Presidential Address

TECHNOLOGY AND HISTORY: "KRANZBERG'S LAWS"

MELVIN KRANZBERG

A few months ago I received a note from a longtime collaborator in building the Society for the History of Technology, Eugene S. Ferguson, in which he wrote, "Each of us has only one message to convey." Ferguson was being typically modest in referring to an article of his in a French journal[1] emphasizing the hands-on, design component of technical development, and he claimed that he had been making exactly the same point in his many other writings. True, but he has also given us many other messages over the years.

However, Ferguson's statement of "only one message" might indeed be true in my case. For I have been conveying basically the same message for over thirty years, namely, the significance in human affairs of the history of technology and the value of the contextual approach in understanding technical developments.

Because I have repeated that same message so often, utilizing various examples or stressing certain elements to accord with the interests of the different audiences I was attempting to reach, my thoughts have jelled into what have been called "Kranzberg's Laws." These are not laws in the sense of commandments but rather a series of truisms deriving from a longtime immersion in the study of the development of technology and its interactions with sociocultural change.

* * *

DR. KRANZBERG, Callaway Professor of the History of Technology at the Georgia Institute of Technology, was the founding editor of *Technology and Culture*, the recipient of the Society for the History of Technology's Leonardo da Vinci Medal in 1967, and president of SHOT in 1983–84. He presented this presidential address on October 19, 1985, at the Henry Ford Museum in Dearborn, Michigan.

[1]Eugene S. Ferguson, "La Fondation des machines modernes: des dessins," *Culture technique* 14 (June 1985): 182–207. *Culture technique* is the publication of the Centre de Recherche sur la Culture Technique, located in Paris under the direction of Jocelyn de Noblet. The June 1983 edition of *Culture technique*, dedicated to *Technology and Culture*, contained French translations of a number of articles from the SHOT journal.

0040-165X/86/2703-0007$01.00

We historians tend to think of historical change in terms of cause and effect and of means and ends. Although it is not always easy to find causative elements and to distinguish ends from means in the interactions between technology and society, that has not kept scholars from trying to do so.

Indeed one of the intellectual clichés of our time, whose scholarly statement is embodied in the writings of Jacques Ellul and Langdon Winner, is that technology is pursued for its own sake and without regard to human need.[2] Technology, it is said, has become autonomous and has outrun human control; in a startling reversal, the machines have become the masters of man. Such arguments frequently result in the philosophical doctrine of technological determinism, namely, that technology is the prime factor in shaping our life-styles, values, institutions, and other elements of our society.

Not all scholars accept this version of technological omnipotence. Lynn White, jr., has said that a technical device "merely opens a door, it does not compel one to enter."[3] In this view, technology might be regarded as simply a means that humans are free to employ or not, as they see fit—and White recognizes that many nontechnical factors might affect that decision. Nevertheless, several questions do arise. True, one is not compelled to enter White's open door, but an open door is an invitation. Besides, who decides which doors to open—and, once one has entered the door, are not one's future directions guided by the contours of the corridor or chamber into which one has stepped? Equally important, once one has crossed the threshold, can one turn back?

Frankly, we historians do not know the answer to this question of technological determinism. Ours is a new discipline; we are still working on the problem, and we might never reach agreement on an answer—which means that it will provide employment for historians of technology for decades to come. Yet there are several things that we do know, and that I summarize under the label of Kranzberg's First Law.

Kranzberg's First Law reads as follows: Technology is neither good nor bad; nor is it neutral.

By that I mean that technology's interaction with the social ecology is such that technical developments frequently have environmental, social, and human consequences that go far beyond the immediate purposes of the technical devices and practices themselves, and the same

[2]Jacques Ellul, *The Technological Society* (New York, 1964), and Langdon Winner, *Autonomous Technology: Technics Out-of-Control as a Theme in Political History* (Cambridge, Mass., 1977).

[3]Lynn White, jr., *Medieval Technology and Social Change* (Oxford, 1962), p. 28.

technology can have quite different results when introduced into different contexts or under different circumstances.

