THE MACHINE IN AMERICA

A Social History of Technology

Second Edition

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CHALLENGE, DEFENSE, AND REVOLUTION IN A POSTMODERN WORLD

AMERICAN TECHNOLOGY during the last quarter of the twentieth century appears to be going through a sea change in response to mounting contradictions within its own structure and operation. The megalith of modern technology—highly structured, centralized, rationalized, homogenized, and universally applied—has been criticized from both ends of the political spectrum, and, of course, defended from the middle. During the 1970s, a concerted critique was mounted from the left, emphasizing smaller scale, environmental concern, and human purpose. During the 1990s, industrial capitalism itself appeared to be groping toward a restructuring of production, one that would restore flexibility, efficiency, and quality in the face of international challenges. At the center there has been a reification—a commitment to continued elaboration as the only possible alternative to a backing down from a posture of technological advance that seems at once natural, even inevitable, but at the same time strangely fragile and threatened.

In 1966 the social critic Lewis Mumford unleashed a withering criticism of the American automobile in particular, but his words stood for modern technology in general:

> Some of the critics have dared to say that the Sacred Cow of the American Way of Life is overfed and bloated; that the daily milk she supplies is poisonous; that the pasturage this species requires wastes acres of land that could be used for more significant human purposes; and that the vast herds of sacred cows, allowed to roam everywhere, like their Hindu counterparts, are trampling down the vegetation, depleting wild life, and turning both urban and rural areas into a single smudgy wasteland.[1]

Typically, Mumford used his criticism to call for a reformation of American life, to be based on a rethinking of priorities. There was, he wrote, a

> need for a conception of what constitutes a valid human life, and how much of life will be left if we go on ever more rapidly in the present direction. What has to be challenged is an economy that is based not on organic needs, historic experience, human aptitudes, ecological complexity and variety, but upon a system of empty abstractions: money, power, speed, quantity, progress, vanguardism, expansion. . . . In short, the crimes and the misdemeanors of the motor car manufacturers are significant, not because they are exceptional but because they are typical.[2]

Mumford's critique ran across a wide front. It explicitly lay the main charge at the door of advanced industrial capitalism, but just as clearly indicted American culture in general, and its technology in particular. Since both culture and technology are socially constructed, of course, the three are inseparably linked. It would have been unrealistic, therefore, to expect that the multifaceted reform movement of the 1970s would fail to include technology on its list of what needed to be changed about America.

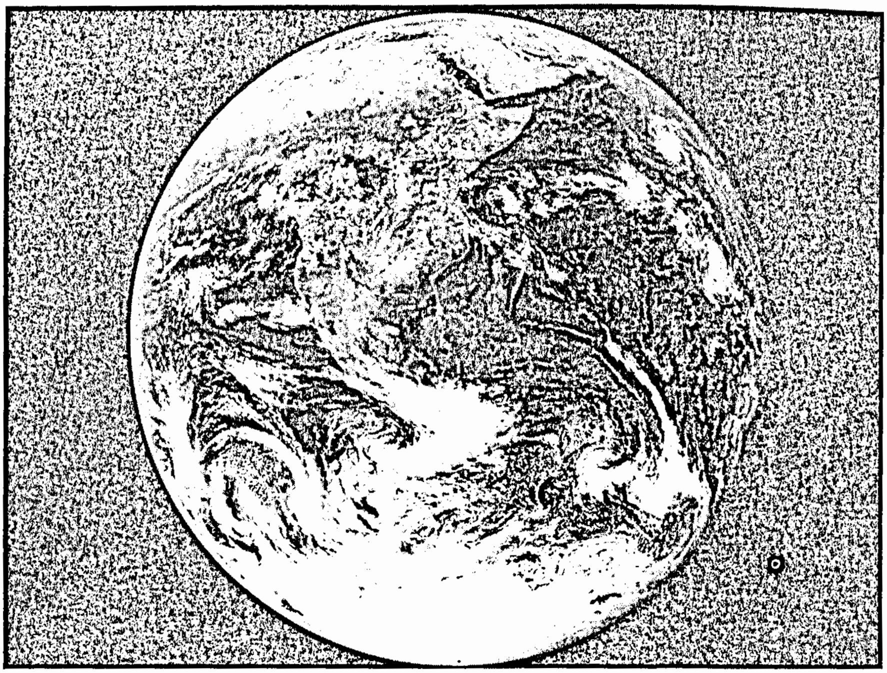
A resurgence of muckraking literature in the 1960s dramatically exposed some of the worst failures of the technology of industrial capitalism after midcentury. Ralph Nader's *Unsafe at Any Speed* (1965), a review of which triggered Mumford's jeremiad, detailed the willingness of Detroit automakers to knowingly produce unsafe automobiles and thus presented a classic portrait of corporate greed and irresponsibility. Rachel Carson's *Silent Spring* (1962) revealed the ecological devastation that was the underside of the nation's infatuation with chemical pesticides. In both instances, the response of the accused—in the one case Detroit, especially General Motors; in the other, the powerful network of chemists, chemical corporations, the Department of Agriculture, and their allies—merely drove home the message that technology was above criticism. Progress was not to be questioned, and those agencies empowered by that technology would go to extraordinary lengths to protect their interests.

