proclivity to liberal causes which contributed to problems that both later endured. One evening in October 1940, Kamen attended a meeting at Oppenheimer's home. The matter under discussion was innocuous enough, but the Radiation Laboratory was already engaged in defense work. A security agent attended the meeting. Thereafter and for at least 13 years Kamen was under surveillance. Very soon Ernest Lawrence and his staff were engaged in an effort to develop equipment for large-scale electromagnetic separation of uranium isotopes. The project led to the erection of a huge plant at Oak Ridge, Tennessee. Kamen was, of course, familiar with what was going on. The situation called for great discretion concerning contacts and conversation. Kamen, the extrovert, was monitored in conversations that he considered to be innocent but that led to a growing dossier. In his activities away from the laboratory, he associated with Russian sympathizers and ultimately dined with two Russians who were on the Soviet Union's consular staff. In July 1944, he was ordered to leave the uranium project immediately. The Army had concluded that he was too much of a security risk. For about nine months, Kamen could find work only in a shipyard. However, in the spring of 1945 he obtained a position at Washington University in St. Louis, where for the next 12 years he exercised national and international leadership in the use of radioactive isotopes in bacteriological and biomedical research.

In 1948, the House Un-American Activities Committee obtained widespread publicity for itself by implying that Kamen had been part of a spy ring working for the Russians. For the next six years Kamen was in many battles, including a successful libel suit against the Chicago *Times* and a successful fight to obtain a U.S. passport. In spite of the nerve-wracking distractions, he was able to be a productive scientist.

Kamen has written a highly readable book, of interest to scientists and comprehensible to a general readership. In spite of, or perhaps because of, the trauma and triumphs that he has experienced, he writes with remarkable objectivity. His analysis of Lawrence and Oppenheimer is particularly insightful. If there is to be a criticism of the book it is that the author did not devote more space to sketches of the many scientists and musicians who were his friends and colleagues.

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On Technological Catastrophe

Normal Accidents. Living with High-Risk Technologies. CHARLES PERROW. Basic Books, New York, 1984. x, 386 pp., illus. $21.95.

This book examines the ways in which complex technological systems fail. Its author, Charles Perrow, argues that we may be intrinsically unable to safely build and manage and maintain our most modern technologies. We can no longer assume that new technologies offer social gains, since their "side effects" may prove catastrophic.

Perrow examines the catastrophic potential of the new technologies through a detailed study of past accidents. He examines nuclear reactor failures, airplane crashes, accidents at sea, dam failures, and problems in controlling nuclear weapons. He suggests that accidents are most likely to happen when the subsystems of a technical complex are "tightly coupled." Thus, for example, in a nuclear reactor the close coupling of water and air pressure lines can lead to a leak of water into the latter if a valve fails to hold or close. Similarly, though the clean and irradiated systems of the reactor are separated, a punctured tube may dump water from the latter to the former. Then, as happened at the Ginna Nuclear Reactor, a sensor, detecting the drop in pressure in the irradiated system, may pump more water through it, thus pushing more water into the clean system. Perrow suggests that when subsystems share pipes, valves, and feedlines while feedback mechanisms automatically control key processes unexpected but normal accidents will occur.

Though Perrow examines the technical causes of accidents in great detail, he analyzes as well some of the ways in which operators create or shape the structure of an accident. Thus for example he shows that ship collisions at sea are not abrupt. Rather, and most remarkably, ships snake toward each other as if they were intending to crash. Through a careful study of investigative transcripts, Perrow suggests that captains in such accidents get a fix on the course of the oncoming ship and simply do not change their minds, despite continuing contradictory evidence. Thus in one case a ship captain on the Chesapeake Bay believed he was following rather than approaching the ship he ultimately collided with. His "mental map" was rigid. Perrow argues that operators frequently ignore alarms and signals because they have malfunctioned in the past.

Perrow's study of the normal accident thus provides a rich framework for the study of ergonomics and accidents. But does he prove his central thesis? How "normal" are these accidents really? Are their dynamics primarily embedded in the complexity of tightly coupled subsystems, or do they fundamentally reflect problems of social organization, work design, management systems, and worker competence? Perrow waxes philosophical. "Man's reach has always exceeded his grasp (and that goes for women too). It should be so. But we might begin to learn that of all the glorious possibilities out there to reach for, some are going to be beyond our grasp in catastrophic ways" (p. 11). Yet many of his stories are about the inadequacy of the grasp itself, about negligent managers, incompetent operators, short-sighted owners, and disorganized social systems.

Consider the fire and explosion at the Flixborough chemical plant. Twenty-eight employees were killed and 36 were injured. As Perrow notes, managers discovered a leak from one of the five reactors and rushed to refit the plant to bypass the disabled reactor. But they did not inspect the other four, they jerry-rigged a scaffolding to support a 20-inch pipe, and they violated industry and manufacturer's recommendations in assembling their bypass piping. Perrow acknowledges that "fairly gross negligence and incompetence seem to account for this accident, but I would resist this conclusion" (p. 111). But why? Perrow's pessimistic supposition that a "fair degree of negligence and incompetence [is to] be expected in human affairs" makes his argument tautological. Only if we expect so little of social organization are such accidents "normal."

Consider nuclear reactors. The quality assurance division in many utilities, the division that watches out for safety problems, has low status and is frequently ineffective. Craft workers dislike the di-

vision's inspections and demands for rework, operators regard its paper checks as burdensome, line managers see its staff as troublemakers, and owners believe that its primary mission is to stave off the Nuclear Regulatory Commission and protect the utility license. This is not normal. It does not represent the farthest reaches of our capacities to organize. It represents instead a particular history of negligence, insularity, and shortsightedness that includes activities verging on the criminal, such as cheating on requalification exams and tampering with production records.