Many of our technology-related problems arise because of the unforeseen consequences when apparently benign technologies are employed on a massive scale. Hence many technical applications that seemed a boon to mankind when first introduced became threats when their use became widespread. For example, DDT was employed to raise agricultural productivity and to eliminate disease-carrying pests. Then we discovered that DDT not only did that but also threatened ecological systems, including the food chain of birds, fishes, and eventually man. So the Western industrialized nations banned DDT. They could afford to do so, because their high technological level enabled them to use alternative means of pest control to achieve the same results at a slightly higher cost.

But India continued to employ DDT, despite the possibility of environmental damage, because it was not economically feasible to change to less persistent insecticides—and because, to India, the use of DDT in agriculture was secondary to its role in disease prevention. According to the World Health Organization, the use of DDT in the 1950s and 1960s in India cut the incidence of malaria in that country from 100 million cases a year to only 15,000, and the death toll from 750,000 to 1,500 a year. Is it surprising that the Indians viewed DDT differently from us, welcoming it rather than banning it? The point is that the same technology can answer questions differently, depending on the context into which it is introduced and the problem it is designed to solve.

Thus while some American scholars point to the dehumanizing character of work in a modern factory,[4] D. S. Naipaul, the great Indian author, assesses it differently from the standpoint of his culture, saying, "Indian poverty is more dehumanizing than any machine."[5] Hence in judging the efficacy of technological development, we historians must take cognizance of varying social contexts.

It is also imperative that we compare short-range and long-range impacts. In the 19th century, Romantic writers and social critics condemned industrial technology for the harsh conditions under which the mill workers and coal miners labored. Yet, according to Fernand Braudel, conditions on the medieval manor were even worse.[6] Certain

[4]E.g., Christopher Lasch, *The Minimal Self: Psychic Survival in Troubled Times* (New York, 1984).

[5]Quoted in Dennis H. Wrong, "The Case against Modernity," *New York Times Book Review*, October 28, 1984, p. 7.

[6]Fernand Braudel, *The Structures of Everyday Life*, vol. 1 of *Civilization and Capitalism, 15th–18th Century* (New York, 1981).

economic historians have pointed out that, although the conditions of the early factory workers left much to be desired, in the long run the worker's living standards improved as industrialization brought forth a torrent of goods that were made available to an ever-wider public.[7] Of course, those long-run benefits were small comfort to those who suffered in the short run; yet it is the duty of the historian to show the differences between the immediate and long-range implications of technological developments.

Although our technological advances have yielded manifold benefits in increasing food supply, in providing a deluge of material goods, and in prolonging human life, people do not always appreciate technology's contributions to their lives and comfort. Nicholas Rescher, citing statistical data on the way people perceive their conditions, explains their dissatisfaction on the paradoxical ground that technical progress inflates their expectations faster than it can actually meet them.[8]

Of course, the public's perception of technological advantages can change over time. A century ago, smoke from industrial smokestacks was regarded as a sign of a region's prosperity; only later was it recognized that the smoke was despoiling the environment. There were "technological fixes," of course. Thus, one of the aims of the Clean Air Act of 1972 was to prevent the harmful particulates emitted by smokestacks from falling on nearby communities. One way to do away with this problem was to build the smokestacks hundreds of feet high; then a few years later we discovered that the sulfur dioxide and other oxides, when sent high into the air, combined with water vapor to shower the earth with acid rain that has polluted lakes and caused forests to die hundreds of miles away.

Unforeseen "dis-benefits" can thus arise from presumably beneficent technologies. For example, although advances in medical technology and water and sewage treatment have freed millions of people from disease and plague and have lowered infant mortality, these have also brought the possibility of overcrowding the earth and producing, from other causes, human suffering on a vast scale. Similarly, nuclear technology offers the prospect of unlimited energy resources, but it has also brought the possibility of worldwide destruction.

That is why I think that my first law—Technology is neither good nor bad; nor is it neutral—should constantly remind us that it is the historian's duty to compare short-term versus long-term results, the

[7]E.g., T. S. Ashton, *The Industrial Revolution, 1760–1830* (Oxford, 1948), and David S. Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present* (Cambridge, 1969).

