Technology 4001

During the seventeenth century “technology" emerged from modern Latin into English to describe a systematic study of the arts. By the early eighteenth century a characteristic definition was: "a description of the arts, especially the mechanical." The word was not yet widely used. In the United States it became more familiar after the publication of *Elements of Technology* in 1832 by a Harvard University professor, Jacob Bigelow. Yet, as Leo Marx has observed, “At the time of the Industrial Revolution, and through most of the nineteenth century, the word *technology* primarily referred to a kind of book; except for a few lexical pioneers, it was not until the turn of this century that sophisticated writers like Thorstein Veblen began to use the word to mean the mechanic arts collectively. But that sense of the word did not gain wide currency until after World War I.” By the end of the nineteenth century the term was embedded in the names of prominent educational institutions such as the Massachusetts Institute of Technology, but it had not become a common term in the discussion of industrialization. People instead employed the terms "the mechanic arts" or the "useful arts" or "science" in contexts where "technology" would now be used. Only in the twentieth century did the word come to mean entire systems of machines, and it can be an annoyingly vague abstraction that is taken to be at once cause and effect. The word's unstable meaning was further complicated in the 1990s, when the mass media and stock market traders used "technology" as a synonym for computers and information systems.

Within the academy, technology became an important element in a number of quasi-deterministic theories. Liberal social planners in the first half of the twentieth century often conceived of technologies as agents of automatic social amelioration, as can be seen in many world's fair exhibits or in the New Deal's vision of the effects of dam building and rural electrification. Likewise, during the 1960s Marshall McLuhan published a series of books which argued that the introduction of certain key innovations in communications, notably the printing press, radio, and television, had widespread, automatic effects. While he has fallen into disfavor, such ideas are still common in journalistic accounts of "technological impact," a phrase that suggests that a new machine comes from outside of society, like a meteor, and has an immediate effect. A spokesman for the MIT Media Lab likewise has made deterministic utopian claims for the computer, asserting that "digital technology can be a natural force drawing people into greater world harmony." Such ideas are misguided. No technology is a "natural force."

In contrast, Marxists depicted technology as decisive factor in social evolution, arguing that each mode of production created a specific set of class relations. Neo-Marxists shifted the focus to technologies as the means of surveillance, social control, and hegemonic domination, exemplified by assembly lines and corporate penetration of popular culture. More recently, postmodernists emphasized how the acceleration of transportation and communication shrank space, sped up time, disconnected voice from presence, subverted boundaries, intensified the circulation of images, and created a prison-house of representation. Other iconoclasts take the ironic view that technologies can lead to unexpected and unwanted results. For example, the computer, brought into a factory to impose more control on workers, in actual use undermines corporate hierarchies and democratizes access to information. Finally, some see advanced technologies as agents of doom. In this view atomic bombs, chemical pollution, biological mutants, malicious computers, or a combination of different technical systems out of control threaten both nature and civilization. In all such approaches, machines seem at the heart of autonomous systems, leading variously to social betterment, oppression, transformation of the lifeworld, ironic reversals of intended results, or apocalyptic destruction. Individually, these varying forms of technological determinism may seem to explain some phenomena; collectively, they contradict one another.

Those working on technology and culture generally conceive of their field in terms of three possible approaches: externalist, internalist, and contextualist. Externalists examine a machine or technology within a cultural system or ambience, including studies of the reception of new machines, examinations of workers' response to new methods of production, comparative work on technology transfer, or studies of how a new machine or process changes hierarchical relations or social practices. In such approaches, the technical characteristics of machines usually are treated as subsidiary matters, and in some cases (but by no means all) technology may again seem a deterministic force.

Internalists reconstruct the history of machines and processes, with an emphasis on the role of the inventor, laboratory practices, and the state of scientific knowledge at a particular time. They chart the sequence that leads from one physical object to the next. This approach grew out of the history of science and intellectual history and flourished in the early years of the field, just after World War II, and is still found useful today. The internalist tends to focus on individual inventors, their competition, their technical difficulties, and their solution of particular problems.

