyngaarden that the National Cancer Institute was planning to study the association between childhood leukemia and electromagnetic fields, Adey said that the N.I.H. scientists who testified at the Goshen trial "as hirelings of vested interests" had clearly called into question the National Cancer Institute's ability to conduct or oversee objective research into the problem.

Early in February of 1989, Adey received a reply from Wyngaarden, saying that he had initiated a "full review" of the circumstances Adey had cited in his letter. The review did not begin until late May, however. Meanwhile, no one has explained how the National Cancer Institute can participate in an objective assessment of childhood leukemia and power-line radiation when several of its leading researchers have testified under oath that there could not possibly be a link between the two.

OVER the years, community opposition to power lines has been mounted in many states. Perhaps the most successful was organized in the summer and the autumn of 1987 by Citizens Against Overhead Power Lines, Inc., a group of homeowners in the Highline area of South Seattle, in Washington State. They waged a campaign against a proposal by Seattle City Light to construct a pair of two-and-a-half-mile-long, 230-kilovolt power lines on either side of State Route 509, between the city's South Ninety-eighth and South 136th Streets.

In May of 1986, City Light had recommended that the two power lines be constructed, and had issued an environmental-impact statement to support the recommendation. Anyone who took the time and trouble to read those portions of the statement which described magnetic fields that had been measured and estimated by the Bellevue, Washington, engineering and consulting firm of Wilsey & Ham might well have been alarmed by the firm's assessment of field strengths given out by the ordinary electrical-distribution lines that had been serving neighborhoods in South Seattle for many years. Over five hundred homes in the area were estimated to contain fields of more than five milligauss, and nearly two hundred of those homes were estimated to have fields of between ten and nineteen milligauss. The magnetic-field strengths on Fourteenth Avenue South were unusually strong, because a pair of high-current distribution feeder cables passed along the street. Wilsey & Ham had estimated that the lowest magnetic-field strength would be created if the proposed transmission lines were installed along Route 509, and that estimate undoubtedly accounted for City Light's recommendation that they be placed there.

As for the health hazards associated with these magnetic fields, City Light's impact statement offered little comfort. It said that the possibility of a correlation between magnetic-field exposure and cancer could not be dismissed, and it acknowledged that the magnetic fields that would be produced between a hundred and a hundred and fifty feet from the

proposed lines would be “stronger than the fields implicated in the early epidemiologic studies.”

On June 29, 1987, the Seattle City Council met and voted seven to one to accept City Light’s environmental-impact statement and its recommendation that the transmission lines be built along State Route 509. By that time, a small group of Highline residents, led by Thomas Manley, a retired teamster who lived on South 136th Street, had begun to get in touch with families living along Route 509 and to organize Citizens Against Overhead Power Lines, Inc. Only eighteen people attended the group’s first meeting, in July, but by November a hundred and fifty families had become members. On December 1st, Manley wrote to Governor Booth Gardner, pointing out that although City Light’s own impact statement had revealed a possible connection between electromagnetic radiation from power lines and brain damage and childhood cancer, the utility had taken the position that it was an “acceptable risk” to build high-voltage power lines within a few feet of residential dwellings. Manley asked for the Governor’s help “to avoid harming children, and to save the City and State the huge expense of future litigation and potential liability.”

By then, City Light had mounted a campaign to counter the appeals made by Manley’s group. The campaign relied in part on the discredited notion that household electrical appliances were more dangerous than power lines. On November 29th, Dennis Gray, the manager of systems engineering for the utility, told the Highline Times that a 230-kilovolt transmission line would create a magnetic field of thirty-three milligauss ten feet inside some property lines, whereas a toaster created a magnetic field of one hundred milligauss and an electric mixer a field of eight thousand milligauss. He did not point out that the magnetic fields from toasters and mixers fall off sharply with distance, and, because they are present only sporadically in homes, do not constitute a source of chronic exposure.

By the end of the year, City Light was having second thoughts about the project, and on January 7, 1988, Randall W. Hardy, the superintendent of the utility, wrote a letter to Norman Rice, the chairman of the City Council’s energy committee, telling him that City Light was proposing a delay in the construction of the Highline substation and the connecting 230-kilovolt transmission lines. Two weeks later, Clyde L. Slemmer, a project-development engineer for the Washington State Department of Transportation, wrote Hardy to tell him that the state would not approve City Light’s request for a franchise to construct over head transmission lines on Route 509, because of traffic safety considerations, obstructions of possible highway expansion by the poles, public opposition to the proposal, and concerns about long-term health effects. “Last but not least, we are concerned about possible litigation and our required hold harmless provisions,” Slemmer told Hardy. “We are not sure how the City of Seattle could hold us harmless from litigation on accident or health effects claims and who would pay the costs of litigation and judgments.”

What Slemmer did not fully address, but what promises to become a major legal problem, is who can be held liable for claims involving cancer and other health problems that may be caused by the electric and magnetic fields that are given off by high-current wires in neighborhood

distribution systems across the nation. In addition, what will be the extent of liability for future claims involving cancer and other illnesses that may result from exposure to the low-level fields emanating from PAVE PAWS and other radars, and from electric blankets, electric mattress pads, and electrically heated water beds? Moreover, what will be the liability of the nation’s vast computer industry for claims arising from illnesses that may be caused by exposure to the low-level electric and magnetic fields that are known to be produced by video-display terminals, of which there are now some thirty million in use in the United States alone? ♦

(This is the second part of a three-part article.)

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