Newton N. Minnow, the youthful appointee to the Federal Communications Commission, called television a vast "wasteland," an attack that raised an outcry but little reform. More generally, Michael Harrington revealed in his book *The Other America* (1962) that Franklin D. Roosevelt's one-third of a nation was still ill-clad, ill-housed, and ill-fed. Betty Friedan, in her classic *Feminine Mystique* (1963), helped revivify the feminist movement by demonstrating that a woman's place in America was in many ways less, not more, free nearly a half century after the franchise. If technology had created or exacerbated a host of serious new problems, it had also failed to significantly solve older, persistent ones, as well.

And the Vietnam War drove home the point that America's massive and sophisticated technological capability, so grotesquely out of scale when compared with that of the invaded Third World nation, could wreak sickening devastation but seemed powerless to win minds and hearts. President Lyndon B. Johnson wanted a Mekong Valley Authority to reproduce the economic miracle that had thirty years before transformed the Tennessee Valley, but instead he provided napalm and carpet bombing.

All these signs pointed toward a technology that was unpalatable, dangerous, and often ineffective at home, and at the same time inappropriate and often vastly destructive abroad. The same social forces that drafted young Americans to go halfway around the world and use napalm and Agent Orange against the people and environment of a small and weak country, also poisoned the workplaces—farms, homes, and shop floors—of America itself. The scientific and engineering research and development that the military-industrial complex channeled into the work of death stole resources from the civilian needs of a country struggling with industrial decline, social inequality, persistent poverty, and environmental degradation.

Before the problem of the Vietnam War could be solved, the nation became aware of the extent and persistence of its environmental crisis. The conservation crusaders of the Progressive Era had worried almost exclusively about the disappearance of natural resources rather than where to put the waste that was inevitably produced when those resources were used. Rachel Carson's decimated population of robins laid low from DDT proved to be only the tip of the iceberg as a series of disasters, from the Santa Barbara oil spill through the Love Canal to Three Mile Island, reminded Americans that



Images of the Earth as a beautiful, fragile, and precious whole reinforced the resistance of the environmental movement in the 1970s to further elaborations of projects for global engineering. Released by NASA in 1972, the photo was taken from Apollo 17, the final lunar landing flight of the Apollo program. Courtesy National Aeronautics and Space Administration.

technological successes bred problems of a comparable or even greater magnitude.

While the environmental movement was still gaining momentum, the energy crisis of the mid-1970s hit. In the preceding century two obvious and significant trends had reached critical proportions: energy consumption per capita had risen sharply, and there had been a shift in source away from renewable fuels (wind, water, and muscle) to nonrenewable (coal, oil, and natural gas). When the Organization of Petroleum Exporting Countries embargoed oil exports in 1974, the true dimensions of America's dependence on petroleum was brought home in the form of higher prices and long lines at the service station.

This constellation of challenges called forth an outpouring of analysis and action that was seen by the defenders of technological advance as a repudiation of progress and, indeed, the entire Enlightenment Project to better the lot of humankind through direct and deliberate action. The hoary specter of Luddism (that often mythologized episode of machine-breaking in Regency England) was raised once more and connected with any questioning of the social uses of science, the priorities of American scientific and technological policy, and the reading of Tarot cards by hippies. Not surprisingly, some of the most Gothic warnings against the questioning of technological progress came from political, military, corporate, and technical leaders of the nation who, quite naturally and rightly, saw their hegemonic sway attacked (though hardly seriously threatened). Ronald Reagan, then governor of California, asserted that trees were the major source of environmental pollution, and President Richard M. Nixon celebrated the high per capita energy use by Americans as sure evidence of their superior civilization.

On both the state and federal levels, however, as well as in a myriad of private initiatives, a new (if not terribly radical) approach to technology was experimented with. The National Environmental Protection Act (1970) laid down the idea of environmental impact reports—studies in advance of development that would try to anticipate negative changes in the environment that might reasonably be expected to result from them. Already in 1967, Representative Emilio Daddario (Democrat of Connecticut) had introduced legislation to establish what came to be the congressional Office of Technology Assessment to provide an analogous service. The National Academy of Sciences (NAS), along with the academies of engineering and public administration, was asked to report on the feasibility of carrying out the two missions that Daddario envisioned: to anticipate the social and environmental effects of new or projected technologies and also to identify potential technologies that needed support and encouragement to be brought forward. The academy ratified the possibility of assessing technology, but articulated four preconditions that revealed both the potentially radical power of the process and the limits beyond which it would not be allowed to probe.

First, the NAS maintained that technological change would continue. "The choice," said the panel, "is between technological advance that proceeds without adequate consideration of its consequences and technological change that is influenced by a deeper concern for the interaction between man's tools and the human environment in which they do their work." Second, they admitted that "our panel starts from the conviction that the advances of technology have yielded and still yield benefits that, on the whole, vastly outweigh all the injuries they have caused and continue to cause." Third, it maintained that "technology as such is not the subject of this report, much less the subject of this panel's indictment. Our subject, indeed, is human behavior and institutions, and our purpose is not to conceive ways to curb or restrain or otherwise 'fix' technology but rather to conceive ways to discover and repair the deficiencies in the process and institutions by which our society puts the tools of science and technology to work."[3]

And finally, all this being so, the panel insisted that "it is therefore crucial that any *new mechanism we propose foster a climate* that *elicits* the cooperation of business with its activities. Such a climate cannot be maintained if the relationship of the assessment entity to the business firm is that of policeman to suspect." In a final effort to contain the potential of technology assessment to radically alter the way in which Americans think about the subject, and the way in which public policy deals with it, the National Academy panel admitted that it had not looked at all at technologies for the military. In short, criticism of technology was not to be allowed to prevent any technology from being implemented (progress was to continue), and both business and the military were to be exempt from criticism, let alone constraint. As President Nixon said, "technology assessment" was all right as long as it did not become "technology harassment." A congressional Office of Technology Assessment (OTA) was finally established in 1972.