In contrast to the general public who often believe that "necessity is the mother of invention," internalists frequently find that inventions were not initially perceived as needed. Railway owners, for example, did not initially use the telegraph to regulate their traffic but merely leased rights-of-way to the new communication technology while running their trains according to a printed schedule. It took more than a decade for them to begin to use the telegraph to keep track of the engines and cars moving about on their system. The technology existed, but its use was not apparent. Alternately, the perception of a social necessity may make a new invention clearly desirable, but this does not always lead to the rapid solution of the problem even if considerable money and talent are made available. Since c. 1900 the need for a light-weight battery that can be rapidly recharged has been perceived, not least to power electric cars, and a succession of inventors including Edison, have failed to create it. No omniscience ensures that an invention's value will be perceived, and no abstract necessity calls needed devices into existence. Needs can stimulate invention, but needs can also remain unmet. On the other hand, inventions such as the telegraph can just as often create a newly perceived "necessity."

Recognizing such complexities, most technology scholars now tend toward contextualism; they see machines as integral parts of the social world. If technologies are shaped by the concerns of society, at the same time they have a reciprocal, transformative effect on the world around them. For contextualists, technology is not merely a system of machines with certain functions; it is deeply embedded in the social construction of reality. Technologies are not implacable forces moving through history; they are inseparable from social processes that vary from one time period to another and from one culture to another. Each technology is an extension of human lives: someone makes it, someone owns it, some oppose it, many use it, and all interpret it. In this approach, which is in sympathy with social and cultural anthropology, systems of tools and machines include the labor needed to use them, the theoretical and practical ideas they embody, the values they represent, the class relations they imply, and the ideologies they are used to reinforce. For example, the nineteenth-century technology of the pocket watch is not merely a thing in itself. The watch implies the factories used to produce it, which required standardization of parts, miniaturization, precision, and the industrialization of craft production. Purchased and proudly displayed primarily by men of means, such watches both democratized ownership of timepieces and reinforced punctuality as a technological value. The addition to the watch of a hand to measure each passing second embodied the precision of scientific time, which gradually replaced the older idea of time based on diurnal and seasonal rhythms. Later, managers used the stop watch to measure job performance and coaches used it assess athletes. The pocket watch did not cause these changes, but it fulfilled newly invented needs and it reinforced changes in the perception and use of time.

As this example suggests, despite the many critical approaches used to study technology, there is increasing agreement that machines are inseparable from cultural context. Furthermore, it is difficult to imagine human beings as pre-technological. Native American peoples, for example, developed tools ranging from snow-shoes, traps, weapons, pottery, ovens, to canals and irrigation systems. All social groups seem to possess tools used to provide music, shelter, protection, and food, and these devices are inseparable from verbal, visual, and kinetic systems of meaning. (Technologies in general pre-exist systems of writing by thousands of years; textualization is a recent event.)

From the arrival of the first European ships in North America, the use of new technologies has been a fundamental instrument in the conquest, settlement, unification, and development of the continent. The technological conquest of the New World was based upon possession of the axe and other metal tools, domestic animals that could be harnessed to the plow, and mills to saw logs and grind corn. During the Colonial era, northern European settlers used these advantages to change the ecology that Native Americans knew, transforming forests into farmland, The confluence of colonial cultures in North America brought into contact a wide range of African, European, and Native American technologies. Native Americans selectively adopted devices from the European invaders, readily incorporating firearms but not the bayonet, metal tools but not moveable type, and so forth. Likewise, Europeans learned new technologies from the Native Americans such as how to make canoes and snowshoes, or how to grow corn, squash, pumpkins and tobacco. Africans brought with them agricultural and building techniques and also reconfigured European technologies. In addition, each European nation had its own technological traditions. The Swedes easily built snug log houses in seventeenth century Delaware; nearby, the English laboriously cut planks out of logs to construct houses that were less well adapted to the cold. Water-driven saw mills were virtually unknown in the British Isles, and colonists soon were purchasing that technology from Germany and Holland. During the colonial period Americans primarily imported technologies and did not make many innovations. This was precisely what mercantilist policy sought: to limit colonial manufacturing to the preparation and supply of raw materials to manufacturers in the mother country. Colonies might produce pig iron or bales of cotton, but factories in Britain would then work them up into finished goods. Due to this restrictive policy, at the start of the American Revolution the colonies possessed only three steam engines and no factories.