Strikingly, though Perrow is an organization theorist of great originality, he fails to pursue the organizational issues in any depth. For example, in analyzing the paradoxes of organizational design in high-risk systems he suggests that we have reached a cultural and organizational cul-de-sac. We need centralized systems to ensure obedient responses in emergencies, but we need decentralized systems so that workers can use their talent and initiative to help solve unexpected problems. Can we ever combine the two?

The paradox is imaginary. There exist close to 3000 factories, designed according to "sociotechnical principles," in which close coordination is achieved between workers and work teams without resorting to hierarchy (see my *Beyond Mechanization: Work and Technology in a Postindustrial Age*, MIT Press, 1984). In such settings, workers are multiskilled, are paid for what they know rather than how hard they work, and belong to semi-autonomous teams that are loosely supervised. Experience in these settings suggests that workers are vigilant and committed to production quality and safety because of their desire to learn, their understanding of plant dynamics and policies, and their close relationships with teammates. Automated factories and high-risk technologies pose new organizational problems, but these are by no means insurmountable. We can run organizations that efficiently deploy and monitor human effort. We've done that well for a century. But today we must learn to develop organizations that organize, distribute, and deploy attention. As we come to understand the economics, sociology, and psychology of attention the normal accident will become increasingly abnormal.

Perrow's conclusions are puzzling. He ranks nuclear power, nuclear weapons, and DNA as the technologies with the greatest catastrophic potential. But nuclear weapons are meant to destroy. Their catastrophic potential is not accidental. Perrow's discussion of DNA, as he admits, is speculative. This leaves nuclear power, the central metaphor of the book. The public dreads this technology. Perrow argues that such dread expresses the public's "social rationality." They fear technologies that have catastrophic potential and are out of their control. But if dread is social is it necessarily rational? Consider driving: We don't control many of the conditions that affect the safety of driving. The "other driver," the speed limit, the car's safety, all intrude. Yet, as many studies suggest, we behave as if we were in control, neglecting for example to use seat belts. We accept the risk only by denying it, by imagining that "it can't happen to us."

These examples suggest that we dread just those technologies that puncture our defenses, our fantasies of being in control. Modern technologies provoke radical ambivalence. They are life-giving yet potentially death-dealing on a large scale. When they are life-giving they symbolize our capacity to push back death. As cultural artifacts they help sustain the necessary myth that our species is immortal and that individuals might one day live forever. (This is the not so secret hope of the DNA revolution). But when they pose risks they threaten to kill us. This ambivalence clarifies what Perrow calls our "dread." Dread emerges, as Freud recognized, when the "repressed returns" in the form of chronic anxiety. The repressed is the deeper knowledge that we will all die and our species will someday disappear. Nuclear power as a metaphor has become the cultural repository for this ambivalence. (Though paradoxically, as Perrow reminds us, nuclear power may be the best answer to the catastrophe of the "greenhouse" effect caused by the burning of fossil fuels.)

Perrow's work reflects this ambivalence, but not self-consciously. He reminds us that social elites have constructed our technologies and that we can abandon them. They are social inventions. Yet he simultaneously evokes a picture of transcendental technologies that defy our organizational capacities. His argument appears, paradoxically at first, to be almost religious in tone; the great "unknowable" now resides in our machines rather than in the heavens. Indeed, in the past religious feelings have been one response to feelings of dread. We acknowledge the superiority of forces we can't control. Perrow has committed himself to such a religious vision of our technological dilemma. Yet his technical competence and organizational savvy highlight the weakness rather than the limits of our organizational grasp. Perrow ignores his own evidence. We can make the normal accident abnormal if we tend to the lively problems of social organization.

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Nuclear Safety: Early Efforts

Controlling the Atom. The Beginnings of Nuclear Regulation, 1946–1962. GEORGE T. MAZUZAN and J. SAMUEL WALKER. University of California Press, Berkeley, 1985. x, 530 pp. + plates. $28.95.

Between 1946 and 1962 nuclear-powered electricity generation was developed to the point of commercial viability. Concurrently, the Atomic Energy Commission (AEC) evolved procedures for safety regulation whose basic structure persisted through the 1970's. In *Controlling the Atom: The Beginnings of Nuclear Regulation, 1946–1962*, George T. Mazuzan and J. Samuel Walker, historians with the Nuclear Regulatory Commission, give a comprehensive history and interpretation of nuclear regulation during this period, detailing the roles and interactions among the AEC, the executive branch, the congressional Joint Committee on Atomic Energy (JCAE), the Advisory Committee on Reactor Safeguards (ACRS), and state governments.

The book discusses the controversial decision to promote private, rather than government, investment in nuclear power plants, even at an early stage of development. This sets up the major themes that underlie the study: first, the conflict between promoting private uses of nuclear power and regulating its safety; and, second, the gap in the AEC between the developmental and safety research programs and the licensing arm of the agency, a gap that both contributed to and grew with increasing formalization of the licensing process.

Mazuzan and Walker discuss controversies and areas of general agreement regarding nuclear policy during the 1950's. Though there was substantial controversy and lack of confidence concerning the AEC's control of radiation releases—cases discussed include weapons fallout, uranium mining, and waste disposal—the public and politicians were in agreement over the desirability of developing nuclear power technology.