A concept closely related to technology assessment was that of "appropriate technology." The large-scale foreign aid programs undertaken after World War II by the American government, as well as by the Soviet Union and other major powers, had for years been supplemented by development projects financed by the World Bank and the International Monetary Fund. Some projects, like the Soviet-supported Asswan Dam built across the Nile River in Egypt, had obvious and immediate side effects, such as the submersion of ancient monuments, the spread of water-related diseases, and the diminution of the fisheries off the mouth of the river. On a more diffuse scale, new agricultural techniques like the green revolution were slowly seen to raise more problems than they solved. In the latter case, dramatic increases in yield per acre of rice were purchased at the price of destroying a peasant culture and making farmers dependent on large inputs of outside resources: bank credit, chemical fertilizers, complex machinery, and the skills to manipulate all these. Stories of large diesel tractors sent to India for use by farmers still using stick plows pulled by water buffaloes began to raise the possibility that some technologies, effective in certain environments, were useless or even harmful in others. That is, for any given place and purpose, some technologies might be appropriate while others might be inappropriate.

Public awareness was galvanized by the publication, by the British author E. F. Schumacher in 1973, of his book *Small Is Beautiful: Economics As If People Mattered.* Schumacher advocated an "intermediate technology" for developing nations: machines and tools better than they had already but not so vastly more powerful and complicated that they destroyed indigenous cultures, devastated the local environment, stifled local initiative, and would soon be abandoned in any case by people who had neither the training nor the money to maintain them properly. Green revolutions, nuclear power plants, jet fighters, and great dams were logical extensions of western technological progress and expanded the power and prestige of local elites but often did little good for common people who most needed potable water and latrines, literacy and family planning.

The notion of appropriate technology, however, also had obvious applications to those nations, like the United States, that could be defined as "overdeveloped" rather than "underdeveloped." The election of Jerry Brown as governor of California in 1974 opened a window of opportunity in that state. Working with his state architect, Sim Van der Ryn, he established the Office of Appropriate Technology to stimulate publicity and programs in that area, and the legislature pressed additional funds on the University of California to institute an appropriate technology research and demonstration program. A special fleet of state vehicles was converted to burn a gasoline-alcohol fuel mixture, and Van der Ryn designed state office buildings using both passive and active solar energy. The state constitution was amended (by popular vote, so that a portion of the Gasoline Tax Fund could be diverted to other forms of transportation), light rail systems and bicycle paths were built, and the state became the largest producer in the country of electricity from windpower.

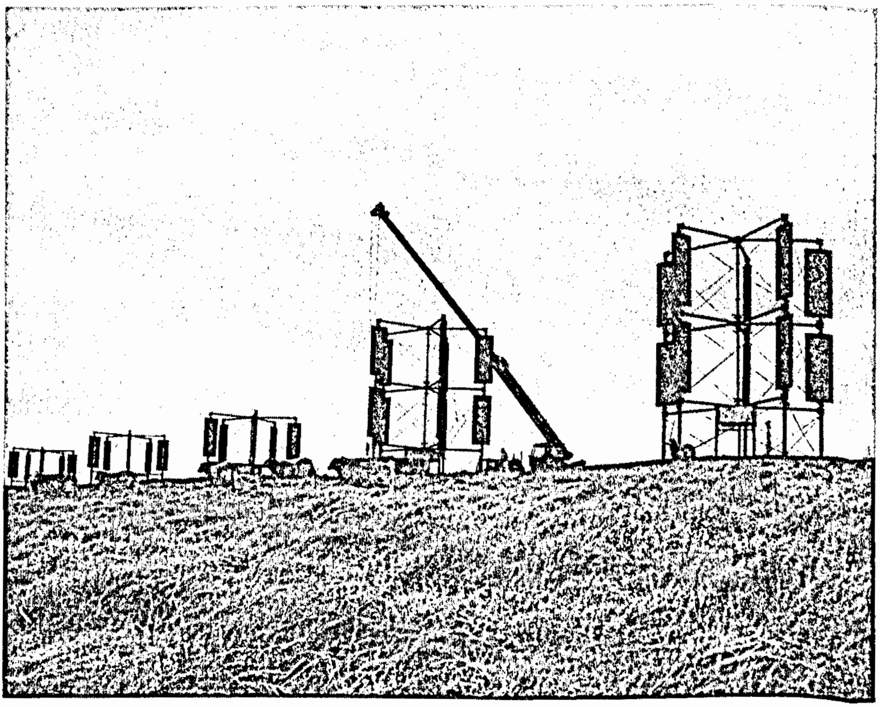
Some of this same technological initiative was evident on the national scene. A National Center for Appropriate Technology was established in 1977 but was situated safely in Montana, not inside the Washington beltway. The Army Corps of Engineers was ordered to survey existing dams in the nation to discover which of them might be retrofitted for low-head hydroelectric production. Legislation was passed requiring electric power companies to buy electricity from any provider at prices reflecting the cost of new production facilities (gas, coal, or nuclear fired) rather than prevailing prices, which

When Jerry Brown became governor of California, he set up the Office of Appropriate Technology to foster technological alternatives for both public and private projects. Before being abolished by his Republican successor, George Dukemajian, OAT made significant advances in the support of solar, wind, light-rail, and other technologies. The gentle and humorous logo of OAT betrayed the style that earned Brown the title of Governor "Moonbeam." Photo in possession of the author.

