PERCEPTIONS OF TECHNOLOGY

Technology is ubiquitous in daily life in developed societies and is becoming so everywhere. It is people's common daily experience (in the workplace, at home, or at leisure) to be immersed in a technological environment.

At an increasing pace since the eighteenth century, some technological artifacts arriving on the scene seemed thereafter to exercise a predominant, even controlling, influence on social life. Common examples are the railroad, the telephone, television, and the computer. That technology plays a significant role in human affairs cannot be disputed. What can be, however, are the interconnections between technology, on the one hand, and the social order: the political process, economic and/or class interests, social attitudes, cultural beliefs, ideological perceptions, and the like. One thing is certain, no present or past technology came into existence as a result of democratic decisions after public debate.

Agency is often ascribed to technology: a technical device is invented and thereby history is changed. The technology represented by the late nineteenth century typewriter, for example, was said to be a major agent for women's independence, because the need for typists permitted them to leave the home and acquire financial security. The automobile is said to have *caused* suburbanization; it also *brought about* a major change in sexual mores. (Of course, these were not the *motivations* for developing those technologies.) A more recent revolution in social and work life was caused by the advent of the personal computer. Furthermore, the development of each generation of more sophisticated computers and software seems to follow the preceding one by a purely internal, technical logic independent of any individual's or group's particular economic or political interests. How valid are such technological-cause/social-effect conceptions?

These are the issues explored in this article. The period of time is limited to the last quarter millenium, most particularly to what might be called "contemporary" technology. Lewis Mumford divides the second millenium into three technological periods named by analogy with the First, Second, and Third Stone Ages. The *eotechnic* extends to about the middle of the eighteenth century. The second, or *paleotechnic,* era extends for less than a century and leads to the neotechnic age. "By 1850," he writes, "a good part of the fundamental scientific discoveries and inventions of the new phase had been made: the storage cell, the dynamo, the motor, the electric lamp, the spectroscope, the doctrine of the conservative of energy" (1). Of course, this was written before TV, nuclear weapons and power, automation, computers, the space age, or organ transplants. In Mumford's terms, "contemporary" includes the late paleo and the neo phases of technology.

DIFFERING VIEWS ON TECHNOLOGY

In the nineteenth century the concept now called technology was called variously the practical, industrial, or mechanic "arts." Webster's 1909 *Second International Dictionary* carried the definition of technology as "industrial science, the science or systematic knowledge of the industrial arts, especially of the more important manufactures." It acknowledged only one dimension of technology. By the 1981 Webster's *New Collegiate Dictionary,* the meaning of technology had become the totality of the means employed to provide objects necessary for human sustenance and comfort.

A dictionary definition cannot convey the rich context of the term but even this dictionary definition implies agency. Whatever technology is, it is the agent that provides what humanity needs for consumption. The "means employed" could be economic, organizational (corporate or governmental), physical (machines, communications systems), scientific (knowledge-based), or intellectual. Leo Marx comments that, although the word "technology" had been used in other senses since the seventeenth century, the present "abstract sociologically and politically neutral" meaning did not appear until the mid-eighteenth century and ". . . in today's singular, inclusive sense did not gain truly wide currency until after World War I. . ." (2).

A century ago, the most common quick response to the stimulus "technology" in a free association might have been "machine," a physical object, an artifact. This is an inadequate conception of contemporary technology. This article is part of a group of articles on technology and society. The term *society* is an abstract concept. It is not simply a collection of people but includes their interactions; relationships; bonds that tie them to political, religious, economic, and cultural institutions; mores; and much more. In the same way, technology is also an abstract concept consisting not merely of a collection of machines, but also including the purposes for which they are designed; the social and institutional contexts in which they are created and used; their interrelationships; maybe even the impact they have on individual and collective human life. Within the past two decades historians and sociologists of technology have introduced broader concepts of technology and technological systems under which even human beings are subsumed as inventors, system builders, corporate executives, and others. These concepts are examined in the section on Social Construction of Technology.

Technology Defined

This general description of "technology" needs further expansion and clarification. Contemporary technology has at least the following dimensions (3):

1. *Physical objects.*
   a. *Materials.* metals, plastics, chemicals, drugs, synthetic fibers.
   b. *Hardware.* tools, instruments, machines, appliances, weapons.
   c. *Structures.* buildings, bridges, plants, dams.
   d. *Networks.* road, rail, pipeline, electric, communications, airline, the Internet.
2. *Know-how.* Not just scientific knowledge but procedures, methods, processes, algorithms, skills, approaches to design, in a word, *technique.* In modern times, some procedures, algorithms and the like are embodied in *software.* Thus, software also forms part of this component of technology. Know-how and software are as much parts of technology as a machine. Indeed, for some, technology is nothing but certain kinds of know-how. It is

   not hardware but knowledge, including the knowledge of not only how to fabricate hardware to predetermined specifications and functions, but also of how to design administrative processes and organizations to carry out specific functions, and to influence human behavior toward specified ends (4).

3. *Organization and System.* The organized structures of management and control; the integrated "administrative processes and organizations" that link together hardware and physical structures into systems.
4. *Economic and Political Power.* The ability to make operational one's wishes regarding the deployment of the other components of technology; power over financial and production processes; the ability to shape social conditions in compliance with one's desired ends.

Each component of technology is discussed in context. It might be argued that the last two categories (especially the last one) are remote from the artifacts and physical networks that everyone accepts as constituting technology and that they fall in the category normally considered part of what is considered "social" rather than "technological." Nevertheless, they fit within Webster's "totality of means" used to satisfy human needs for food and well being. Some define technology and technological systems to include even more components than those specified here. (See the section on Social Constructivism.) Nevetheless, it is useful to bear in mind that many in the past used the term "technology" to refer only to physical objects. We continue this usage when discussing past stages in history.

Progress and Technological Optimism

The eighteenth century saw the flowering of an era of intellectual ferment in Europe known as The Enlightenment. It looked upon human reason as the means for finding truth and for an almost limitless expansion of knowledge. Together with science, reason would bring an increased understanding of nature and an improvement of the human condition. Earlier scientific work had already brought a great expansion in human understanding of astronomy, physics, optics, and other sciences, and this progress in science was expected to continue.