[8]Nicholas Rescher, *Unpopular Essays on Technological Progress* (Pittsburgh, 1980).

utopian hopes versus the spotted actuality, the what-might-have-been against what actually happened, and the trade-offs among various "goods" and possible "bads." All of this can be done only by seeing how technology interacts in different ways with different values and institutions, indeed, with the entire sociocultural milieu.[9]

* * *

Whereas my first law stresses the interactions between technology and society, my second law starts with internalist elements in technology and then stretches to include many nontechnical factors. Kranzberg's Second Law can be simply stated: Invention is the mother of necessity.

Every technical innovation seems to require additional technical advances in order to make it fully effective. If one invents a lathe that can cut metal faster than existing machines, this necessitates improvements in the lubricating system to keep the mechanism running efficiently, improved grinding materials to stand up under the enhanced speed, and new means of taking away quickly the waste material from the item being turned.

Many major innovations have required further inventions to make them completely effective. Thus, Alexander Graham Bell's telephone spawned a variety of technical improvements, ranging from Edison's carbon-granule microphone to central-switching mechanisms. A variation on this same theme is described in Hugh Aitken's book on the origins of radio, in which he indicates the various innovative steps whereby the spark technology that produced radio waves was tuned into harmony (syntonized) with the receiver.[10] In more recent times, the design of a more powerful rocket, giving greater thrust, necessitates innovation in chemical engineering to produce the thrust, in materials to withstand the blast, in electronic control mechanisms, and the like.

A good case of invention mothering necessity can be seen in the landmark textile inventions of the 18th century. Kay's "flying shuttle" wove so quickly that it upset the usual ratio of four spinners to one weaver; either there had to be many more spinners or else spinning had to be similarly quickened by application of machinery. Thereupon Hargreaves, Cartwright, and Crompton improved the spinning pro-

[9]The "New Directions" program session at the 1985 SHOT annual meeting indicated that historians of technology are continuing to broaden their concerns and are indeed investigating new areas of the sociocultural context in relation to technological developments.

[10]Hugh G. J. Aitken, *Syntony and Spark: The Origins of Radio* (New York, 1976).

cess; then Cartwright set about further mechanizing the weaving operation in order to take full advantage of the now-abundant yarn produced by the new spinning machines.

Thomas P. Hughes would refer to the phenomenon that I have just described as a "reverse salient";[11] but I prefer to call it a "technological imbalance," a situation in which an improvement in one machine upsets the previous balance and necessitates an effort to right the balance by means of a new innovation. No matter what one calls it, Hughes and I are talking about the same thing. Indeed, Hughes has gone further in discussing technological systems, for he shows how, as a system grows, it generates new properties and new problems, which in turn necessitate further changes.

The automobile is a prime example of how a successful technology requires auxiliary technologies to make it fully effective, for it brought whole new industries into being and turned existing industries in new directions by its need for rubber tires, petroleum products, and new tools and materials. Furthermore, large-scale use of the auto demanded a host of auxiliary technological activities—roads and highways, garages and parking lots, traffic signals, and parking meters.

While it might be said that each of these other developments occurred in response to a specific need, I claim that it was the original invention that mothered that necessity. If we look into the internal history of any mechanical device, we find that the basic invention required other innovative changes to make it fully effective and that the completed mechanism in turn necessitated changes in auxiliary and supporting technological systems, which, taken all together, brought many changes in economic and sociocultural patterns.

* * *

What I have just said is virtually a statement of my Third Law: Technology comes in packages, big and small.

The fact is that today's complex mechanisms usually involve several processes and components. Radar, for example, is a very complicated system, requiring specialized materials, power sources, and intricate devices to send out waves of the proper frequency, detect them when they bounce off an object, and then interpret them and place the results on a screen.

That might explain why so many different people have laid claim to inventing radar. Each is perfectly right in pointing out that he pro-

[11]Thomas P. Hughes, "Inventors: The Problems They Choose, the Ideas They Have, and the Inventions They Make," in *Technological Innovation: A Critical Review of Current Knowledge*, ed. Patrick Kelly and Melvin Kranzberg (San Francisco, 1978), pp. 166–82.

vided an element essential to the final product, but that final product is composed of many separate elements brought together in a system that could not function without every single one of the components. Thus radar is the product of a packaging process, bringing together elements of different technologies into a single device.