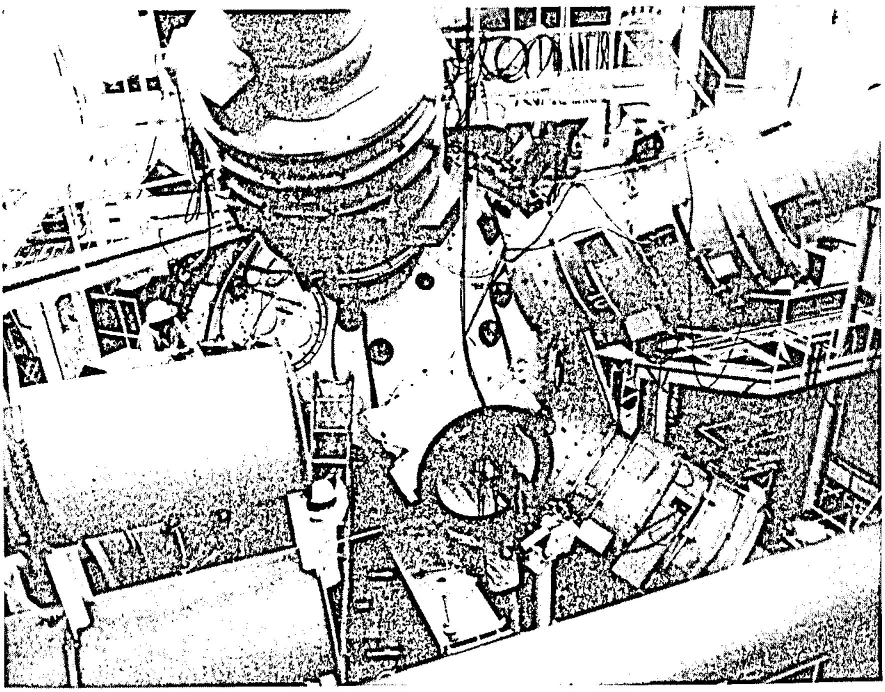
reflected older plants and cheaper hydroelectric facilities. An initiative to develop solar power was both hopeful and instructive.

The idea was an old one. In 1805 Oliver Evans had advocated solar power to raise steam for his engines. "I am fully of the opinion," he wrote, "that the time will come when water will be raised in great quantities by the heat of the sun at a very small expense, for various purposes; but," he warned, "the expense of such inventions cannot, in many instances, be borne by those who have the mental powers to design; at least it is highly imprudent for them to risk it. In such cases," he concluded, "aid from government becomes necessary."[4] In 1974 the Congress appropriated $77 million for research and development on and demonstration of solar power generation and an additional $60 million to demonstrate the feasibility of solar heating and cooling of buildings. At the same time, the heavily subsidized (though still not competitive) nuclear energy program received $2.2 billion, a fair measure of how wedded the nation remained to powerfully entrenched subsidies and technologies. In 1977 the first funds were released to the new Solar Energy Research Institute, located at Golden, Colorado, and run by the Department of Energy (DOE), which administered the nuclear program as well.

Significantly, it proved extremely difficult for the DOE to break its habit of massively supporting only huge programs emanating from the military-industrial complex. One of the major proposals for solar development came from the Boeing Aerospace Company to orbit a mirrored satellite (perhaps 25 square miles in area) 23,000 miles above the earth to focus and reflect the sun's rays down to a "power tower" below. The tower would then reflect the rays to mirrors on the ground, which would use the intense heat to raise steam for the generation of electricity in a nearby power plant. The



Although the appropriate technology "movement" of the 1970s disappeared, the technologies themselves persisted and developed. In the 1990s, a California firm building advanced-design windmills for electrical production, in part a legacy of the Brown years, won the right to construct a windfarm on the Queen's lands near Bridgend, Wales. Courtesy Wind Harvest Company.



One "high-tech" answer to environmental concerns and threats of energy shortages was the development of fusion technologies. In an attempt to "harness fusion as a safe, economical, and inexhaustible energy source," the Department of Energy spent more than $176 million on Nova, the world's most powerful laser, the target chamber of which is shown here. Courtesy Lawrence Livermore National Laboratory.

resulting electricity would, of course, then be distributed by an existing electrical utility to its customers.

The proposal demonstrated how persistent was the example of nuclear technologies and the utilities industry. As the magazine *Science* commented in 1977, "Solar energy is democratic. It falls on everyone and can be put to use by individuals and small groups of people. The public enthusiasm for solar is perhaps as much a reflection of this unusual accessibility as it is a vote for the environmental kindness and inherent renewability of energy from the sun." As the journal also noted, however, "Despite the diffuse nature of the resource, the [DOE's] research program has emphasized large central stations to produce solar electricity in some distant future and has largely ignored small solar devices for producing on-site power—an approach one critic describes as 'creating solar technologies in the image of nuclear power.'" In short, the government program was bent on developing a solar technology that would perpetuate Taylorist and Fordist techniques and structures. As *Science* concluded, "the massive engineering projects designed by aerospace companies which dominate much of the program seem to have in mind the existing utility industry—rather than individuals or communities—as the ultimate consumer of solar energy equipment."[5]