The Enlightenment overlapped with the First Industrial Revolution which, first in England, later in its North American colonies and in Western Europe, brought new sources of power, new machines, and new forms of production. (The Second Industrial Revolution, still in progress, began after WWII with the rapid development of automation and robotics, computer technology, telecommunications, and space technology.)

Just as The Enlightenment fostered an inquisitive, scientific, upbeat perspective on the growth of knowledge and human understanding of the world, a strong optimistic belief grew, starting in Mumford's paleotechnic period, that what we now call technology would constitute the means for a continual transformation of the future toward the betterment of human life, toward "progress." Technology was viewed as the driving mechanism for progress, and it was celebrated because things seemed to be improving with time and also that this improvement was cumulative and growing. (Not everyone was in this celebratory mode; see the section on Luddites.)

As the nineteenth century went on, many ". . . expressed an unbounded enthusiasm for the machine age, so much so that one gets the impression that heavier and heavier doses of technology are being prescribed for the solution of societal ills. Inspired by their contacts with the great inventions of the age, writers and artists purposely endowed steamboats, railway locomotives, machinery, and other inanimate objects with life-like qualities in order to cultivate emotions of wonderment, awe, magic . . . in their audiences" (5).

These emotions were also created at the many international expositions extolling technology, mounted in various world cities, starting with the Great Exhibition of Industry of All Nations in 1851 at the Crystal Palace in London. It was a spectacular success. Hoping to re-create the spirit and success of the London Exhibition, the much smaller New York Crystal Palace Exposition opened in 1853. It closed prematurely at a loss because of construction flaws. Even so, paeans were written about "the glorious results of industry and skill." (Technology had not yet acquired its present connotation, its most common stand-in at the time being "industry.") The major attraction at the 1879 Paris exposition commemorating the centennial of the French Revolution was the technologically dramatic Eiffel Tower, right next to the palace of machines. The motto of the 1933 Century of Progress World's Fair in Chicago was emblazoned across the entrance: Science Finds—Industry Applies—Man Conforms.

After some of the major traumas of the twentieth century, many associated with "advances" in weaponry and new technology, the vision of progress has dimmed substantially. (Some examples: the horrors of poison gas and other weapons in the trench warfare of WWI; the Holocaust and the destructiveness in WWII, including the atomic bomb; Bhopal and Chernobyl; environmental pollution and imminent ecological disaster.) Nevertheless, the ideology of "progress" has persisted into modern times, most often in a technocratic guise. (The ideological use of that concept is found in a mid-twentieth century corporate slogan of the General Electric Company: "Progress is our most important product.") There is no doubt that tremendous changes have occurred in society and in human life since the advent of The Enlightenment and the scientific and industrial revolutions. Unlike "progress," however, "change" does not carry a polarity, and not all change is progressive.

TECHNOLOGICAL DETERMINISM

What impels the development of technology? Does the technology developed in any one period result from the then-current state of scientific knowledge and technological development? Is it, rather, the result of social, economic, moral, ideological, or political forces? The "progress" that was welcomed and celebrated in the nineteenth century implied a chain of causation and effect: applications of advances in scienific knowledge resulted in the invention and development of technological devices and systems whose widespread adoption resulted in changes in social life.

"Hard Determinism"

In the last two centuries, as one technological development followed another (from steel making to railroads, from the telephone to electric lighting, from automobiles to airplanes, from computers to robots to space rockets), an impression has been created that human will and desire have no bearing on the technological state of affairs at any given time. Neither do social goals and yearnings, or politics. Given the state of technology in any era and knowledge of the laws of nature then current, what follows technologically is determined, independent of people's individual or social aspirations.

In this view, it is the state of science and technology that determines social structure. The latter adapts to technological change. This schema was dramatically presented in the 1933 Chicago World's Fair guidebook amplifying its motto:

> Science discovers, genius invents, industry applies, and man adapts himself, or is molded by, new things . . .. Individuals, groups, entire races of men fall into step with . . . science and technology (3).

The irony that human beings should willingly bow to the dictates of a technological imperative escaped the promoters of technology. More recent technology promoters and beneficiaries of the wealth it brings them have a similar outlook:

> We must now plan on sharing the earth with machines . . .. But much more important is that we share a way of life with them . . .. We become partners. Machines require for their optimum performance, certain patterns of society. We too have preferred arrangements. But we want what the machines can furnish, and so we must compromise. We must alter the rules of society so that we and they can be compatible (7).

Does Ramo really mean "compromise?" He doesn't say that if human social life, the patterns of society, are not optimum for the machine, then redesign the machine. On the contrary, the prescription is to change society, to change people to make them conform to the machine. No suggestion that the machine be constructed to be compatible with human processes and goals but that humanity accept the social patterns needed by machines. (Ramo represents the R in the TRW Corporation.)

In this outlook, technological development follows a self-determined sequence and technologically developing societies must, of necessity (and willingly), follow such a sequence. ". . . the steam-mill follows the hand-mill not by chance but because it is the next stage in a technical conquest of nature that follows one and only one grand avenue of advance" (8). Such a view is buttressed by the frequent occurrence of "simultaneous invention," the independent appearance of the same (or similar) technological inventions by different individuals in different parts of the world, as if the condition of technology was then ripe for such a development. "Hard determinism" is the designation given to this unidirectional concept that technology drives history.

An expansion of this view implies that the technology existing and dominant at any particular time must have best fulfilled some objective criteria to reach its dominant state. Competing technologies must have been evaluated on their technical merits by competent engineers and on their economic merits by hard-nosed entrepreneurs and found wanting. Perhaps there was even a "technology assessment," judging competing technologies along many dimensions and deciding on the specific one that objectively met all the important criteria. Such a description makes it appear that the deployment of technology follows a Darwinian pattern, that machines evolve through a process similar to natural selection in the biological realm. Those technologies that survive must have been the fittest, in some sense.