In his fascinating account of the development of mass production, David A. Hounshell tells how many different experiments and techniques were employed in bringing Ford's assembly line into being.[12] Although many of the component elements were already in existence, Ford put these together into a comprehensive system—but not without having to develop additional technical capabilities, such as conveyor lines, to make the assembly process more effective.

My third law has been extended even further by Thomas P. Hughes's 1985 Dexter Prize–winning book *Networks of Power*. What I call "packages" Hughes more precisely and accurately calls "systems," which he defines as coherent structures composed of interacting, interconnected components.[13] When one component changes, other parts of the system must undergo transformations so that the system might continue to function. Hence the parts of a system cannot be viewed in isolation but must be studied in terms of their interrelations with the other parts.

Although Hughes concentrates on electric power systems, what he provides is a paradigm that is applicable to other systems—transportation, water supply, communications, and the like. And because entire systems interact with other systems, a system cannot be studied in isolation any more than can its component parts; hence one must also look at the interaction of these systems with the entire social, political, economic, and cultural environment. Hughes's book thus provides excellent case studies proving the validity of the first three of Kranzberg's Laws, and also of my fourth dictum.

* * *

Unfortunately, Kranzberg's Fourth Law cannot be stated so pithily as the first three. It reads as follows: Although technology might be a prime element in many public issues, nontechnical factors take precedence in technology-policy decisions.

Engineers claim that their solutions to technical problems are not

[12]David A. Hounshell, *From the American System to Mass Production 1800–1932: The Development of Manufacturing Technology in the United States* (Baltimore, 1984), chap. 6.

[13]Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore, 1983), p. ix.

based on mushy social considerations; instead, they boast that their decisions depend on the hard and measurable facts of technical efficiency, which they define in terms of input-output factors such as cost of resources, power, and labor. However, as Edward Constant has shown in studying the Kuhnian paradigm's applicability to technological developments, many complicated sociocultural factors, especially human elements, are involved, even in what might seem to be "purely technical" decisions.[14]

Besides, engineers do not always agree with one another; different fields of engineering might have different solutions to the same problem, and even within the same field they might disagree on what weight to assign to different trade-off factors. Indeed, as Stuart W. Leslie demonstrated in his Usher Prize article on "Charles F. Kettering and the Copper-cooled Engine,"[15] the most efficient device does not always win out even in what we might regard as a narrowly technical decision within a single industrial corporation. Although Kettering regarded his copper-cooled engine as a technical success, it never went into production. Why not? True, it had some technical "bugs," but these could not be successfully ironed out because of divisions between the research engineers and the production people—and because of the overall decision that the copper-cooled engine could not meet the corporate demand for immediate profit. So technical worth, or at least potential technical capability and efficiency, was not the decisive element in halting the copper-cooled engine.

In *Networks of Power* Hughes likewise demonstrates how nontechnical factors affected the efficient growth of electrical networks by comparing developments in Chicago, Berlin, and London. Private enterprise in Chicago, in the person of Samuel Insull, followed the path of the most efficient technology in seeking economies of scale. In Berlin and London, however, municipal governments were more concerned about their own authority than about technical efficiency, and political infighting meant that they lagged behind in developing the most economical power networks.

Technologically "sweet" solutions do not always triumph over political and social forces.[16] The debate a dozen years ago over the super-

[14]Edward W. Constant, *The Origins of the Turbojet Revolution* (Baltimore, 1980). This book was awarded the Dexter Prize by SHOT in 1982.

[15]Stuart W. Leslie, "Charles F. Kettering and the Copper-cooled Engine," *Technology and Culture* 20 (October 1979): 752–76.

[16]Eugene B. Skolnikoff states, "Technology alters the physical reality, but is not the key determinant of the political changes that ensue," in *The International Imperatives of Technology: Technological Development and the International Political System* (Berkeley, Calif.: University of California Institute of International Studies, n.d.), p. 2.

sonic transport (SST) provides an example. Although the SST offered potential advantages, its development to the point where its feasibility and desirability could be properly determined was never allowed to take place. Economic factors might have underlain the decision to cut R&D funds for the SST, but the public decision seems also to have been based on a fear of the environmental hazards posed by the supersonic aircraft in commercial aviation.