By 1990 the DOE was spending $12.2 billion a year but very little of that was going for research and development that might reduce the nation's reliance on oil as an energy source: $8.8 billion was still being poured into its nuclear weapons program, and another $1.5 billion was expected to pay the first year's bill for an open-ended program to clean up the nuclear waste from weapon's plants around the country. Another $1 billion was devoted to atom-smashing research, not including the estimated $11 billion cost of the projected Superconducting Super Collider. Clean coal, electric cars, and so forth account for less than $1 billion, of which $35.5 million was earmarked for research on solar-voltaic cells to convert sunlight directly into electricity, a technology first developed in 1954. Dr. Maria Telkes, on being given the first Achievement Award by the Society of Women Engineers in 1952 for her work on solar energy, remarked that the field had not been developed as fast as nuclear energy because, "you see, sunshine isn't lethal."[6] It makes obvious that, contrary to the old saw, not everything that can be done will be done.

The demise of appropriate technology as a movement during the early years of the 1980s suggests some of the dimensions of both its appeal and its danger. On one important level, it was a potential threat to those economic and political interests with much invested in large-scale systems of modernist technologies, like the automobile, the agroindustrial farm, and the fossil-fuel or nuclear power plant. Technologies are never simply machines: they are also the nub of accumulated power. On another level, the masculine values of violence, conquest, and dominance that are built into so much of our technology was equally threatened by the possibility of a more responsive, gentle, "feminine" set of technologies. A movement that celebrated the ideals of small and soft could hardly have recommended itself to believers in more traditional masculine values. After the feminizing effect of losing the war in Vietnam, the decade of Reagan and Rambo, with its commitment to standing tall and being number one again, created a powerful cultural backlash against any attempt to redirect or even rethink American technology.

An attempt to redress the gender imbalance of the American engineering profession was also, in part, an implied criticism of the way things were being done. The debate over whether women in engineering somehow "softened" engineering itself, or whether they themselves were more likely to be masculinized by the experience, was only one aspect of the major effort, during the 1970s, to attract more women into what was the most male-dominated profession in the nation. Less than 1 percent of engineers were female, and a perceived national shortage of engineers was reinforced by the contemporary movement for womens' rights, to highlight the issue.

The Society of Women Engineers, which had been established in 1950 to support that corporal's guard of women who entered the profession during World War II, chose for itself two apparently conflicting goals. First, it sought to attract more young women into engineering schools. Second, it necessarily had to deal with the powerful and long-entrenched patriarchy of the profession. To the extent that it openly battled prejudice and sexism in engineering schools and practice, however, it risked frightening off prospective recruits. Although over the next two decades the proportion of women students in engineering schools rose to about 15 percent, the larger possibilities inherent in even a partial degendering of American technology has thus far failed to develop. The profession has remained a bastion of white, male culture.

The search for new technological paradigms and initiatives of the 1970s revealed promising areas for research and development, as well as new relationships among those social agencies that made the choices between and helped shape technological developments. The political boundaries articulated by the National Academy of Sciences in its report on technology assessment, however, proved to be controlling. Technological change was not to be slackened, its overall beneficence was not to be doubted, corporate control was not to be threatened, and the economic and environmental effects of military technology were to be ignored. The cultural hegemony of industrial technology might be questioned, but it was not to be seriously challenged.

No system lasts unchanged, however, and dominant institutions maintain their hegemony by making some concessions to external criticism from time to time. Safety belts became mandatory on cars, fleet mileage improvement was required by legislation, the supersonic transport (SST) was killed (or at least put off), solar-powered calculators became available (if only from

Japanese manufacturers), and at some sites around the country freeways were not built, dams were designed with fish-ladders, and toxic sites were cleaned up. More important, the contradictions internal to modern technology began to force many corporations to rethink the very Taylorist and Fordist bases of the system.

In particular, three important trends have developed over the past two decades. First, entrepreneurs have rediscovered the opportunities in smaller market shares that can be exploited by smaller, more flexible, and specialized technologies and firms. Second, the vastly increased mobility and speed of transportation and communication have encouraged the globalization of operations. Third, and perhaps most important, mass production, at least in some key heavy industries, is giving way to what has come to be called "lean" production.

The globalization of services and production has been a signal characteristic of industrial operations in the past two decades. The computer and satellite communications have combined to make the transfer of capital over any distance instantaneous. The stock markets of London, New York, and Tokyo make trading a nearly twenty-four-hour activity; American tourists in Sydney can use their bank cards in an automatic teller machine and have cash in hand credited against their bank account in the United States. Hotel reservations anywhere in the United States can be made by using an 800 telephone number that connects with computers operated by inmates in a women's prison in North Carolina. An insurance company in the United States can have claim forms put into computers by housewives working part-time at piece rates on impoverished Caribbean islands. "Computing to work" involved not only stockbrokers and consultants who worked from their homes in the country, but also an uncounted number of women in what were coming to be called "home-computer sweatshops."