"Soft Determinism"

While judging that technology is indeed a force that brings about social change, "soft determinism," a milder version of the concept of technological determinism, acknowledges a reciprocal relationship: that socioeconomic or political forces, in turn, influence the development of technology. One propeller of technology, at times culminating in war, is national rivalry. The existence or anticipation of war, a matter not itself strictly technologically determined, spurs the development of weapons and the technologies necessary for their manufacture. The development of tanks, submarines, planes, and other increasingly sophisticated weapons, such as guided missiles and nuclear weapons, is undertaken not because they constituted the next step in a technological development following a linear path, but because the social/political conditions of war or preparations for war impelled their development. On the other hand, the level of scientific knowledge at any given time limits the potential development of such weapons. (No atomic bomb during World War I, say, because the requisite scientific knowledge was unavailable at the time.)

But it is not solely in weaponry that the military is powerfully involved in shaping technology. It supports research and development generally in many areas of technology. Clearly, the military's penchant toward command and control, regimentation and hierarchy, skews the development of technology in directions to serve these requirements.

Another argument countervailing to hard determinism holds that the direction of technological change depends to some extent on social policy. Heilbroner gives the example of interchangeable parts in manufacturing. Although the concept was first introduced in France and England, he reports, it was exploited in the United States first. Among other social/economic factors, the difference was that it received government support in the latter but not in the former. Hence, social policy sometimes plays a role in technological development (8, p. 62).

Note also that the context within which the concept of technological determinism is embedded is itself a specific socioeconomic system, one that seeks to maximize the profit to capital. It is possible to conceive of a socioeconomic system with different imperatives and social goals: minimizing the use of nonrenewable natural resources ("walking lightly on the earth"); maximizing the equitable distribution of the benefits of technology; maximizing the use of the creative energy of all persons; and the like. Under such a regime it is easy to conceive that technological development could take different directions. (After all, it was social activism, not maximizing profit, that brought about the recognition that the deployment of technology was inhospitable to people handicapped in certain ways. Inaccessible public accommodations and transportation, the common design of streets with curbs and public places (restaurants, stores, theaters, workplaces, even college classrooms) constituted impediments to those who lacked mobility and required the use of a wheelchair.)

Neutrality of Technology

For some who share a zeal for "high-tech," "advanced" technology, whether technology determines the nature of society or vice versa is not significant. Rather, they view technology as a neutral tool that, independent of anyone's motivations, exists in the social environment and can be used for good or evil. Consequences follow from individuals "using" the existing technology. Samples of such thinking follow:

> [I]t was not really technology but the selector or user of it, man, who should be faulted. Surely everyone understands that science and technology are mere tools for civilized man. (7, p. vi)

> Thus we manufacture millions of products to enhance our physical comfort and convenience . . .. But in doing this, we overlook the need to plan ahead. (9)

> Technology per se can be regarded as either good or bad, depending on the use man makes of it . . .. Nuclear power provides a good example, for the power within the atom can be used for constructive or destructive purpose, as man chooses. (10)

> The only positive alternative to destruction by technology is to make technology work as our servant. In the final analysis this surely means mastery of man over himself, for if anyone is to blame, it is not the tool but the human maker and user. (12)

> Mind determines the shape and direction of technology . . .. If technology is sometimes used for bad ends, all bear responsibility. (13)

Note the use of the singular term "technology," without qualifier, in all of these statements. Common threads in such declarations are that

"technology" is a mere passive tool whose consequences depend on the uses to which "we" put it;

if "technology" is "used" harmfully, "humans" are to blame;

"technology" itself is neutral and embodies no values;

"technology's" role regarding issues of power and control is entirely passive.

Although meant to be explanatory, the quoted statements ascribe action to vague nouns and pronouns whose antecedents are unclear: "technology," "humans," "our," "mind," "we," "all." What is meant by the generic "technology"? Are "all" individuals (workers, military officers, corporate executives) equally responsible for the "use" of technology? Is it an abstract "mind" that shapes technology or some specific minds imbued with specific ideologies? Are the "we" who overlook the need to plan ahead the same "we" who manufacture? Does anyone's profit enter the picture? Are there not specific individuals, institutions, and groups whose interests are major factors in the development and deployment of various technologies?

What can choice in "using" technology mean in contemporary developed society? Individuals, mostly as personnel, are embedded in an organized employment structure in which they perform specific, well-defined functions. For the proper functioning of the order, the totality of these functions must be coordinated and articulated. In this context, the concept of technology as a neutral tool for autonomous individuals to "use" as they choose cannot be reconciled with the need to keep "the system" running. It is not meaningful to imagine individuals in their capacities as employees and personnel, from operators of the most sophisticated equipment on the assembly line to airline pilots, from supermarket checkout clerks to hamburger slingers at the fast-food outlet, as autonomous wielders of neutral tools to achieve their individually chosen goals. Individuals have little discretion or autonomy in the manner in which they utilize the technology appropriate to performing their function (14).

As consumers also, people have little choice in how they "use" technology to reach their aims. The function of a vacuum cleaner is to clean a carpet. If one's goal is to mix the ingredients for a cake, one cannot use a vacuum cleaner for the purpose. It is not meaningful to describe the choice of a mixer instead of a vacuum cleaner as being "for constructive or destructive purpose." Are there different ways to "use" an urban subway? In what different ways can an individual use a television receiver? Thus, the view that technology in some generic sense is neutral and that its impact depends on how one "uses" it is meaningless.

Autonomous Technology

In Western societies the march of progress was noted and celebrated for some two centuries. One technological development followed another with increasing frequency, each leading to changes in social life. "The automobile, the airplane, the nuclear reactor, the space rocket, the computer—all have stood as representations of the now familiar set of phenomena: the growth of scientific knowledge, the expansion of technics, and the advent of rapid social change" (14, p. 45).

On this model, the technologies of broadcast and cable television systems are made possible by growth in the sciences of photography, electromagnetics, electronics, optics, and others. Based on such sciences, inventors and engineers create technological artifacts: picture tubes, cameras, electronic devices, antennas, transmission cables, and the like. These are assembled into a system: television, which then leads to social change. (See the section on Social Constructivism for a different account.)