Environmental concerns have indeed assumed a major place in public decisions regarding technical initiatives. These concerns are not groundless, for we have seen how certain technologies, employed without awareness of potential environmental effects, have boomeranged to present hazardous problems, despite their early beneficial effects. Many engineers believe that hysterical fear about technological development has so gripped our nation that people overlook the benefits provided by technology and concentrate on the dangers presented either by ill-conceived technological applications or by human error or oversight in technical operations. But who can blame the public, with Love Canal and Bhopal crowding the headlines?[17]

American politics has now become the battleground of special-interest groups, and few of these groups are willing to make the trade-offs required in many engineering decisions. In the case of potential environmental hazards, Daniel A. Koshland has stated that we can satisfy one or the other of the different groups, but only at a cost of something undesirable to the others.[18]

Especially politicized has been the question of nuclear power. The nuclear industry itself has been partly to blame for technological deficiencies, but the presumption of risk by the public, especially following the Three Mile Island and Chernobyl accidents, has affected the future of what was once regarded as a safe and inexhaustible source of power. The public fears possible catastrophic consequences from nuclear generators.

Yet the historical fact is that no one has been killed by commercial nuclear power accidents in this country. Contrast this with the 50,000 Americans killed each year by automobiles. But although antinuclear protestors picket nuclear power plants under construction, we never see any demonstrators bearing signs saying "Ban the Buick"!

[17]Speaking of the Bhopal tragedy, President John S. Morris of Union College has said: "Methyl isocyanate makes it possible to grow good crops and feed millions of people, but it also involves risks. And analyzing risks is not a simple matter" (*New York Times*, April 14, 1985).

[18]Daniel A. Koshland, "The Undesirability Principle," *Science* 229 (July 5, 1985): 9.

Partly this is due to the public's perception of risk, rather than to the actual risks themselves.[19] People seek a zero-risk society. But as Aaron Wildavsky has so aptly put it, "No risk is the highest risk of all."[20] For it would not only petrify our technology but also stultify developmental growth in society along any lines.

Nevertheless, the fact that political considerations take precedence over purely technical considerations should not alarm us. In a democracy, that is as it should be. To deal with questions involving the interactions between technology and the ecology, both natural and social, we have devised new social instruments, such as "technology assessment," to evaluate the possible consequences of the applications of technologies before they are applied.

Of course, political considerations often continue to take precedence over the commonsensible results of comprehensive and impartial technological assessments. But at least there is the recognition that technological developments frequently have social, human, and environmental implications that go far beyond the intention of the original technology itself.

* * *

The fact that historians of technology must be aware of outside forces and factors affecting technology—from the human personality of the inventor to the larger social, economic, political, and cultural milieu—has led me to Kranzberg's Fifth Law: All history is relevant, but the history of technology is the most relevant.

In her presidential address to the Organization of American Historians several years ago, Gerda Lerner pointed out how history satisfies a variety of human needs, serving as a cultural tradition that gives us personal identity in the continuum of the past and future of the human enterprise.[21] Other apologists for the profession point out that history is one of the fundamental liberal arts and is essential as a key to an understanding of the future.

No one would quarrel with such worthy sentiments, but, to repeat questions raised by Eugene D. Genovese, "If so, how can we explain the

[19]See Dorothy Nelkin, ed., *Controversy: The Politics of Ethical Decisions* (Santa Monica, Calif., 1984).

[20]Aaron Wildavsky, "No Risk Is the Highest Risk of All," *American Scientist* 67 (1979): 32–37.

[21]Gerda Lerner, "The Necessity of History and the Professional Historian," *Journal of American History* 69 (June 1982): 7–20.

dangerous decline in the teaching of history in our schools; the cynical taunt, 'What is history good for anyway?' "[22] Although historians might write loftily of the importance of historical understanding by civilized people and citizens, many of today's students simply do not see the relevance of history to the present or to their future. I suggest that this is because most history, as it is currently taught, ignores the technological element.

Two centuries ago the great German philosopher Immanuel Kant stated that the two great questions in life are (1) What can I know? and (2) What ought I do?