As the "modern" nation's infrastructure of roads, bridges, and railways continued to disintegrate, a "postmodern" information "superhighway" was being born. In 1969 the Pentagon had supported the creation of a computer network to aid scientists working on defense research and development. It was demonstrated to the public in 1972, it was modified in 1980 to allow linking with other networks, and the next year claimed 2,000 users. By 1993, however, that number had grown to 15 million, and new users were logging on at the rate of 1 million a month. With the election of Bill Clinton to the presidency in 1992, and especially of his vice president Al Gore, the dream of

The plan to build an "information highway" across the nation was an infrastructural project that deliberately recalled the interstate highway network of the 1950s. Given a boost by the election of Bill Clinton to the White House in 1992, the "highway" was a direct descendent of a computer network developed by the Pentagon's Advanced Research Projects Agency (ARPA) in the early 1970s. Note that the "users" are all universities, think tanks, and government agencies. *Science,* 175 (March 10, 1972), iv.

even larger networks, possibly fiber optic, moved closer to reality. Despite warnings that such powerful information technologies would further divide American society into haves and have-nots, the vision of 500 channels of television and instant access to all the books in the Library of Congress was proving irresistable. Computers, cellular telephones, fax machines, and television—all in the home and each connected with all others—promised new possibilities and profits: home shopping, movies on demand, ordering pizza for home delivery, and news programs individually tailored to the curiosity of each customer.

Just as textile and shoe production fled the Northeast earlier in the century to seek a cheaper and more easily disciplined work force in the South, so have American firms taken advantage of transportation and communications improvements to move their production facilities abroad in recent times. Fields in Mexico, once used to raise corn, beans, and squash for the local campesinos now raise out-of-season asparagus to be flown by jet to North American markets. Assembly processes especially, being labor intensive, have been sent to southeast Asia, the Caribbean, or Mexico. Cheaper labor (which no longer needs to have the old skills), tax incentives, and an absence of environmental or work regulations make the moves attractive. The picture is complicated, however, by the fact that while Ford automobiles may now be made in Mexico and Dodges in Japan, some Hondas are made in Ohio. Not only does this seeming anomaly confuse the patriotic urge to "Buy American" (does one support American jobs [Honda] or American capital [Chrysler]?), but it suggests that the old method of cutting the wages of labor is not now the only, or perhaps the best, way to remain competitive.

The dream has died hard. At least since Karel Capek's play *R.U.R.* introduced the word *robot* in 1923, the notion of such entities performing the difficult, dirty work of life has been a persistent ideal. They would be more easily controlled than flesh-and-blood workers, less subject to fatigue, work unceasingly, with predictable accuracy, and never go on strike or sue for injury. Ira Levin's novel *The Stepford Wives* (1972) suggested that the domestic and sexual work of women might also be performed by robots, although, of course, they would be ones that looked like the real thing. The literature of science fiction kept the dream alive, and by 1988 some 15,000 robots were actually at work in American industry. Although they lacked the recognizable features of the familiar android, they performed tasks such as spot-welding automatically, replacing human workers in a manner by now expected and accepted. Robots, however, were as much a sign of the old ways of mass production as an indication of new departures. Computers made it possible to quickly reprogram general-purpose machine tools, thus avoiding the use of dedicated tools that could perform only one task and reintroducing a measure of flexibility into the productive process. In most cases, however, these existed as "islands of automation" rather than as integrated parts of a new and larger scheme.

Lean production, on the other hand, with its related techniques of just-in-time inventory control and the subcontracting of such tasks as secretarial work and delivery of the finished product, has begun to seriously erode the old sureties of Fordism and Taylorism. Developed by the Japanese automobile industry, particularly at Toyota by Taiichi Ohno and Eiji Toyoda beginning in the 1950s, this new process came to embody elements of both mass production and the even older methods of craft (batch) production.

Under the craft method of making cars, parts were bought from suppliers who worked independently, then skilled craftspeople fitted them together with a great deal of filing. Gradually the car was built up, piece by piece, each fitted to the last, and because of "dimensional creep" no two turned out to match each other, let alone the original plans. Such a system was expensive, and the resulting machines were difficult and expensive to repair.

The system of mass production pioneered by Henry Ford insisted that all parts supplied be designed and manufactured to a single gauge, and they were then assembled by un- or semiskilled workers who were able to simply put them together without further fitting. Special machine tools were dedicated to making only a single part, thus sacrificing flexibility for accuracy and speed of production, and finally assembly workers were placed along a moving line of vehicles to further speed up the work.

A line of specialized workers extended out from both ends of this assembly process. On one end, a host of engineers and managers designed the components and the machines to manufacture them. On the other, an army of tool-repair specialists, quality inspectors, and "rework" people took over specialized tasks that before had been the responsibility of the craft workers themselves. Especially important were the reworkers, who corrected the mistakes on cars before they left the factory. A single manager had the power to stop the line, but because mistakes were more easily corrected than avoided, the incentive to "move the metal" was strong. Indeed, when Toyoda visited Ford's River Rouge plant in 1950, it was producing 7,000 cars a day. In Japan, his family's firm, Toyota, had made only 2,685 cars in thirteen years. By a judicial combination of borrowing and innovation, Toyoda and Ohno were able not only to vastly increase their production but to do so with half the investment in human resources, manufacturing space, tools, and engineering-hours spent in model design: hence the term *lean.*

One key to the process was having assembly workers operate in teams, giving them the work elsewhere assigned to the repair, inspection, and rework people, on the assumption that mistakes could be prevented, not just repaired. Each worker had the ability and responsibility to stop the line if mistakes appeared. Since lifetime employment meant that workers were a fixed cost, the company invested in upgrading and using the full skill of their employees. In this way, the actual assemblers added even more value to the product, and the army of reworkers, which in American plants did not add value at all, was virtually eliminated.