For different reasons, after the American Revolution Thomas Jefferson and other agrarians also advocated that the United States remain an agricultural nation, with its workshops still in Europe. In their view, agriculture was the only true source of wealth, while cities and factories weakened the body politic, breeding servility and dependence. Jefferson modified his views after the United States lost access to European goods during the Napoleonic wars, however, and advocated production sufficient to supply domestic needs. Nevertheless, Britain's smoky mills and miserable proletariat shocked early American travellers, and even those who sought to industrialize the new nation self-consciously tried to avoid the errors of European nations. They did so by constructing water-driven mills, which produced no smoke, were limited in size by the flow of water available, and were not concentrated in large cities but scattered through the countryside. Indeed, while there were a few larger water-powered mill towns, such as Lowell and Lawrence, they were in fact not typical. By 1838 the Census enumerated more than 60,000 water-powered mills and factories widely dispersed through rural areas, most commanding less power than a family car today. At the same time, there were fewer than 1,000 stationary steam engines, few more powerful than the water wheel.

These chnages soon became the subject of literature and art. Leo Marx's seminal *The Machine in the Garden* showed how nineteenth-century American writers, painters, and orators developed a complex perception of technology that found expression through the pastoral genre. Through it they explored the threats that such machines as steamboats and locomotives posed to a nation that had identified itself with the supposed virtues of the natural world and which cherished rural life in a middle landscape between the wilderness and the city. As industrialization and urbanization proceeded, the pastoral became a more difficult literary response to sustain, but it by no means disappeared, and can clearly be discerned in F. Scott Fitzgerald, William Faulkner, and other modernists.

In the mainstream popular culture of 1900-1950, however, most Americans saw themselves as an ingenious people, a nation of tinkerers and inventors who would industrialize without creating either a proletariat or unhealthy industrial cities. This self-perception has largely disappeared today, as part of a general renunciation of the idea of American exceptionalism, but the national character long was thought to be exemplified by a pantheon of inventors, such as Eli Whitney, Robert Fulton, Alexander Graham Bell, Thomas Edison, Henry Ford, and the Wright Brothers. Recently, Newt Gingrich's *To Renew America*, restated this argument and praised America's "spirit of invention and discovery" as the inevitable product of a free market society without a caste system. In this view, Americans are ingenious Yankees who are adept at the democratic dispersal of useful improvements.

In fact, the United States long benefited from immersion in a transatlantic interchange of designs, techniques, and scientific knowledge. Americans learned from visits to European factories, from fairs and congresses, and from skilled immigrants. The American iron industry was started by English and German immigrants in the colonial period. Major nineteenth century advances such as Bessemer steel and the open-hearth process were developed in Europe and transferred to the United States. The first textile mills in the United States were copies of British mills built by skilled immigrants. Early canals and railroads likewise evolved from British models. Whitney was not the first to invent a cotton gin; Fulton's steamboat used a British engine; Edison freely acknowledged his debt to Michael Faraday and others who had worked with electricity before him. When Americans did begin to produce new inventions and designs during the nineteenth century, they hardly did so in splendid isolation.

John Kowenhoven argued in *Made in America* that there was a distinctive American machine design, exemplified in such artefacts as the American axe, the clipper ship, the loosely jointed American locomotive, and the Model T. Ford. All were characterized by simplicity, plainness, efficiency, and a functional aesthetic. Furthermore, Americans early began to build machines to last only a short time. This practice emphasized immediate practical results, and assumed that machines would be replaced frequently. Where the English built locomotives to last indefinitely, Americans expected better ones to be invented before long. Likewise, where

Europeans early demanded efficiency from stationary steam engines, Americans at first preferred cheapness and simplicity in operation, and willingly used more fuel. For example, Oliver Evans invented a new steam engine which ran at high pressure and quickly became standard on American steamboats.