To answer Kant's first question, we can learn the history of the past. I look on history as a series of questions that we ask of the past in order to find out how our present world came into being. We call ours a "technological age." How did it get to be that way? That indeed is the major question that the history of technology attempts to answer. Our students know that they live in a technological age, but any history that ignores the technological factor in societal development does little to enable them to comprehend how their world came into being.

True, economic and business historians have perforce taken cognizance of those technological elements that had a mighty effect on their subject matter. Similarly, social historians of the *Annales* school have stressed how technology set the patterns of daily life for the vast majority of people throughout history, and Brooke Hindle, in a fine historiographical article, has indicated how some of our fellow historians have begun to see how technology impinges on their special fields of study.[23] But for the most part, social, political, and intellectual historians have been oblivious to the technological parameters of their own subjects.

Perhaps most guilty of neglecting technology are those concerned with the history of the arts and with the entire panoply of humanistic concerns. Indeed, in many cases they are disdainful of technology, regarding it as somehow opposed to the humanities. This might be because they regard technology solely in terms of mechanical devices and do not even begin to comprehend the complex nature of techno-

[22] Eugene D. Genovese, "To Celebrate a Life—Biography as History," *Humanities* 1 (January–February 1980): 6. An analysis of today's low state of the history profession is to be found in Richard O. Curry and Lawrence D. Goodheart, "Encounters with Clio: The Evolution of Modern American Historical Writing," *OAH Newsletter* 12 (May 1984): 28–32.

[23] Brooke Hindle, " 'The Exhilaration of Early American Technology': A New Look," in *The History of American Technology: Exhilaration or Discontent?* ed. David A. Hounshell (Wilmington, Del., 1984).

logical developments and their direct influences on the arts, to say nothing of their indirect influence on mankind's humanistic endeavors.

Yet anyone familiar with Cyril Stanley Smith's writings would be aware of the importance of the aesthetic impulse in technical accomplishments and of how these in turn amplified the materials and techniques available for artistic expression.[24] And any historian of art or of the Renaissance should perceive that such artistic masters as Leonardo and Michelangelo were also great engineers. That relationship continues today, as David Billington has shown in stressing the relationship of structural design and art.[25]

Today's technological age provides new technical capabilities to enlarge the horizons and means of expression for artists in every field. Advances in musical instruments have given larger scope to the imagination of composers and to musical interpretation by performers. The advent of photography, the phonograph, radio, movies, and television have not only given artists, composers, and dramatists new tools with which to exercise their vision and talents but have also enlarged the audience for music, drama, and the whole panoply of the arts. They also extend our audio and visual memory, enabling us to see, hear, and preserve the great works of the past and present.

In the field of learning and education, there is little point in belaboring the impact of writing tools, paper, the printing press, and, nowadays, radio and TV. But there is also an indirect influence of technology on education, one that makes it more possible than ever before in human history for larger numbers of people in the industrialized nations to take advantage of formal schooling.

Let me give a brief example drawn from American history. Thomas Jefferson was very proud of the educational system that he devised for the state of Virginia. But in his educational scheme, only a very small percentage could ever hope to ascend to the heights of a university education.

This is not because Jefferson was an elitist. Far from it! But the fact is that the agrarian technology of his time was not productive enough to allow large numbers of youth to participate in the educational process. From a very early age, children worked in the fields alongside

[24]See especially Cyril Stanley Smith's Usher Prize article, "Art, Technology, and Science: Notes on Their Historical Interaction," *Technology and Culture* 11 (October 1970): 493–549.

[25]See David Billington's Dexter Prize–winning book, *Robert Maillart's Bridges: The Art of Engineering* (Princeton, N.J., 1979), and "Bridges and the New Art of Structural Engineering," *American Scientist* 72 (January–February 1984): 22–31.

their parents or, if they were town dwellers, were apprenticed to craftsmen. Only when great increases in agricultural and industrial productivity were made possible by revolutionary developments in technology did society acquire sufficient wealth to keep children out of the work force and enable them to attend school. As the 19th century progressed, first elementary education was made compulsory, then secondary education, and by the mid-20th century, America had grown so wealthy that it could afford a college education for all its citizens. True, some students drop out of high school before completing it, and not everyone going to college takes full advantage of the educational opportunities. But the fact is that the majority of Americans today have the equivalent education of the small segment of the upper-class elite in preindustrial society. In brief, technology has been a significant factor, not only in the pattern of our daily lives and in our workaday world, but also in democratizing education and the intellectual realm of the arts and humanities.