Auto assembly, however, accounts for only 15 percent of the manufacturing process of a car; the rest is spent in making the ten thousand component parts. Both Fordism and the corporate structure developed at General Motors by Alfred P. Sloan dealt with a small army of parts and subcomponent suppliers, some in-house and many outside the organization. These suppliers (typically 1,000 to 2,500 of them for American cars) were challenged to make the lowest possible bid for each part and were kept independent of both the automobile company and each other. Under the Japanese system, many fewer suppliers were dealt with, they were arranged in tiers from suppliers of single parts on up to complex subcomponent systems, and they were urged to trade information and cooperate with both the purchaser and each other. Finally, they delivered their parts to the assembly plant often on a hourly basis, new parts not being made until the last box of them had been returned empty (hence the notion of just-in-time inventory). The result of all these changes is a greater flexibility of production, a combination of the economies, without the scale, of mass production. The monolithic imperative—best expressed in Henry Ford's remark that customers could have cars in any color as long as it was black—promises to be replaced by some of the variety and choice of the handicraft-production era.

Lean production, then, is a thorough and systemic reordering of the method and assumptions of the mass production that has been emblematic of American production for nearly the entire twentieth century. By 1990 it had begun to make some American automobile plants nearly as efficient as the best Japanese, but only with a wrenching effect on the social context of manufacturing in this country. Like every technology, automobile production is embedded in a complex environment of geography, class, economics, gender, and politics. A society painfully adjusted to mass production over many decades is not easily accommodated to another system.

Lean production, however effective in beginning to make American manufacturing more profitable and however suggestive of a large-scale change in the way technology is structured in American society, addresses only a part of the problem of modernist logic. The entire question of American "competitiveness," as it is called, has to do with public policy as well as private gain, since the actions and options of governments at all levels, especially the federal government, have always played a decisive role in shaping the nation's technology.

Despite the fact that much of what has passed for "science policy" in the years since World War II has, in reality, dealt with technology, the United States has no explicit policy for technology itself. From the 1950s on, American policy has been concerned with investing heavily in military technology, with the idea that civilian applications would "spin off" and prove adequate to keeping the nation in the forefront of industrial progress. As one veteran science policy observer noted in 1991, "In the era immediately following World War II, the United States had a virtual monopoly on new technology. This was fostered by spin-offs from defense R & D. . . . However defense R & D gradually ceased to be a stimulus to the civilian economy. Global competition in high technology emerged."[7] Critics such as Seymour Melman had for years argued that "profit without production," that is, the wholesale investment of the nation's technical resources in research and development for the military rather than the market, was having a devastatingly distorting effect on the American economy.

Much of this cold war effort was funneled through the Defense Advanced Research Projects Agency, called DARPA. Over the years, such areas as computers and artificial intelligence were forced ahead strongly by this agency. Still in 1991, of the $1.3 billion the federal government spent on "advanced manufacturing and materials," more than 40 percent came from the defense budget, including $100 million a year to improve the manufacture of computer chips and $311.5 million for a program known as Manufacturing Technologies (Mantech), which looks particularly at machine tools and automatic machinery.

During the 1980s, however, DARPA began to concentrate more on strictly military hardware. One Pentagon agency, the Strategic Computing Project, which worked on such devices as a robot tank, alone had a budget of more than $100 million a year beginning in 1983. Congressional demands for a technology policy were resisted by the administrations of Ronald Reagan and George Bush as calls for an "industrial policy," an activity that would make the criteria of federal technology spending more open, explicit, and, presumably, democratic.

As Representative George Brown, Jr. (Democrat of California) commented, "We have been imprinted with a national security mentality in interpreting the federal role for technology" but "commercial technology development can no longer be a stepchild of the defense structure."[8] By the 1990s, the U.S. government spent only 0.2 percent of its research and development budget for industrial development, compared with 4.8 percent in Japan and 14.5 for West Germany. For defense, however, the United States spent 65.6 percent, compared with 4.8 for Japan, and 12.5 for Germany. For energy, the United States spent 3.9 percent of its R & D budget, Japan 22.8 percent, and Germany 7.8.

Faced with White House refusal to alter its priorities, the Congress in 1987 reconstituted the old (1901) National Bureau of Standards into the new National Institute of Standards and Technology to focus on civilian industrial problems and opportunities. The Reagan and Bush administrations, however, failed to put any significant resources into it. In the early 1990s the Critical Technologies Institute was created under the Office of Science and Technology Policy to pursue civilian initiatives, but its funds, too, were provided by the Pentagon. The difficulty in shifting from cold war patterns of technological support to something different, despite mounting evidence of its doing more harm than good as the century closes, is clear evidence of the fact that the political matrix of technology, like the hardware itself, is designed to privilege certain power relationships and deny others. The military-industrial complex's monopoly on the public definition and support of technology is deeply rooted in the nation's historical experience.

Since World War II the technological efforts and priorities of the government have been warped by science as well as by the military. The notion championed by Vannevar Bush, that new technology flows from basic scientific research, was embedded in the common phrase "Research and Development" and implied a system of priorities as well as an explicit theory of change. The phrase reversed—Development and Research—seems not only awkward to pronounce but wrongheaded in meaning. To suggest that technological change should be aimed at a purpose (development), and that research should follow only as a way around problems as they come up, flies against the priority built into "R & D," that one should do research for its own sake and then develop whatever possibilities it might present. The historic conflation of technology with science policy continues to obscure such political advantage.