Note the social change attendant on the "technology" of television in late twentieth century United States, for example. Unlike forty years earlier, on average, individuals spend over six hours *daily* watching television, of which at least one hour consists of enticing commercials urging viewers to purchase and use this or that specific product. Individuals spend this time alone or in the company of a few other household members, with little or no social interaction. It is easy to conceive that this atomized social life, with little interpersonal interaction (discussing events and concerns with neighbors, attending social or cultural gatherings, participating in political discussions or debates) results from television technology.

It can be argued forcefully, on the other hand, that the specific nature of the "vast wasteland" of TV is not an inherent characteristic of the technology of electronics, video tubes, TV antennas, video cameras, etc., but results from the ideology of the socioeconomic system that gives first place to maximizing private profit. A system with different social goals could lead to different social outcomes, even with the same physical technology, as previously noted. Thus, the awarding of publicly owned TV spectrum space could be carried out under different principles, recognizing the spectrum as a public resource to be used for public purposes, not for private profit. Program financing could be achieved by methods that give control to viewers rather than to advertisers and by similar mechanisms not predicated on maximizing the private profit of sellers and buyers of advertising.

Back from the example of television to the main narrative. The arrival on the scene of a particular technological development, or a related set of them, seems to result in a change in social existence. What's more, some say, this process is autonomous and inevitable, obeying only the normal operation of the free market. In the face of market-driven industrialization and modernization, how can there be human choice in technological advance? If a machine or technique "outperforms" others, then the latter are at a disadvantage. Such a disadvantage is overcome by adopting the competing machine or technique and even developing further "advances." The same applies to the technology of weapons. The development of a weapon in one country is quickly followed by its adoption elsewhere. Such considerations can result in viewing "technology" as possessing autonomy.

Ideological Technologies

Although humans must be involved somewhere in such a linear, automatic process driven by its own momentum (scientific knowledge → technology → social change), do individuals or groups make choices and take independent actions that result in "controlling" some specific technologies? Assuming that individuals or groups play such roles, are these roles decisive or do they conform to the requirements of the specific technology itself? Are humans involved as individuals or by way of institutions in society (government agencies, corporations)? Do economic or ideological motivations of individuals play a decisive role?

The Example of Numerically Controlled Machine Tools. David Noble (15–17) provided an important answer to such questions after an exhaustive seven-year investigation of the machine tool industry in the United States and its adoption of numerical control (NC) of machine tools in the decades following World War II. (Noble reviewed the public literature; studied the personal papers of contributors to the process; consulted internal documents of corporations engaged in the development of automated machine tools; consulted contracts given by the Air Force to MIT and others in support of the development; pored over archival material while a faculty member at MIT; and interviewed individuals who had participated in the process at its inception and along the way.) He reaches several important conclusions:

At the time that NC was being developed, several other approaches to automated machine tools existed besides the ultimately adopted one. One was the record-playback (RP) system where a skilled machinist's detailed motions were recorded (on punched cards or magnetic tape) during machining of a piece on a machine tool. Subsequently, other copies of the part would be machined by automatically playing back the tape. This process retained an important role for skilled workers.

The major reason for the adoption of computer-controlled machining over other methods like record-playback was to remove decision making in production processes from the skilled workers on the shop floor and shift it instead to management. This process of deskilling of workers has been a major thrust of management from the early days of the First Industrial Revolution. See the later section on Luddites.) Noble describes the efforts of a number of machine-tool designers who developed several varieties of automated machine tools to be operated by knowledgeable machinists. "The aim was to take advantage of the existing expertise, not to reduce it through deskilling; to increase the reach and range of machinists, not to discipline them by transferring all decisions to management; to enlarge jobs, not to eliminate them in pursuit of the automatic factory" (17, p. 69). Although such machines were simpler and, hence, cheaper than the competing computer-controlled machines, management never adopted them.

No economic advantages of computer control over record-playback or other schemes have been demonstrated; no comparisons of the systems have been made, or are even possible, because, at every turn, those making the decisions opted for NC for noneconomic reasons. This is contrary to the common belief that whatever technology exists must have won out economically over competitors in the free market.

Some two thirds of the funding for the development of computer control came from the military, specifically the U.S. Air Force, through contracts provided to corporations and universities (particularly MIT). The same funding was ultimately unavailable to those who sought to develop record-playback (or other) systems, including an entrepreneur who obtained the initial contract for such a system from the Air Force. It is not surprising that military funds played a significant, even determining, role in this and other major technological developments (the airplane, for example) and that, contrary to the ideologically accepted view of market determination of technology, these nonmarket-driven technological developments may not have occurred without such funding.

Noble describes the fascinating story of entrepreneur John Parsons who in mid-1949 obtained a contract from the U.S. Air Force to develop a "cardamatic" contour-cutting machine to be controlled by a punched card reader. Parsons had earlier entered into an "agreement" with IBM to develop the needed "data-input reader." Later in 1949 Parsons awarded a subcontract to the Servomechanisms Laboratory at MIT for technical assistance in the servomechanisms area. MIT had had a long history of military support during and following World War II. At the time, MIT engineers were heavily engaged in developing computers and computer systems. According to Noble, their enthusiasm for computer control and their close contacts with the Air Force were compelling; Parsons never knew what hit him. Within six months of MIT's involvement in the project, Parsons and his vision had been discarded and MIT, with its different aims, was running the project. Specific individuals at MIT (department chairs, project directors, lab heads) were the determining actors. The Air Force continued to fund the MIT numerical control project for some 10 years, and Parsons was never able to bring his vision to fruition. Belated recognition for him as the inventor of automatic machine tools arrived when Ronald Reagan awarded him the National Medal of Technology in 1985 and he was inducted in 1988 into the National Inventors Hall of Fame: Thomas Edison and the Wright Brothers are among its 100 inductees (15, pp. 96-143).