However, such vast generalizations might do little to convince the public of the wisdom of Stanley N. Katz's vision of scholars participating "in public discourse in order to recover the traditional role of the humanist as a public figure."[26] But the relevance of the history of technology to today's world can be spelled out in very specific terms. For example, because we live in a "global village," made so by technological developments, we are conscious of the need to transfer technological expertise to our less fortunate brethren in the less developed nations. And the history of technology has a great deal to say about the conditions, complexities, and problems of technology transfer.

Likewise, we are faced with public decisions regarding global strategy, environmental concerns, educational directions, and the ratio of resources to the world's burgeoning population. Technological history can cast light on many parameters of these very specific problems confronting us now and in the future—and that is why I say that the history of technology is more relevant than other histories.

One proof of this is that the outside world, especially the political community, is becoming increasingly cognizant of the contributions that historians of technology can make to public concerns. Whereas several decades ago historians were rarely called on to provide information to Congress on matters other than historical archives, memorials, and national celebrations, nowadays it is almost commonplace for historians of technology to testify before congressional committees dealing with scientific and technological expenditures, aerospace developments, transportation, water supplies, and other

[26]Stanley N. Katz, "The Scholar and the Public," *Humanities* 6 (June 1985): 14–15.

problems having a technological component. Congressmen obviously think that the information provided by historians of technology is relevant to coping with the problems of today and tomorrow.

Leaders in all fields are increasingly turning to historians of technology for expertise regarding the nature of the sociotechnical problems facing them. Let me give a few more specific examples. SHOT is an affiliate of the American Association for the Advancement of Science (AAAS), and there was a time when historians of technology appeared only on the program sessions of Section L of the AAAS, the History and Philosophy of Science. But historians of technology also have important things to say to a public larger than that composed of their historical colleagues. Hence it was a source of great personal pride to me—almost paternal pride—when, at the 1985 AAAS meeting, Carroll Pursell appeared on a program session with a congressman and a former assistant secretary of commerce; the program dealt with certain social and economic problems affecting the United States today, and Pursell's historical account of the technological parameters was truly germane to the thrust of the discussion. Similarly, at a recent conference, at my own Georgia Tech, on the problems expected to affect the workplace in the future, David Hounshell provided a meaningful technological historical context for a discussion that involved top labor leaders, political figures, and corporate executives. (I took family pride in that too!)

I regard this entrance of historians of technology into the public arena as empirical evidence of the true relevance of the history of technology to the worlds of today and tomorrow. To reiterate, all history is relevant, but the history of technology is most relevant. The rest of the world realizes that, and SHOT is working to make our historical colleagues from other fields recognize it too.

* * *

This brings me to my final law, Kranzberg's Sixth Law: Technology is a very human activity—and so is the history of technology.

Anthropologists and archaeologists studying primate evolution tell us of the importance of purposive toolmaking in the formation of *Homo sapiens*. The physical development of our species is apparently inextricably bound up with cultural developments, so that technology is classed as one of the earliest and most basic of human cultural characteristics, one helping to develop language and abstract thinking. Or, to put it another way, man could not have become *Homo sapiens*, "man the thinker," had he not at the same time been *Homo faber*, "man the maker."

Man is a constituent element of the technical process. Machines are made and used by human beings. Behind every machine, I see a face—indeed, many faces: the engineer, the worker, the businessman or businesswoman, and, sometimes, the general and admiral. Furthermore, the function of the technology is its use by human beings—and sometimes, alas, its abuse and misuse.

To those who identify technology simply with the machines themselves, I use the computer as a metaphor to show the importance of the interaction of human and social factors with the technical elements—for computers require both the mechanical element, the "hardware," and the human element, the "software"; without the software, the machine is simply an inert device, but without the hardware, the software is meaningless. We need both, the human and the purely technical components, in order to make the computer a usable and useful piece of technology.