At London's Crystal Palace exhibition of 1851, European observers found some American machines unlike their own. Yet they did not speak at once of an "American system of manufacturing," an idea invented in the early twentieth century, when some historians began to herald interchangeable parts, the assembly line and mass production as defining national hallmarks. Two characteristic heroes in this account were Eli Whitney and Henry Ford. From the moment that Whitney displayed ten muskets with interchangeable parts to President-elect Thomas Jefferson in 1801, he was credited with creating a uniquely American approach to production. Machines would make identical parts for other machines. But Whitney did not mass-produce interchangeable components for muskets in 1801; they remained an idea more than a reality for years. Furthermore, the idea of interchangability itself was first dreamed in France, during the eighteenth century, by General Jean-Baptiste de Gribeauval. Whitney's workmen made reasonably standardized parts, to be sure, but they did so by hand-filing what came out of the moulds. An astute self-publicist, Whitney emphasized the possible results of his system and made it the ideal toward which many manufacturers strove. Yet the "American system" was not self-conscious even in 1851, and a British Parliamentary committee found that in 1854 the gun maker Samuel Colt had not yet managed the precision necessary to make identical parts. Rather, they were "very nearly alike."

Even though interchangability itself was more a goal than an achievement, first-hand witnesses did find American production methods distinctive. An English workingman who came to the United States during the Civil War found that "there are few trades which have not been materially changed" after they crossed the Atlantic. He emphasized that "division of labour is carried out in all the various branches of skilled labour to the fullest possible extent; this system not only facilitates production, but it conduces to perfection in the workmen; machinery, too, is used for every purpose to which it can be applied." This was a difference less in the machines than in management, which most vigorously pursued interchangability and the sub-division of labor in the United States. The end result of this process was the assembly line perfected by Henry Ford at his Highland Park Plant in 1912. Whitney's factory had required fewer skilled workman than any previous armoury, but Ford went much further. His semi-skilled workmen could learn their tasks in a matter of days, and most of them became largely interchangeable as well.

Mass production has many forms, however. If Ford led the world automotive sector for at least a decade, transforming the nature of capital-intensive industry in the process, Americans did not follow his lead in all areas. A mature industry such as textile manufacturing during the years when Ford was in the ascendancy was less advanced than much of continental Europe, where textile shifted to individual electric drive, and achieved higher productivity because their machines ran at faster and more constant speeds. In contrast, many American manufacturers adopted group drive, typically one motor mounted on the ceiling to drive four machines by belt. Their spindle speed was slower, but as a largely non-union country US wages were often low in semi-skilled jobs, making it unnecessary to maximize capital investment in machinery. No such thing as “Fordism” emerged in this and other industries.

The conclusion that US industries varied considerably likewise emerges if one examines how workers were paid. The heavily-capitalized assembly line encouraged manufacturers to adopt fixed hourly wages, because workers had no choice but to keep up the pace. In contrast, work by piece-rate in the twentieth century enjoyed a revival in labor-intensive industries, such as the shops of the General Electric and Westinghouse. Highly skilled work increasingly was done on the basis of daily quotas, with incentives for exceeding them. Skilled workers often worried that management might discharge slower hands or accumulate a surplus of manufactured goods and then lay people off. To counter such fears, welfare capitalists urged corporations to look after their health, safety, and well-being, in part for humanitarian reasons, but also on the grounds that welfare programs increased loyalty and efficiency, while diminishing labor unrest.

Not only were some large companies run without the assembly line, while pursuing welfare capitalism as a matter of enlightened self-interest. As late as 1930 less than half of all American business had embraced the corporate form. If the great corporations producing steel, oil, rubber, and automobiles were highly visible, most firms were smaller, many family-run. Usually cautious in their development and labor-intensive in their work, they were not necessarily economic and technological backwaters, but could be profitable and innovative. Some specialized in customized production. Others made highly differentiated luxury goods, and, given the growth of middle class consumption, this was a reasonable strategy. Mass-produced goods proved to be less attractive to most consumers than more unique items; department stores profited less from products of the assembly line than from batch-production items such as Wilton carpets, lamps, quality furniture, and other individualized home furnishings.

In short, there was neither a single "American system" of manufacturing in the early twentieth century, nor a monolithic "Fordist" system of production, but rather at least three systems were in place. Older industries, such as textiles, kept wages low and modernized equipment selectively with that factor in mind. Newer mass-production industries, epitomized by Ford, developed a high wage policy, for which they demanded fast-paced routine work on assembly lines. Highly-skilled work developed in yet a third direction, as companies adopted piece-rates and individual incentives. Rather than conceive of technology as a single force or system, such as Taylorism or Fordism, it is more accurate to see individual technologies immersed in economic and social systems that shape their use.