Examples from the First Industrial Revolution. Another answer to the major question, whether actions of ideologically or economically motivated individuals are controlling in the development of technology, comes from the early history of the First Industrial Revolution. In his study of the textile industry's birth in England, David Dickson shows that the rise of the factory system and the organization of work in factories were largely a managerial necessity rather than a technological one. It was done for "curbing the insolence and the dishonesty of men." The rising class of factory owners and their champions made no bones about it. Specific machines introduced into factories by specific individuals or groups of entrepreneurs had as their major purposes the subduing and disciplining of workers.

Speaking of one invention in the textile industry, Andrew Ure, an early champion of industrial capitalists, wrote: "This invention confirms the great doctrine already propounded that when capital enlists science in her service, the refractory hand of labour will always be taught docility." Samuel Smiles, biographer of several industrialists of the period, provides further confirmation: "In the case of the most potent of self-acting tools and machines, manufacturers could not be induced to adopt them until compelled to do so by strikes. This was the case of the self-acting mule, the woolcombing machine, the planing machine, the slotting machine, Nasmyth's steam arm and many others" (19).

Was the factory system of manufacturing (replacing the earlier "putting-out" system) established to house previously unavailable, larger and more complex machines? David Landes describes four main reasons for the introduction of the factory system.

> The merchants wanted to control and market the total production of the weavers so as to minimize embezzlement; to maximize the input of work by forcing the weavers to work longer hours at greater speeds; to take control of all technical innovations so that it could be applied solely to capital accumulation; and generally to organize production so that the role of capitalist became indispensable. (20)

An illustration is provided by Richard Arkwright's water-frame spinning machine. It

> was originally designed as a small machine turned by hand and capable of being used in the home. It was Arkwright's patent that enclosed the machine within a factory, had it built to large-scale specifications, and henceforth refused the use of it to anyone without a thousand-spindle mill. (21)

It was the economical and ideological interests of Arkwright and his partners that foreclosed the alternative of domestic-scale water-frame spinning, that is, social change resulted from the economic interests of a few, mediated by the form of technology this interest demanded.

Many of the larger, multiple-operator, power machines were not developed and introduced until after the factory-based system was established. Thus, the factory system was not needed for technological reasons to house new machines.

It was, rather, a managerial necessity. Once in existence, however, the factory permitted the use of waterpower and, eventually, steam power. With power machines, entrepreneurs demanded more speed-up by workers; daily work time became no shorter than 10 hours but most often 14 hours or more, mostly every day of the week, even for women and children as young as ten.

Thus, the early history of the First Industrial Revolution illustrates once again the major influence of the ideology and economic interests of specific individuals or groups, endowed with power, on the chain of causation leading to the specific forms taken on by technology, that then lead to social change.

Working conditions in industrial societies have improved since then, not as consequences of technology but of extended conflict by those most affected, against unbearable conditions of working life imposed by industrial managers. The 8-hour day and 40-hour workweek were not benefits that flowed organically from technology, but were the result of century-long struggles by working people. One might expect that the tremendous advance of technology in the Second Industrial Revolution of the last half-century would permit a further reduction of daily and weekly hours of work, but it has not happened. Instead a greater disparity in income and wealth has occurred between those who work and those who control and manage the means of production.

The Case of Parkway Bridges. Over half a century, starting in the 1920s, Robert Moses, under various official titles, supervised the construction of the major infrastructure of New York: bridges, roads and highways, and other public works. The multilane parkways running from New York City to Long Island required bridges over them to permit cross traffic. Moses designed these bridges to inhibit the passage of public buses under them. It was a simple matter of designing the bottom of the bridges (at the outer edge of the parkway) to be unusually low, just three-quarters of the height of the typical public bus. Very few low-income or black people owned cars in earlier decades of his tenure, which meant that Robert Moses' bridge "technology," together with his veto of an extension of the Long Island Railroad to Jones Beach on Long Island, effectively prevented such people from enjoying the beach. It was not the technology that produced the societal effect, it was the social ideology of class and race adhered to by a powerful individual, mediated through a technology favoring private automobiles over public transportation (23).

The McCormick Reaper Case. Similar lessons follow from other events in the history of industrial development. An illustration where an individual's economic and ideological interests were furthered through the mediation of technology dates from the 1880s. Cyrus McCormick manufactured mechanized agricultural equipment in Chicago. In the early 1880s, unhappy with working conditions in the McCormick plant, skilled workers were trying to organize a union, something McCormick violently opposed. He installed relatively new and unproven pneumatic molding machines in his factory at a cost of about $500,000. (In year 2000 values this is equivalent to more than $100 million.) The significance was that only unskilled workers were needed to operate these machines, thereby eliminating the skilled workers. The machines were inefficient and produced inferior products at higher costs. Their real purposes were getting rid of the "troublemakers," destroying the union, and cowing the remaining workers. Those goals achieved, the machines were abandoned (24).

Technology in Support of Ideology

Cyrus McCormick was not the first to use specific machines in factories to tame workers rather than as tools of production. As noted above, it was common practice in the early years of the First Industrial Revolution in England. "Machines . . . introduced not merely to create a framework within which discipline could be imposed but often as a conscious move on the part of employers to counter strikes and other forms of industrial militancy" (19, p. 79). The contribution of machines to the success of industrialization did not lie mainly in the increased production they made possible but equally in their contribution in establishing the prerogatives of management over labor.

Although the physical objects and know-how components of technology play prominent roles in the preceding cases and others like them, if those components are viewed as constituting all of technology, then technology itself is just a mediating mechanism, a tool, for achieving some other (social, managerial, or ideological) purpose. In the McCormick case, the ideological purpose of controlling workers was achieved in a brief time, after which the physical technology was discarded. In the Robert Moses case, the physical technology, still in use, continues to exercise its original social and ideological purposes. The same is true of the factory system from the First Industrial Revolution. Although it appears that the physical technology determined the subsequent social development, technology itself was not the independent variable. Rather, individuals or social classes, in their own ideological interests, acted to create and introduce the physical technology that then resulted in societal changes. Political and economic power was the determining factor in the cases just treated.