Those of you who were at our Silver Anniversary meeting in 1983 will recall that I told an anecdote, which I sometimes use to quiet my most voluble antitechnological humanistic colleagues. A lady came up to the great violinist Fritz Kreisler after a concert and gushed, "Maestro, your violin makes such beautiful music." Kreisler held his violin up to his ear and said, "I don't hear any music coming out of it."

You see, the instrument, the hardware, the violin itself, was of no use without the human element. But then again, without the instrument, Kreisler would not have been able to make music. The history of technology is the story of man and tool—hand and mind—working together. If the hardware is faulty or if the software is deficient, the sounds that emerge will be discordant; but when man and machine work together, they can make some beautiful music.

People sometimes speak of the "technological imperative," meaning that technology rules our lives. Indeed, they can point to many technical elements, such as the clock, that determine the character and pace of our daily existence. Likewise, the automobile determines where and how we Americans live, work, think, play, and pray.

But this does not necessarily mean that the "technological imperative," usually based on efficiency or economy, necessarily directs all our thoughts and actions. We can point to many technical devices that would make life simpler or easier for us but which our social values and human sensibilities simply reject. Thus, for example, Ruth Schwartz Cowan has shown in her Dexter Prize–winning book, *More Work for Mother*, how communal kitchens would be feasible and save the mother from much drudgery of food preparation. But our adherence to the concept of the home has made that technical solution unworkable; instead, we have turned to other technologies to ease the housework and cooking chores, albeit requiring more time and attention from mother.[27]

In other words, technological capabilities do not necessarily determine our actions. Indeed, how else can we explain why we have spent billions of dollars on nuclear power plants that we have had to abandon before they were completed? Obviously, other human factors proved more powerful than the combined technical and economic pressures.

Our reluctance to bow to the "technological imperative" is shown by the great efforts to make machines "user friendly"—and we are also embarking on the task of making humans "machine friendly" through educational programs in "technological literacy" and through the work of our SHOT special-interest groups to reach out to a wider public.

One final note on this point. Today's technology makes possible teleconferencing. Hence it would be cheaper to stay at home and have the papers and discussions of the SHOT meeting brought to us by telecommunication devices. But here we are, gathered together in Dearborn, Michigan, because we recognize that there is more to be derived from a SHOT meeting than the fine scholarly papers. There is the stimulation and camaraderie of being together and bouncing our ideas off one another in a face-to-face context. SHOT meetings are notable for their collegial atmosphere. Perhaps it is because we are still a relatively young discipline, so that the average age of historians of technology is probably younger than that of those in other, older fields. Or perhaps it is because we have very efficient program and local arrangements committees, which tend to our needs and provide the wherewithal for our conviviality.

All that is so, but I also believe that SHOT meetings are so friendly and wonderful because we are united in our pursuit of knowledge. Surely we sometimes disagree in our interpretations of the historical facts; we would be less than human if we did not, and we would not be doing our proper job as scholars if we accepted unquestioningly everything our colleagues said.

But more important, we are united in our concern to understand the past—and also look at the future. Remember that I pointed out earlier that Immanuel Kant said that the two great questions in life are, first, What can I know? and, second, What ought I do?

What we can know is how our present world came to be, and that requires a knowledge of the development of technology and of its interactions with culture and society—the very things for which we stand. But we also have a mission in relation to the second of Kant's

[27]Ruth S. Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (New York, 1983), chap. 5.

great questions—What ought we do with our knowledge?—for we possess special capabilities because of our growing knowledge and understanding of technological developments and their varying interactions with the sociocultural milieu.

After all, we call ours a man-made world. And it is that, because mankind, with the aid of its technology, has fashioned our physical and social environment, our institutions, and other accoutrements of our society. But if ours is truly a man-made world, I claim that mankind can *re*-make it. And in that remaking process, the history of technology can play a very important role in enabling us to meet the challenges besetting mankind now and in the future.

That might seem a vain, utopian ideal. But historians of technology who have studied the great triumphs of the human mind and ingenuity embodied in mankind's technological accomplishments (and also mankind's failures) throughout the ages—such historians can indeed "dare to dream" of remaking ours into a better world.