This in turn means that both gender and racial relations also inflect the design, purchase, use and cultural meaning of technologies. For example, during the 1920s radio was a largely male hobby, but in the 1930s manufacturers quickly feminized cabinet design to fit into the living room, while broadcasters developed programming to accord with household routines. Early electric cars were intentionally designed for women, based on the idea that they were appropriately cleaner, slower, easier to start, and limited to a smaller travel radius compared to gasoline cars. African-Americans were denied access to many skilled positions but dominated a few unskilled areas, as in the case of the railway porters. Similarly. Chinese immigrants long were limited to work in laundries and restaurants. Most typists and telephone operators had been women, while most telegraphers, mechanics, engineers, inventors, and computer programmers have been white men. Such divisions have in turn shaped the definition of technology itself, which at times is assumed to be essentially white and male. There is nothing inevitable about the gendered and racialized adoption and use of particular technologies, however. Street railways, electrical tools, automobiles, televisions, computers, or telephones, can be designed, manufactured, and incorporated (or not) into society in many ways.

An important part of this incorporation is symbolic and psychological. Americans have proven to be strongly attracted to spectacular new technologies, often interpreted in terms of the sublime. In the philosophy of Immanuel Kant the sublime is an emotion linked to immense natural objects, such as mountains, or forces, such as hurricaines. But by 1832 an American writer was prepared to assert that "Objects of exalted power and grandeur elevate the mind that seriously dwells on them, and impart to it greater compass and strength. Alpine scenery and an embattled ocean deepen contemplation, and give their own sublimity to the conceptions of the beholders. The same will be true of our system of Rail-roads. Its vastness and magnificence will prove communicable, and add to the standard of the intellect of our country." From the inauguration of the Erie Canal in 1825, Americans have integrated new technologies into a national identity that earlier had been more inspired by Nature and Nature's God than by artifice. The nation typically dedicated its railroads, suspension bridges, skyscrapers, dams, and immense factories on the Fourth of July. Few Europeans would consider using even a day of their month-long vacations to see a rocket launch, but in the 1960s and 1970s millions of Americans with only half that much time off journeyed to Florida and waited for days to witness a blast off, as epitomized in the 1969 launch of Apollo XI. At such events, the public transforms individual experiences of technological power and immensity into visible signs of an ideal America. That such sublimity seems to be not a social construction, but a transcendent encounter with reality, is a measure of the central place of technology in the history, politics, and culture of the United States.

Bibliography

Adas, Michael, *Machines as the Measure of Men* (Ithaca: Cornell University Press, 1990)

Cowen, Ruth Schwartz, *More Work for Mother* (New York: Basic Books, 1984).

Hounshell, David A., *From the American System to Mass Production, 1800-1932.* (Baltimore. Johns Hopkins University Press, 1984)

Kasson, John, *Civilizing the Machine: Technology and Republican Values in America, 1776-1900* (New York: Penguin, 1977).

Kouwenhoven, John, *Made in America: The Arts in Modern Civilization* (New York: Norton, 1967. Reprint of 1948).

Marx, Leo, *The Machine in the Garden* (New York: Oxford University Press, 1965).

Marx, Leo, "Technology: The Emergence of a Hazardous Concept," *Social Research,* 64:3 (1997), pp. 965-988.

Meikle, Jeffrey, *American Plastic: A Cultural History*, (New Brunswick: Rutgers University Press, 1995).

Nye, David E., *American Technological Sublime* (Cambridge: MIT Press, 1994).

Nye, David E., *Consuming Power: A Social History of American Energies* (Cambridge: MIT Press, 1998).

Scranton, Philip, *Endless Novelty*: *Specialty Production and American Industrialization, 1865-1925* (Princeton: Princeton University Press, 1997).

Staudenmaier, John, *Technology's Storytellers* (Cambridge: MIT Press, 1985)

Tenner, Edward, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences,* (New York: Random House, 1996).

Winner, Langdon, *Autonomous Technology: Technics Out-of-Control as a Theme in Political Thought* (Cambridge: MIT Press, 1977).