Quick Technological Fix. In the section on Ideological Technologies, examples described technology being introduced for malignant social purposes. There is a strain of thought that technology is introduced consciously to "solve" existing social problems. Hence, its social purposes might be viewed as benign. Examples of "social problems" are rapidly increasing population, rising world temperature, deterioration of the environment, shortage of water. Some contend that such social problems result from people's individual acts: they do not limit the size of their families, they use water profligately, and so on. Confronted by such problems, the question becomes

> . . . to what extent can social problems be circumvented by reducing them to technological problems? Can we identify Quick Technological Fixes for profound and infinitely complicated social problems, "fixes" that are within the grasp of modern technology, and which would either eliminate the original social problem without requiring a change in the individual's attitude, or would so alter the problem as to make its resolution more feasible? (25).

A technological fix, then, is a means to eliminate or meliorate a social problem. It is tempting to say that such a technology is "socially constructed" because its origin is a social problem. (See the section on Social Construction of Technology.)

As a then new technological fix, Weinberg suggests the intra uterine device. "The IUD does not completely replace social engineering by technology; . . . yet . . . the IUD so reduces the social component of the problem as to make an impossibly difficult social problem much less hopeless." (Unfortunately for the author, this technological fix turned out to be so harmful to the health of women using it, that a class action legal suit was successfully brought against the manufacturer, and the device was removed from sale. It was more like a technological hoax than a technological fix.)

As a further example, Weinberg suggests that the hydrogen bomb is "the nearest thing to a Quick Technological Fix to the problem of war." He suggests nuclear desalting plants as the technological fix to solve the problem of water shortage throughout the world.

> I have little doubt that within the next ten to twenty years we shall see huge dual-purpose desalting plants springing up on many parched seacoasts of the world.

He sees cheap energy from nuclear reactors as a megatechnological fix for a wide range of "social problems": "help feed the hungry of the world"; eliminate pollution resulting from burning gasoline in automobiles and from burning fossil fuels generally; and the solution of other problems, all from the cheap electricity from nuclear plants. (A pioneer in atomic energy research and development, Alvin Weinberg directed the Oak Ridge National Laboratory in the U.S. for 18 years until 1977. By 1996, 30 years had passed since his paper first appeared; yet his anticipated large-scale nuclear technological fix has yet to materialize, nor is it likely ever to do so.)

Many proposed technological fixes seem to revolve around "mega" fixes: the hydrogen bomb, nuclear power plants, and the like. Lewis Mumford observed that, from earliest recorded history "right down to our own day, two technologies have recurrently existed side by side: one authoritarian, the other democratic; the first, system-centered, immensely powerful but inherently unstable, the other, man-centered, relatively weak, but resourceful and durable" (26). The technological fixes proposed above are mostly of the authoritarian form: large-scale, centralized, hierarchically controlled, inflexible, high-risk, capital-intensive, dependency-imposing.

Identification of a "social problem" (including the wants of people for this or that) is taken as the beginning point. Then technology is to be unleashed to provide a fix. Generally speaking, two mechanisms are invoked to balance the *availability* of a good (water, energy, or anything) with what is thought to be the "need" for this good: supply expansion or demand reduction. Proposing a technological fix is almost always for supply expansion. It is thought that demand reduction requires a change in people's attitudes and practices. "One does not wait around trying to change people's minds: if people want more water, one gets them more water, rather than requiring them to reduce their use of water" (25).

Weinberg's assumption seems to be that, if a resource is overused, it must be the result of individual predilections. In this context, a suggestion of "conservation" evokes certain thoughts: conservation means not using, so doing without. That means self-denial and sacrifice of the good things in life. Because individuals in a consumer society are conditioned to accept the goods that they own and consume as a measure of human worth, conservation seems to require a psychologically unacceptable reduction in personal worth. But conservation does not imply self-abnegation and doing without. It means altering *social* practices so as to achieve benefits with a less profligate use of resources.

Matters under the control of institutions, rather than of "people," have much more to do with conservation than personal habits: building codes calling for improved insulation; architectural designs; lighting standards; packaging standards that avoid multiple packaging; air-conditioning methods that do not release CFCs; adequate public transportation systems; cogeneration (the use of industrial process heat to produce electricity first); reuse of production-generated waste (burning walnut and pecan shells to produce heat and electricity for a nut-processing plant); improved efficiency of engines, motors, and machines of all types. All of these suggestions also constitute technological fixes, but not the mega fixes that technophiles have in mind. Although individuals have a conserving role to play in adopting less wasteful practices, the major gains from conservation would come from changing *institutional* practices. Even recycling materials, in which individuals must participate, requires organization by institutions.

LUDDITES AND LUDDISM: TECHNOPHOBIA AND TECHNOPHILIA

From a distance of some 200 years, the First Industrial Revolution is almost universally viewed as a positive development and an essential precursor of current (turn of the third millenium) life in developed countries. For most of the participants in that upheaval, however, it seemed like an unmitigated impoverishing disaster. (Refer to the section on Autonomous Technology.) In the early years of that epoch, there were spasmodic instances when "machine-breaking" was undertaken by workers to challenge what they saw as destroyers of their way of life: the new machines and their owners.

Such activities reached a climax during the interval from late 1811 to early 1813 when organized groups of workers in the textile trades within central/north England, where that trade flourished, undertook a campaign to smash machines and recover their way of life. Groups of men would enter the factories under cover of darkness to smash the machines. In manifestos and handbills justifying their actions and in petitions for redress, they made references to a fictitious leader "Ned Ludd" (sometimes "General", "Captain" or "King" Ludd) from which they became known as "Luddites." [The most well researched and extensive treatment of this movement is that of Kirkpatrick Sale (27). Also significant is E. P. Thompson's monumental history (28).]

The Luddites were selective in the machines they smashed. The small spinning jennies with fewer than 24 spindles that a single person could operate would be spared, as would the smaller looms. They were not opposed to machinery in general but the machines in factories whose owners deprived them of livelihood and autonomy in their work, who imposed dehumanizing conditions, now recognized and condemned as illegal and immoral child labor and sweatshop practices: "Machinery hurtful to Community" as they put it. Although vague threats were sometimes made in their handbills, they generally eschewed violence against persons and they enjoyed local support in the geographical area of their activities. "Luddite" was a term of opprobrium by the factory owners and government officials but one of approbation by the local populace. The authorities heavily repressed them.