In his book *The Condition of Postmodernity* (1989), the geographer David Harvey argues that "there has been a sea-change in cultural as well as in political-economic practices since around 1972." He writes of "the rise of postmodernist cultural forms" and "shifting dimensions of time and space," as well as "the emergence of more flexible modes of capital accumulation."[9] During the postwar boom, the technologies (and techniques) of the interwar years were perfected and formed the basis of both American prosperity and American worldwide hegemony: mass-produced consumer goods, petrochemicals, radio and television, steel and construction. During the 1970s and 1980s, wartime and postwar technologies, aerospace, and especially the computer and other aspects of electronics came to the fore, along with newer forms of production, consumption, labor control, and finance.

Postmodernity is most easily seen, of course, in its artistic manifestations, especially architecture, for which, in fact, the term was coined. But the notion is helpful also in making sense of a host of other phenomena from cultural pluralism and feminism to the spread of nuclear, chemical, and biological weapons to emerging nations; from the Rust Belt and factories along the Mexican border to the success of Japanese consumer durables and the frenzy of corporate mergers financed by junk bonds. The demise of the "metanarrative" and the shift in power from the center to the peripheries is true both within and without the field of technology. Neither capitalism nor industrial technology are likely to disappear any time soon, but it is even more certain that they will not remain "modern" in the sense that they have come to be known over the past century and a half.

Mumford's plea to form a clear conception of "what constitutes a valid human life" moves the argument far beyond the balance of trade and even the number of manufacturing jobs created. The industrialization of American agriculture in the twentieth century, for example, broadly laid out along both Taylorist and Fordist lines, has made it the most productive in terms of produce per person-hour in the world. But here, as elsewhere in technology, the process has created a tightly organized agroindustrial complex, at the cost of fragmenting other, and perhaps more important relationships: people driven from the land and small towns dying; soils and groundwater poisoned, some perhaps forever; crops bred, grown, and processed to maximize value added in economic terms but stripped of nutritional value and taste; petroleum-based systems of cultivation that are energy sinks (requiring more British thermal units to grow than they produce in crops); the loss of a way of life that had its own values, not least of all a realistic sense of scale, cause, and effect. Whether one looks at industrial production, biological reproduction, domestic workplaces, the mechanism of war, or the machinery of government, the same restructuring of meaning through modernist technology can be seen and increasingly appears problematic.

Noam Chomsky has asked how it came to be that the freest, most democratic nation in the world has such a narrow and impoverished range of political discourse, how ideas not acceptable to the dominant authorities are so easily and effectively marginalized and trivialized. It can also be asked how modern American technology, so ripe with the promise of variety and empowerment, leads instead to monolithic systems that constrict rather than liberate, that often undermine rather than reinforce our professed values as a nation.

Whether Mumford's jeremiad is heard or ignored as the United States moves into the twenty-first century, one part of the National Academy of Science's insight into technology assessment is correct: human behavior and purpose are the true and proper subject of our concern. They erred, however, in thinking that human behavior and purpose are separate from technology. The three are, in fact, inseparable; technology can only be understood and used to best advantage when seen as the very embodiment of human behavior and purpose.

5. The Ad Hoc Committee for the Triple Revolution, *The Triple Revolution* (Santa Barbara, 1964), 5.

6. *Technology and the American Economy,* Report of the National Commission on Technology, Automation, and Economic Progress, 1 (February 1966), 110–11.

7. *Wall Street Journal,* June 17, 1968.

8. Henry R. Luce, *The American Century* (New York, 1941), 30, 37.

9. Raymond Williams, *Television: Technology and Cultural Form* (New York, 1975), 20.

10. Ibid., 26.

CHAPTER 13: CHALLENGE AND CHANGE IN A POSTMODERN WORLD

1. *New York Review of Books,* 6 (April 28, 1966), 3, 5.

2. Ibid., 5.

3. National Academy of Sciences, *Technology: Processes of Assessment and Choice* (Washington, D.C., 1969), 3, 11, 15, 78–79.

4. Quoted in Bathe, *Oliver Evans,* 97.

5. *Science,* 197 (July 15, 1977), 241.

6. Society of Women Engineers, *Achievement Award, 1952–1974* (n.p., n.d.).

7. Philip H. Abelson in *Science,* 252 (May 10, 1991), 757.

8. *Science,* 252 (April 5, 1991), 21.

9. David Harvey, *The Condition of Postmodernity* (Oxford, 1989), vii.

CHAPTER 14: OUR (UN)WIRED WORLD

1. Rosalind Williams, "Cultural Origins and Environmental Implications of Large Technological Systems," *Science in Context,* 6, 2 (1993), 381, 382, 389, 395.

2. Quoted in the *Sydney Morning Herald,* February 19, 2006.

3. Paul Ceruzzi, "An Unforeseen Revolution: Computers and Expectations, 1935–1985," in *Imagining Tomorrow: History, Technology, and the American Future,* ed. Joseph J. Corn (Cambridge, 1986), 191.

4. Quoted in Mike May, "How the Computer Got Into Your Pocket," *Invention and Technology,* 15 (Spring 2000), 49.

5. Quoted in James C. Williams, "Frederick E. Terman and the Rise of Silicon Valley," in *Technology in America: A History of Individuals and Ideas,* ed. Carroll W. Pursell, Jr. (2d ed., Cambridge, 1990), 284.