More recently, *Luddite* or *neo-Luddite* has become a derisory term used by champions of high tech to condemn those who question any aspect of modern technology, even those who advocate using the technological fix of solar power, rather than nuclear power. However, some regard the term as a badge of honor and give *themselves* this designation. One has written:

> In contrast to the original Luddites, who focussed on the particular effects of particular machines, the neo-Luddites are concerned about the way in which dependence upon technology changes the character of an entire society. (29)

A derogatory term often hurled at neo-Luddites is "technophobe": one who fears technology, or has technophobia. Those enamored of high tech, who must have the latest model of whatever is available, might be called "technophiles," lovers of technology. However, technophilia does not carry the derogatory implication that technophobia does. (Fearing technology may not be totally irrational in view of the millions that are annually killed or maimed in automobile or industrial accidents or who suffer from the effects of toxic materials worldwide.) Fear, though, is not the emotion that characterized the original Luddites or the more recent neo-Luddites. The more appropriate emotion describing their outlook was hatred, not blind, irrational hatred but one based on the perception that technology is destroying a way of life, community. The Luddites were not wrong about that. Their way of life is gone forever.

SOCIAL CONSTRUCTION OF TECHNOLOGY

As noted, technological determinism is the view that technology, though dependent on science, is an independent variable that determines social outcomes. A somewhat softer version acknowledges that social conditions (government policy, military requirements) can encourage or inhibit the development of specific technologies. This "soft" version modifies but does not negate technological determinism. There are also cases where the specific interests of individuals or classes preceded and structured the technology made possible by advancing science. The resulting social change becomes embedded in the form of technology flowing from those special interests.

Are there situations, however, where the tables are turned, where the "social" in a given society serves to determine the nature of specific technologies and their introduction into society? For answers, one must look beyond technological artifacts and systems themselves (air transport, power systems, television broadcasting) and explore the socioeconomic milieu in which they are developed and deployed. In some cases, indeed, economic, political, even ideological interests of specific individuals or classes might determine the outcome, as discussed in the section on Ideological Technologies. The accounts that follow illustrate other possibilities.

Social Constructivism

Social scientists (sociologists, historians, and others) cannot set up societies for experiments to discover general social truths. Instead, they undertake historical case studies from which generalizations are drawn. If one's field is history or sociology of technology, the case studies deal with the successful (or failed) introduction of specific technologies. Then generalizations are made and tested against other case studies, possibly resulting in changes in the generalizations.

The Case of the Bicycle. Though flawed, the most common explanatory model for technological and social change has been the linear one: science → technology → social change. By necessity, this model concentrates on *successful* technologies that produce social change. Trevor Pinch and Wiebe Bijker suggest a more multidimensional model: innovations are first exposed to social groups that then react to them. Their reactions result in variations on the innovation which are again exposed to forces in society. The process is repeated until the technology is stabilized at its ultimate state: "closure" is achieved (30).

The case study they use is the development of the bicycle. They look at dozens of design variations before closure: size of wheels; propulsion systems; seat position; wheels with and without pneumatic tires; and other variations. The problems or interests of different social groups (e.g., sport cyclists, touring cyclists, racers, people with less strength) shaped the final outcome.

". . . the invention of the 'safety bicycle' was not an isolated event . . . but a nineteen-year process (1879—1898)." During the process, "there were growing and diminishing degrees of stabilization of the different artifacts (i.e., parts of the bicycle)." The ultimate bicycle reached its final (successful) appearance through the mediation of different social groups with different problems that had to be solved before closure.

It can be contended that the bicycle is not comparable, either as technology or as the locus of social change, to automobiles, automated systems of production, electric power, and the like. The social change associated with the latter are truly momentous. The bicycle is certainly a useful mode of transportation for individuals in large cities (Amsterdam, Beijing) and small. It has even been an important transporter of weapons and supplies (along the "Ho Chi Minh trail" in Vietnam). Nevertheless, generalizations about social change drawn from its development should be tempered by realism.

Both Social and Technological Determinism

Other, more significant, case studies have yielded more complex models of interaction of the physical with the social. Some say that neither technological determinism nor social constructivism adequately account for complex social-technological interactions.

The Case of Electric Power Systems. Thomas P. Hughes carried out a particularly significant study of this nature. His major case study was the invention, development, and deployment of electrical power systems, beginning with the first, that of Thomas Edison, and continuing with detailed studies of both large and small systems in California and the central power-generating stations in Berlin, Chicago, and London. Studying conditions both internal to the systems being built and in their environment, he refers to inventors, engineers, system managers, and financiers as "system builders (32)." From the comparative study of the Berlin and London systems, Hughes illustrates how technological systems are shaped by the surrounding social milieu. In the imperial context of Germany, the electrical power system in Berlin was centralized, encompassing six large power plants. On the other hand, in more democratic London, each municipal borough regulated its own power system, resulting in over 50 small plants. Both systems persisted for decades. The result: per capita consumption of electricity in London fell far below that in Berlin. (Though not expressed by Hughes, one might see ideological concepts here: viewing high electrical power consumption as socially desirable; democratic government as detrimental to technological development!)

Hughes' concept of technological system is all-encompassing; components include physical artifacts (generators, transmission lines, transformers, end-use devices) and also

organizations (manufacturing enterprises, utilities, banks)
scientific components (books, journals, research programs)
legislation and agencies of government
natural resources (mines, oil wells)
humans (inventors, engineers, managers, financiers, workers).

(All but "workers" in the latter category are called "system builders.") Workers are human, of course, so they must be included in that category. Nevertheless, within the technological system, they play the same role as interchangeable parts.

For Hughes, the question of causation is not either/or. It is neither technological determinism nor social constructivism he says; technological systems: "are both socially constructed and society shaping" (33). From the given description of a technological system how could it be otherwise? Indeed, Hughes illustrates by many examples that, at every point in the design and deployment of a technological system, the "external environment" must be factored in. Thus, technology is not distinct from the political, social, and economic environment. All are integrated. Indeed, he coined a term that has become a metaphor for this interconnectedness. The social, economic, political, and technological all form a "seamless web."

Variations on Social Construction. Two views have been examined in this section, first, that the social, standing apart from the technological, "constructs" the technology, and second, that the technological, the social, the economic, and the political are all part of a seamless web and the development and deployment of technology is the outcome of all interacting with all. A variation of this last view is championed by Michel Callon who conceives of science, various natural or technological artifacts (catalysts, batteries, even electrons), specific groups of people (engineers, users, government agencies, manufacturers) and others as "actors." Together they form an "actor network" of heterogeneous components, each actor interacting with others. There is no distinction between human and nonhuman actors, or between individuals and organizations. Technological change is the result (34). This model again comes from a case study, this time of the proposed development of an electric vehicle in France and its eventual failure.

The concepts of technological system and actor network have much in common. Because the technology in question actually failed and was not introduced into society, one cannot examine the resulting social change and draw conclusions.

Although other variations of the preceding concepts have appeared, each based on one or more case studies, the differences in outlook and terminology might be significant for sociologists or historians but are less so for engineers.

Technological Momentum

In his study of systems, Thomas Hughes introduced another concept to explain the development of technology, technological momentum. "A more complex concept than determinism and social construction, technological momentum infers that social development shapes and is shaped by technology. Momentum is also time dependent" (35). Hughes arrives at this concept from the study of large systems, not only electric power systems but also many others. In the early phases of technological systems, besides the physical components, the system has inventors, innovators, managers, financiers, and, of course, workers. As systems evolve, become more complex ("thereby gathering momentum"), and mature, "the system became less shaped by and more the shaper of its environment." "Characteristics of technological momentum include acquired skill and knowledge, special-purpose machines and processes, immense physical structures, and organized bureaucracy."

As skills and knowledge acquired during the development and operation of large technological systems find their way into textbooks, new engineers and inventors are trained and eventually apply this knowledge and skill in new enterprises, thus continuing technological momentum. An example given is the application of skills and knowledge acquired during the development of railroads in mid-nineteenth century United States to the problems of constructing intraurban transportation systems (subways, elevated rail) and interurban electric rail systems that proliferated in the period 1890–1910.

This picture fails to explain the fate of interurban electric rail systems that had grown up with such momentum from that time through the 1920s. Many of them were acquired by automobile manufacturers and oil companies; soon after that they went out of existence. It has been contended that these interurban rail systems were destroyed in furtherance of the corporations' desire for more private gain through increased use of automobiles (36). Was it technological momentum or economic power that achieved these results?

Another Hughes example is the existence of major, extensive, but underutilized physical plants of a German chemicals company (BASF) after World War I, when the need for the chemicals it had been manufacturing had dropped. Also underutilized were the "research and development knowledge and construction skills" of the company's "numerous engineers, designers and skilled craftsmen" made idle by the end of the war. These embodied technological momentum temporarily marking time. So, the company board chairman, Carl Bosch (who invented the major chemical process on which the company was founded) "had a personal and professional interest in further development and application" of this process. He put his employees to work to develop new chemical products and later engaged in further research and development from which new products emerged and the company grew. "Momentum swept BASF . . . into the Nazi system of economic autarky" (35, pp. 109–110). Hughes offers this as an example of technological momentum. Another way to describe it is power, economic and political power, whose possessors can create all the "momentum" that they want and that their power makes possible (see the next example). One can easily conclude that the industrialist's "personal and professional interest," together with the economic power resulting from his war work, would have been sufficient to carry the day, even with new employees and new plants lacking previous "momentum."

The same misapprehension is evident in other examples. Especially striking as an example of technological momentum is Hughes' description of the pursuit of atomic weapons in the United States following WWII (35, p. 111).

> Immediately after World War II, General Leslie Groves displayed his system-building instincts and his awareness of the critical importance of technological momentum as a means of ensuring the survival of the system for the production of atomic weapons embodied in the wartime Manhattan Project. Between 1945 and 1947, when others were anticipating disarmament, Groves expanded the gaseous diffusion facilities for separating fissionable uranium at Oak Ridge; persuaded the General Electric Company to operate the reactors for producing plutonium at Hanford, Washington; funded the new Knolls Atomic Power Laboratory; established the Argonne and Brookhaven National Laboratories for fundamental research in nuclear science; and provided research funds for a number of universities. Under his guiding hand, a large-scale production system with great momentum took on new life in peacetime. Some of the leading scientists of the wartime project had confidently expected production to end after the making of a few bombs and the coming of peace.

This is not a convincing description of technological momentum as previously defined by Hughes. This situation is unlike the Bosch/BASF case, where the existing idle plants and idle system builders with acquired skill and knowledge were said to constitute the "momentum." Here a lone general (presumably backed by military economic power) did not just use already-existing momentum but, against the expectations of the "leading scientists" (and the active opposition of some), went about *creating* and funding major new laboratories, presumably staffed by new people, both lacking momentum. The "system-building instincts" and awareness of momentum of this one military officer are offered as the means for initiating a nuclear arms race whose mammoth consequences are still incalculable, and this in the face of "leading scientists" who expected otherwise. Again it seems that other explanatory concepts besides momentum, such as insitutional power of the military, personal ambition, and ideological commitments are decisive. Not General Groves' "system building instincts," but hard cash, after all, was what "persuaded" GE.

CONCLUDING OBSERVATIONS

Technology has been transformed from its humble beginnings as hardware resulting from scientific knowledge into a multidimensional phenomenon. The one dimension that has been inadequately emphasized by writers in the field is economic and political power that supports ideological persuasions. The specific forms that technology takes are strongly based on this power. Other forms of technological systems are imaginable under different principles of social life.

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PERCEPTION, SPEECH. See SPEECH PERCEPTION.